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MSD-012
Ecosystem and Natural Resources

Block

2

LAND AND WATER RESOURCES

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BLOCK 2 INTRODUCTION

This is the second block of the course 'Ecosystem and Natural Resources' and discuss the concept of land, soil and water as resource.

Unit 1 presents the concept of land as a resource, and unsustainable land use practices. The unit also gives the various ways of sustainable land management and the challenges associated to it.

Unit 2 introduces you to the concept of soil, its characteristics, its formation and the sustainability issues associated to soil.

Unit 3 furnishes you information about the importance of water as a precious resource, physical and chemical unique properties of water and different types of pollution of water. The unit also furnishes information about the consumption and impacts of water pollution both within states/countries and transboundary.

Unit 4 provides you an insight about the impact of economic development on global water resources, individual, national and international efforts and conflicts regarding water sharing. The impacts of climate change on water resources and conservation methods are also given in this unit.

UNIT 1 LAND

Structure

1.0 INTRODUCTION

Land is a natural resource that supports different aspects of human life. It serves as storage for water and nutrients required for plants and other organisms. Land is chiefly valued for its potential to grow food for humanity as well as for other terrestrial creatures. As per the environmental conditions and quality of the soil system, land is put in several uses that are often referred as land uses. Quality of land is often perceived in terms of productivity of the land. Human has been modifying land and soil system throughout the human history. However, in the last few decades, a number of unsustainable land use practices, particularly those involved in intensive agriculture, have negatively af fected the productive capacities of land across the world. Ensuring sufficient global food production to feed the huge world population is increasingly being perceived as a major challenge of the twenty first century. Maintenance of productive capacity of land is therefore a critical aspect of sustainable development.

The present unit provides a comprehensive picture of land resources while underpinning the currently prevailing unsustainable land use practices and subsequent land degradation. The unit also proposes that land use planning, evaluation and integrated land management are some of the options for sustainable land management.

1.1 OBJECTIVES

After reading this unit, you will be able to:

- describe and discuss the concept of land as a resource;
- discuss different unsustainable land use practices and consequent land degradation; and
- explain the ways of sustainable land management and the challenges associated to it.

1.2 LAND AS A RESOURCE

Land is the solid surface of the globe or is the part of the earth that is not covered by water. It usually supports biological production. Its components are soil, vegetation, animals and microorganisms. Terrain or the physical features of land is included in its description. When assessing land resources for agricultural development, the components also include climate, particularly rainfall and temperature, number and distribution of people, crops, domesticated animals, machinery, roads and markets. In fact land is a natural resource that supports different aspects of human life including economic activities, transports, communications systems, recreation, and waste disposal.

As it provide substrate for biological production particularly for plant and tree growth, land is used for producing food, fodder, medicine, fiber and other associated materials. The volume of production depends on the extent and yield of the cultivable land, which, in turn, is flexible according to human attitude. Land use describes how a piece of a land is managed or used by humans. Land cover is the observed physical or biological cover of land such as vegetation or man-made features. The physical limits of cultivable land are temperature, moisture, topography and soil. Land quality is also governed by past and present human activities, e.g. reclamation from the sea, vegetation clearance, and human induced land degradation.

Land is resource of multiple uses and hence its comprehensive valuation is too complex. Land pricing is one way of land valuation which calculates value of land on the basis of its biological productivity. There are different grades of land depending on their productivity. Value of wildlife habitat and aesthetic qualities is not easily determined by economic measures. Some lands are so special that they are protected and maintained as parks and wilderness areas to protect rain-forests, endangered species and other unique resources. Land management is the management of land primarily for agriculture. Land on which commercial production or subsistence agriculture is not possible, is left for construction, leisure activities, nature reserves or other purposes.

1.3 LAND USE CLASSIFICATION AND LAND CHARACTERISTICS

Several land use classification systems have been developed around the world. Commonly used land use classifications includes categories like forests, land not available for cultivation, other uncultivated land, fallow land and net sown area. Land not available for cultivation includes barren and waste land, and land put to non-agricultural uses, e.g. buildings, roads, factories, etc. Other uncultivated land (excluding fallow land) includes permanent pastures and grazing land, land under miscellaneous tree crops groves (not included in net sown area), and cultruable waste land (left uncultivated for more than 5 agricultural years). Fallow land includes current fallow (left without cultivation for one or less than one agricultural year) and other than current fallow (left uncultivated for the past 1 to 5 agricultural years). Net sown area represent land presently occupied by certain crop and includes rainfed and irrigated agricultural land. Area sown more than once in an agricultural year plus net sown area is known as gross cropped area.

Major land use types and land utilization types are two successive hierarchy of describing land uses. A major kind of land use is a major subdivision of rural land use, such as rainfed agriculture, irrigated agriculture, grassland, forestry, or recreation. Major kinds of land use are usually considered in land evaluation studies of a qualitative or reconnaissance nature. A land utilization type is a kind of land use described or defined in a degree of detail greater than that of a major kind of land use. In detailed or quantitative land evaluation studies, the major land use types usually consist of land utilization types. They are described with as much detail and precision as the purpose requires. A land utilization type consists of a set of technical specifications in a given physical, economic and social setting. This may include current environment or a future plans for land improvement e.g. an irrigation and drainage scheme. Land utilization types are defined for the purpose of land evaluation.

Two terms, multiple and compound land utilization types, refer to situations in which more than one kind of land use is practiced within an area. A multiple land utilization type consists of more than one kind of use simultaneously undertaken on the same area of land, each use having its own inputs, requirements and produce. For example- timber plantation used simultaneously as a recreational area. A compound land utilization type consists of more than one kind of use, undertaken on areas of land which for purposes of evaluation are treated as a single unit. The different kinds of use may occur in time sequence (e.g. as in crop rotation) or simultaneously on different areas of land within the same organizational unit. For example, mixed farming involves both arable use and grazing.

A land characteristic is an attribute of land that can be measured or estimated. Examples are, slope angle, rainfall, soil texture, available water capacity, biomass of the vegetation, etc. Land mapping units, as determined by resource surveys, are normally described in terms of land characteristics.A land quality is a complex attribute of land which acts in a distinct manner in its influence on the suitability of land for a specific kind of use. Land qualities may be expressed in a positive or negative way. Examples are, moisture availability, erosion resistance, flooding hazard, nutritive value of pastures, accessibility etc. Where data are available, aggregate land qualities may also be employed, e.g. crop yields, mean annual increments of timber species.

A land quality is not necessarily restricted in its influence to one kind of use. The same quality may affect different land use types. There are a very large number of land qualities, but only those relevant to land use alternatives under consideration need be determined. A land quality is relevant to a given type of land use, if it influences either the level of inputs required, or the magnitude of benefits obtained, or both. For example, capacity to retain fertilizers is a land quality relevant to most forms of agriculture, and one which influences both fertilizer inputs and crop yield. Erosion resistance affects the costs of soil conservation works required for arable use, whilst the nutritive value of pastures affects the productivity of land under ranching.

1.4 UNSUSTAINABLE LAND USE PRACTICES

The failure to manage land resources in an integrated, holistic manner has led to a number of serious problems and barriers to sustainable development. Unsustainable land use practices include the overexploitation, pollution and destruction of natural resources. No society intentionally destroys its future well-being or survival by engaging in unsustainable practices. However, economic pressures as well as simple necessities driven by needs for short-term survival can lead to the degradation or destruction of the resource base needed for long-term survival and economic well-being. Government pricing structures, subsidies, tax incentives, and trade policies relating to food, wood, energy, and mineral resources may encourage or even force land users to deplete natural resources and thus to undermine their own livelihood. Both national and international economic policies can drive land users toward unsustainable practices.

Land degradation can occur when the land's carrying capacity is reduced by extreme weather, such as droughts, or by overgrazing or erosion. Some regions are much more susceptible to these problems because of their climate, soils, topography, or other factors. Inequitable distribution of land and other resources can also effectively reduce the carrying capacity of the land. Land degradation accelerates when people are forced to use marginal lands. Lack of long-term land tenure or lack of the technology needed to determine and assign land tenure can lead to land degradation by users who have no incentive to improve or conserve resources for the future.

The concentration of population in urban areas has the advantages of increased efficiency and reduced costs for social and physical infrastructure, but the expansion of urban areas also has a direct effect on the adjacent environment. Critical thresholds may be exceeded in the environment's self cleansing potential. The water and energy resources may be insufficient to meet the needs of urban development, industrialization, and domestic use. For example, firewood is a common energy source for cooking and heating in most developing countries. The need for firewood in urban areas can easily exceed annual production. An increase in the cost of energy is not the only consequence. Deforestation decreases the buffering capacity of the adjacent environment and leads to erosion and less efficient agriculture, transportation, and industry. Industrial and urban effluent can make surface water unsuitable for agricultural irrigation.

One of the causes of the self destruction of a society' s resource base is overpopulation. The situation is particularly difficult, if the local or regional soil and climate are too poor to guarantee profitable and sustainable use of external inputs in agriculture and a low supply of qualified labour and other economic conditions hinder the creation of nonagricultural employment, such as in desert margins and semi-arid regions. Large scale technological investments in these regions are economically unfeasible because of the lack of purchasing power of the local population and the lack of opportunities to increase production. In the long run, however, neglect of marginal regions will threaten the more productive ones because the deterioration or loss of the marginal regions' ecological, social, and economic functions, may be critical to the well-being of the more productive regions.

Environmental problems are inevitably linked to social and economic problems, including unemployment, poverty, disease, and starvation. Permanent destruction or degradation of the land's capacity to provide economic and environmental benefits is a major problem. Throughout the world, in both developed and developing countries, examples can be found of erosion, desertification, collapse of fisheries and other resource stocks, depletion of groundwater, salinization of soils, dumping of toxic mine wastes and the extinction of species and loss of biodiversity. Degradation of the land's capacity to support human populations can also lead to uncontrolled urbanization, mass migration, and social conflicts.

Inefficient use of resources is another grave problem. Without an integrated approach to land management, technologies are often used that are inappropriate for a particular region or type of land. For example, irrigation projects are developed in dry regions where agricultural production is actually limited by a lack of soil nutrients rather than by a lack of water. The use of valuable resources, such as fertilizers and pesticides, can be excessive, unnecessary, or even detrimental to agricultural efficiency and can lead to pollution and health problems in both rural and urban areas. Increasing costs for water purification and treatment of pollution-caused diseases are often borne by sectors of society that have had nothing to do with causing the pollution. The inefficient use of energy resources is a major impediment to sustainable development in all its aspects. Experience throughout the developing world has demonstrated that the most effective solutions to many land-use problems draw on a combination of local knowledge and advanced technologies.

1.5 LAND DEGRADATION

Land degradation may be defined as the loss of actual or potential production of biomass from a land or loss of its capacity to regulate the environment as a result of natural or anthropogenic factors. Loss of productive land adds to the difficulty of feeding an increasing world population. Almost one-sixth of the land area of the world has already been degraded to a greater or lesser extent. Natural processes such as erosion, soil acidification and soil salinization are exacerbated by man's activities. These activities include cultivations, irrigation and the use of nitrogen fertilizers, techniques on which agricultural production depends and will continue to depend in the future.

Estimates indicates that about 13% of the total land is affected to some extent by degradation. About 38% of the degradation is described as 'light', 46% as 'moderate' and 16% as 'strong' and 'extreme'. Of the various forms of degradation, water and wind erosion affect 84% of the degraded area, chemical degradation 12%, and physical degradation 4%. The continental areas that are most affected are Africa and Central America, although all are affected to some extent.

There are two general reasons for man-made degradation of land, which tends to occur particularly during periods when countries are undergoing economic development. First, an increase in the population leads to cropping of less suitable land, overgrazing and increased demand for wood as fuel and timber for buildings. Fallows are replaced by continuous cultivation, steeply sloping land is brought into cultivation, and plant nutrients are removed and not replaced, a phenomenon also known as nutrient mining. The second reason is that, national policies usually encourage industrialization and create pricing structures for agricultural products, that favour urban populations at the expense of farmers; cheap food is imported. The infrastructure in rural areas is neglected, investment in agriculture is insufficient, and farmers receive too little information to improve their techniques.

The effects of land degradation are two fold: on-site effects, that reduce crop yields, and off-site effects such as the deposition of silt in storage dams and river beds, and acidification and eutrophication of surface waters. Reduction or prevention of land degradation is therefore essential for economic reasons as well as to preserve natural ecosystems. Over the last few decades, it has been shown that degradation can be prevented on land that is cultivated. Techniques for its control and for the recovery of damaged land are economically viable, but are not sufficiently applied. The careful planning of land use, using the knowledge and techniques now available, including land surveys, should allow us to conserve our limited land resources.

Land degradation involves soil erosion, desertification and several changes in chemical and physical properties of soil. Soil erosion means removal of part or all of the soil by the action of water or wind and deposition of its components elsewhere. Loss of topsoil by erosion reduces crop yields because of the attendant loss of nutrients, water storage capacity and structural aggregates. Desertification refers to land degradation in dryland areas, with the implicit assumption, that it is caused by both a run of years of low rainfall and inappropriate forms of land use and management. Chemical changes in soil or land include nutrient depletion, salinization, acidification, pollution etc. Physical changes in soil include compaction, surface sealing, crusting and water logging. All these changes make the soil system less productive, vulnerable and less resilient in different spatial and temporal scale.

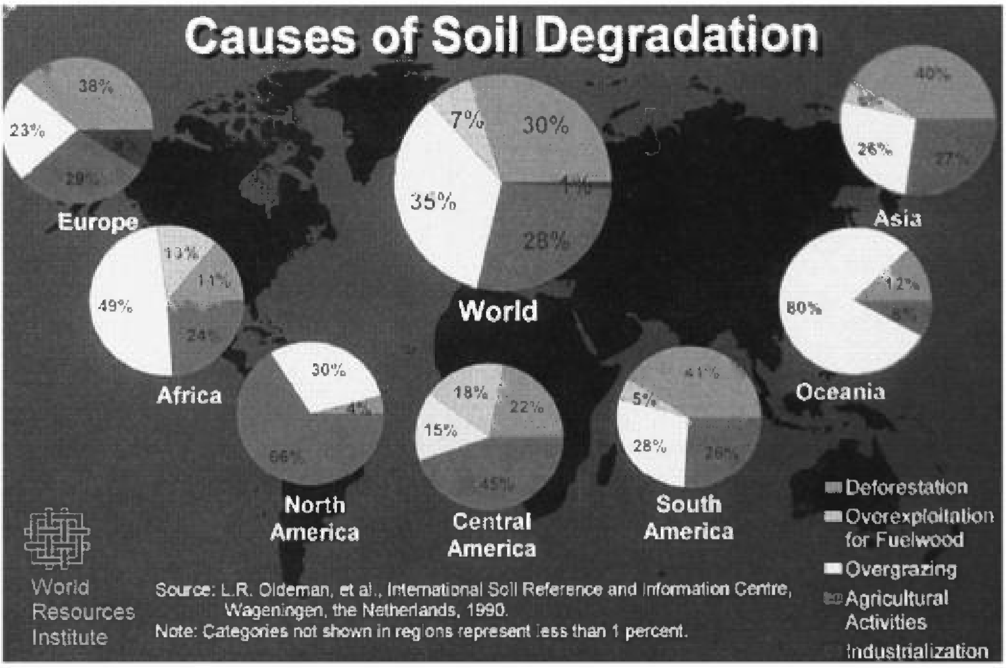

Fig. 1.1: Causes of Soil Degradation around the world

(Source http://www.globalchange.umich.edu)

Check Your Progress 1

Note: a) Use the space given below for your answer.

b) Compare your answers with those given at the end of the unit.

1) Why is land considered a resource?

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2) What are the major reasons of land degradation?

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1.6 SUSTAINABLE LAND MANAGEMENT

Sustainable land management (SLM) is defined as a knowledge based procedure, that helps integrate land, water, biodiversity, and environmental management (including input and output externalities) to meet rising food and fiber demands. while sustaining ecosystem services and livelihoods. SLM is necessary to meet the requirements of a growing population. Improper land management can lead to land degradation and a significant reduction in the productive and service functions.

In simple terms, SLM involves preserving and enhancing the productive capabilities of land in cropped and grazed area; sustaining productive forest areas and potentially commercial and non commercial forest reserves; maintaining the integrity of watershed for water supply and hydropower generation needs and water conservation zones and the capability of aquifers to serve the needs of farm and other productive activities.

SLM also includes actions to stop and reverse degradation or at least to mitigate the adverse effects of earlier misuse. Impacts of misuse of the natural resources (land, water, vegetation) and loss of the heritage in land management (indigenous crops, cultivation and animals) are mainly related to the population pressure and the migration of people from rural areas to the urban i.e. from the upstream to the downstream in an intra basin as well as an inter provincial scale. This process leads to the degradation of the prime lands adjacent to the settlement areas and the rural areas by abandonment.

SLM do not operate in isolation from other environmentally strategic interventions. For example, SLM will clearly overlap with, and to some extent be dependent on, progress in improving the sustainability of agriculture, as well as associated soil conservation efforts; responsible water management; and accountable livestock management and reduced impact logging practices. However, there are manifestly important aspects of SLM, that singularly pertain to the most significant land issues, namely sustaining soil productivity and averting land degradation.

The causes of the more obvious kinds of degradation have been fairly well documented. These causes can be grouped, in general terms, into three categories. First category includes degradation owing to chemical and physical processes resulting from interaction between the prevailing agricultural and industrial technologies and the surrounding land resource base. Second category includes degradation of a grander or "macro" nature, such as global warming or volcanic eruption, whose consequences can be anticipated even if the onset of damage cannot be forecasted with precision. Third category includes degradation whose roots are of behavioral nature. These can be deliberate, which are result of improper private incentives ultimately linked to market failure; or stemming from lack of knowledge or from technologies.

Decisions regarding use of land resources are governed by a complex set of socio-economic, developmental and environmental parameters. Land use planning, land evaluation and integrated land management are the major elements which play important role in sustainable land management. In the following sections these have been described in details.

1.7 LAND USE PLANNING AND EVALUATION

Decisions on land use have always been part of the evolution of human society. In the past, land use changes often came about by gradual evolution, as the result of many separate decisions taken by individuals. In the more crowded and complex world of the present, they are frequently brought about by the process of land use planning. Such planning takes place in all parts of the world, including both developing and developed countries. It may be concerned with putting environmental resources to new kinds of productive use. The need for land use planning is frequently brought about, however, by changing needs and pressures, involving competing uses for the same land.

The function of land use planning, is to guide decisions on land use in such a way that the resources of the environment are put to the most beneficial use for man, whiles at the same time conserving those resources for the future. This planning must be based on an understanding both of the natural environment and of the kinds of land use envisaged. There have been many examples of damage to natural resources and of unsuccessful land use enterprises, through failure to take account of the mutual relationships between land and the uses to which it is put. It is a function of land evaluation, to bring about such understanding and to present planners with comparisons of the most promising kinds of land use.

Land evaluation is concerned with the assessment of land performance when used for specified purposes. It involves the execution and interpretation of basic surveys of climate, soils, vegetation and other aspects of land in terms of the requirements of alternative forms of land use. To be of value in planning, the range of land uses considered, has to be limited, to those which are relevant within the physical, economic and social context of the area considered, and the comparisons must incorporate economic considerations.

Land evaluation, often answers the questions like: How is the land currently managed, and what will happen if present practices remain unchanged? What improvements in management practices, within the present use, are possible? What other uses of land are physically possible and economically and socially relevant? Which of these uses offer possibilities of sustained production or other benefits? What adverse effects, physical, economic or social, are associated with each use? What recurrent input e are necessary to bring about the desired production and minimize the adverse effects? What are the benefits of each form of use?

Certain principles are fundamental to the approach and methods employed in land evaluation. Land is often classified in terms of land capability and suitability. Land capability is viewed by some scientists as the inherent capacity of land to perform at a given level for a general use, and suitability as a statement of the adaptability of a given area for a specific kind of land use. Evaluation requires a comparison of the benefits obtained and the inputs needed on different types of land. Evaluation is made in terms relevant to the physical economic and social context of the area concerned.

1.8 INTEGRATED LAND MANAGEMENT

An integrated approach to land management identifies the social, economic, and environmental requirements of all stakeholders in society; develops possible land use options; and indicates the combination of options needed to optimally meet these requirements for the long term. It is a comprehensive approach to deal with the complexity associated to land resource. Integrated land management (ILM) is an interdisciplinary approach which visualizes use of land with different perspectives and identifies the best combination of land management option for the given piece of land or landscape. The logical sequence of procedures in an Integrated land management (ILM) approach includes the following:

- Provide opportunities for stakeholders, including decision makers, land management planners, land users, land owners, and beneficiaries of land services, to identify their requirements and needs.
- Collect information about the physical, social, and economic conditions of the land area, and use this information to evaluate current and potential land conditions.
- Identify spatial planning units for the land area, as well as options for each unit in terms of use; long term economic returns; input–output relationships; and predicted social, economic, and environmental impacts.
- Provide opportunities for the stakeholders to discuss and reach a consensus on the optimum land use and management system for each planning unit.
- Establish the institutional, legislative, and cadastral infrastructure needed to implement the agreed upon land uses and long term land management.

The ILM approach is not a fixed procedure but a continuous, iterative process of planning, implementation, monitoring, and evaluation, that strives to meet as many of society's economic, social, and environmental needs as possible without penalizing any sectors of society or sacrificing future benefits. The essential components of this approach are independent of scale and are therefore applicable at the global, national, district, village, and farm levels. However, although the basic technical ILM methodologies are already available, their application in many parts of the world is limited by training, financial, and institutional constraints. Access to appropriate technologies is a key to effective ILM on a global scale.

1.9 CONTRIBUTION OF SCIENCE AND TECHNOLOGY IN LAND USE MANAGEMENT

The solutions to the complex, interacting issues of land management require contributions from the physical, biological, and social sciences. Fortunately, most of the basic scientific knowledge and applied technologies needed for land management are already available. These include global satellite surveillance systems and powerful computer based GIS, as well as other methods for planning and evaluating land use, reducing wind and water erosion, and increasing the productivity of the land. Some of these technologies have been well developed for many years, whereas others are currently undergoing rapid development. Several are already being applied to land management problems around the world. However, in many cases, the critical technologies that are widely used in developed countries are not available in the developing countries, where they are most needed, which contributes to many of the environmental and socioeconomic problems currently experienced around the world. Even where technology and information are already available in developing countries, they are not at present optimally used because of ineffective information storage, retrieval, or sharing.

Typical examples of advanced information technology are the satellite images of the Earth, that indicate the conditions of the land and clarify the connections between different regions. Analysis of digital information from satellites and aerial photography allows us to accurately monitor land conditions over large areas and increases the value of traditional ground based surveys of soil properties, land use, crop productivity, mineral resources, and land ownership. Dissemination of this type of information in a form useful to all land use stakeholders requires a number of different approaches. The basic form of information needed for ILM is the map, either printed on paper in traditional formats or contained in computer based GISs. Obtaining and analyzing this information, are the first steps in identification of options for land management.

Remotely sensed data have proven indispensable for undertaking accurate soil surveys; evaluating deforestation, desertification, mining impacts and other forms of land degradation; evaluating the response of natural vegetation and agriculture to variations in climate, such as droughts, monsoons, low temperature and determining actual land use patterns, including urbanization and industrialization, as well as agriculture. Satellite imagery provides a powerful vehicle for guiding land use policies at the national, regional, and local levels. This information makes government policymakers aware of the large scale impacts of local activities and provides a means of integrating local knowledge about effective land use practices into a regional or national land management framework.

1.10 CONSTRAINTS ON INTEGRATED LAND MANAGEMENT

Numerous barriers impede the effective implementation of ILM at both local and global scales. Some of these barriers can be removed by technology, but many result from the fact that existing technologies are unavailable where they are most needed. Removal of many of the barriers to ILM requires decisions about resource allocation at national and international levels. Barriers to ILM are of four general types: limited access to appropriate information and technology; weaknesses in institutional infrastructure; unsustainable land use practices; and conflicts between land use goals.

The starting point for ILM is information on the quality of land resources and their actual land use. This includes information on basic land properties, such as the potential for forestry, agricultural production, mineral extraction, and biodiversity; inherent limitations to the various forms of land; susceptibility to desertification, erosion, groundwater pollution, and other forms of degradation; distribution of land uses and ownership; regulatory constraints; and urban and industrial impacts. Unfortunately, for many critical land management situations in the developing world, the needed information either does not exist or is not available in a usable form.

A primary reason for the lack of basic information is the difficulty of obtaining access to the technological tools needed to collect and analyze information. Tools and scientific methods for evaluating the information needed to make land use and development decisions already exist, but they are not uniformly available in all parts of the world. In some cases, the funds to acquire the technology are insufficient; in other cases, the infrastructural and educational base to support the technology after it is acquired is inadequate. Effective transfer of specific technologies and knowledge from one country to another is hampered by the lack of common methods and definitions for basic land properties, such as soils, climate, land uses, and types of land cover. Standardized definitions for these properties are being developed through joint efforts of UNEP and FAO.

Lack of cooperation and communication between agencies may lead to duplication of effort and waste of resources. Inadequate institutional mechanisms for transferring information about market conditions and business opportunities may be as damaging as a lack of information about agricultural technologies. In some cases, technologies have been introduced without emphasizing their drawbacks, such as the toxic side effects of an overuse of biocides. Without a two way transfer of information, extension services are unable to create the required link between the farmer's needs and the research findings. Research institutes that concentrate on the well-endowed regions may produce results that have little relevance to the less-endowed regions. A rich fund of indigenous knowledge built up over generations can be quickly lost, reducing opportunities for sustainability. Hybridization of ecologically sound, indigenous farming and modern, high input agriculture may result in the most efficient use of inputs and create the best chance for economic feasibility, with minimal ecological side effects.

1.11 LAND USE PATTERN AND LAND MANAGEMENT IN INDIA

Geographical area of India is 32.87 lakh square kilometers which represents only 2.4% land of the world. India accommodates over 17% world population. Due to high population, per capita land availability in India is less than 0.3 ha, which is lowest in the world. About 72% population in India lives in rural areas while the world average of rural population is about 50%.

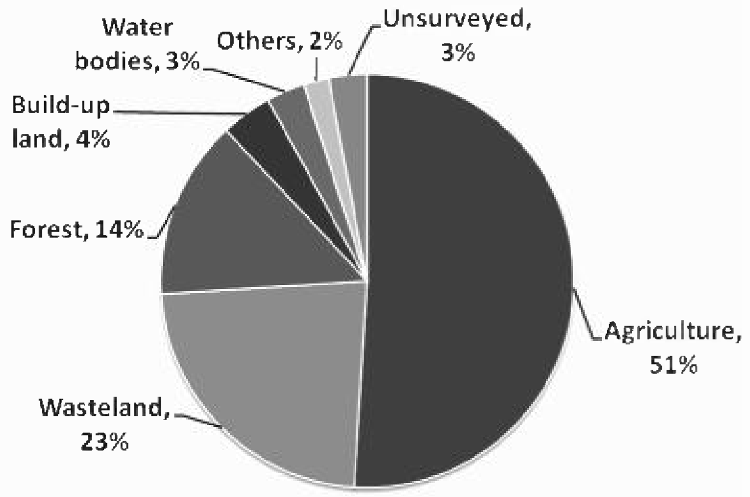

Fig 1.1: Area under broad land use - land cover categories in India in 1988-89
(Source: nrsc.gov.in)

Fig. 1.2: Area under broad land use – land cover categories in Indian in 1988-89

Source: nrsc.gov.in

The pattern of land use in the country is determined by geophysical, economic and institutional factors, i.e., the existing land use pattern in different regions have evolved as a result of interaction of these factors. Area under broad categories of land use- land cover in the years 1988-99 is illustrated in the given pie-chart. It shows, that agriculture occupies more than half of the total area of the country. A large part of the total land is rendered as waste land due to natural as well as anthropogenic reasons. Forest area is about 14% of the total land, which in fact represents the area occupied by dense forests. As per another survey done in 2001, total area under forests is about 20.55% in India. The variation in the figure is largely due to different survey criteria or methodologies used to measure area. Build up area is about 4% is which is gradually increasing year after year as a result of increasing urbanization.

India has a diverse agro-climate, topography and soil types, on the basis of which it has been categorized into various regions. Major part of the country is rainfed. Rainfall, therefore, constitutes an important parameter in the classification of the country into various regions for the purpose of planning. National and regional land use planning is facilitated by the Agro-Climatic Regional Planning Project of the Indian Planning Commission. The Commission has divided the country into 15 agro-climatic regions for allocation of technical and scientific inputs to the agriculture and allied sectors. These zones have been created on the basis of climate, in combination with soil and other factors that affect the agriculture in the region.

Land use management is one of critical concerns for the country. In 1991, the National Consultation on the Prospective Plan for Conservation, Development, and Management of Land Resources identified major policy issues and called for an integrated, scientifically sound approach to the management of land resources in the country. Initiatives that have been taken include, comprehensive land use planning to govern mining, quarrying, industrial uses, and urban development; coordination of related sectoral policies, such as the National Forest Policy, National Water Policy, National Housing Policy, and National Land Use Policy; higher priority for protective and regeneration aspects of forestry; diversification of agriculture, with special attention to problems of soil salinity, water logging, acidity, and drought prone and desert areas; mitigation of hazards, such as floods and earthquakes, in susceptible areas; proper training of personnel; and continued updating of the information on land resources in India through remote sensing and computerized data banks.

Considering the multiplicity of factors, that govern land use decisions in the country like India, a holistic and integrated approach to land use planning and management is required for sustainable development. Both advanced and traditional technologies have an essential role in integrated land use planning and management. There is need to work for developing four basic components of integrated land management. These are information, involvement, empowerment and facilitation. Government policies will have to foster the above components, in order to cater the needs of huge population of the country whose economy largely depends on the productivity of its agricultural land.

At the time of independence, ownership of land was concentrated in the hands of a few. This led to the exploitation of the farmers and was a major hindrance towards the socio economic development of the rural population. Equal distribution of land was therefore an area of focus of Independent India's government, and land reforms were seen as an important pillar of a strong and prosperous country. Department of Land Resources under the Ministry of Rural Development is the nodal agency for matters related to land reforms including distribution of ceiling surplus land, computerisation of land records and updating of land records.

The system of land records management varies from State to State, often even within a State, depending upon their historical evolution and local traditions. Several departments are involved in managing land records in most of the States, and the citizen has to approach 3 to 4, or even more, agencies for complete land records, e.g., Revenue Department for textual records and mutations; Survey & Settlement (or Consolidation) Department for the maps; Registration Department for verification of encumbrances and registration of transfer, mortgage, etc.; the Panchayats (in some States, for mutation), and the municipal authorities (for urban land records), leading to wastage of time, exposure to rent seeking, and harassment.

In 2008, it was decided to merge the two existing Centrally-sponsored schemes of Computerization of Land Records (CLR) and Strengthening of Revenue

Administration & Updating of Land Records (SRA&ULR) and to replace them with a modified Centrally-sponsored scheme in the shape of the National Land Records Modernization Programme (NLRMP), with the ultimate goal of ushering in the system of conclusive titles with little guarantee in the country.

Check Your Progress 2

Note: a) Use the space given below for your answer.

b) Compare your answers with those given at the end of the unit.

1) How are science and technology helpful in land management?

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2) What are the major constraints in integrated land management?

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1.12 LET US SUM UP

- Land is a natural resource, that supports different aspects of human life including food production for huge world population.
- The failure to manage land resources in an integrated, holistic manner has led to a number of serious problems and barriers to sustainable development.
- Sustainable land management is defined, as a knowledge based procedure, that helps to integrate land, water , biodiversity and environmental management to meet human needs while sustaining ecosystem services.
- Science and technology play crucial role in integrated land management. Remote sensing technologies are particularly useful in land use evaluation and planning.
- Numerous barriers impede the effective implementation. These include unavailability of information, coordination and technology required for land management.
- Four basic components are required for integrated land management for most of the countries: information, involvement, empowerment andfacilitation.

1.13 KEY WORDS

Soil	:	Layer of unconsolidated particles derived from weathered rocks, organic material, water and air that support plant growth.
Land Utilization Types	:	Typology to define land use in more details than major land use type and it consists of a set of technical specifications about land.
Land Suitability	:	Statement of the adaptability of a given area for a specific kind of land use.
Land Capability	:	Land capability is the inherent capacity of land to perform at a given level for a general use.
Integrated Land Management	:	An integrated approach to land management that balances the social, economic, and environmental attributes of a piece of land.
Remote Sensing	:	Technology to sense object from distance; for example using satellite imageries.

1.14 REFERENCES AND SUGGESTED FURTHER READINGS

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- http://www.fao.org/nr/land/use/(Food and Agriculture Organization)

1.15 KEY TO CHECK YOUR PROGRESS

Check Your Progress 1

1) Your answer must include the following points:

   - Land is used for growing agricultural crops (including horticultural and plantation crops as well as the medicinal plants and ornamentals)

- Land supports various social, economic, cultural aspects of human life

2) Your answer must include the following points:
   - Land use intensification for short term gains
   - Lack of proper land use management

Check Your Progress 2

1) Your answer must include the following points:
   - Science and technology provides information and technological support for land management
   - Remote sensing helps in land use planning and evaluation
2) Your answer must include the following points:
   - Unavailability of sufficient technologies
   - Lack of co-ordination between the management agencies

UNIT 2 SOIL

Structure

2.0 INTRODUCTION

Soil is the third basic component of the nature, besides air and water. Soil is technically defined as the layer of unconsolidated particles derived from weathered rocks, organic material, water and air that supports plant growth. Soil provides a medium in which an amazing variety of organisms live. Soil plays critical role to sustain life in terrestrial environment. Since human is terrestrial creature and largely dependent on land based food resources, his survival on the planet, to a great extent depends on maintenance of fertility of soil to grow enough food for the huge population. Soil fertility connotes the ability of soil to supply nutrients for plant growth and is a governed by numerous biophysical factors including type of management applied.

The present unit aims at building basic understanding about soil and its different attributes. In order to build perspective about soil system, the unit is based on the basic concept of soil science and soil ecology. Attempts have been made to simplify the technical description of the subject.

2.1 OBJECTIVES

After reading this unit, you will be able to:

- describe and discuss the concept of soil and its formation;
- discuss components and fertility attributes of soil; and
- explain the sustainability issues associated to soil.

2.2 CONCEPT OF THE SOIL

Soil forms a thin layer over the Earth's surface and acts as the interface between the atmosphere and lithosphere. It is a multiphase system, consisting of mineral material, soil organisms, plant roots, water, gases and organic matter at various stages of decay. The soil scientists define soil as "a natural body, synthesized in profile form from a variable mixture of broken and weathered minerals and decaying organic matter, which covers the earth in a thin layer and which supplies, when containing the proper amounts of air and water, mechanical support and, in part, sustenance for plants". Webster's New Universal Unabridged Dictionary describes soil in the simplest way as "the upper layer of earth, which can be dug or plowed and in which plants grow."

Soil means different things to different users. For example, to the geologist and engineer, the soil is little more than finely divided rock material. The hydrologist may see the soil as a storage reservoir affecting the water balance of a catchment, while the ecologist may be interested only in those soil properties that influence the growth and distribution of plants and animals. The farmer is naturally concerned about the many ways in which soil influences crop growth and the health of his livestock, although frequently his interest does not extend below the depth of soil disturbed by a plough (15–20 cm).

Soil is a natural body consisting of layers (soil horizons) of mineral constituents of variable thicknesses, which dif fer from the parent materials in their morphological, physical, chemical, and mineralogical characteristics. Soil, strictly speaking, is a weathered rock material and pack loosely with organic matter, forming a soil structure filled with pore spaces. These pores contain soil solution (liquid) and air (gas). Accordingly, soils are often treated as a three state system. Most soils have a density between 1 and 2 g/cm^3. Soil is also known as earth: it is the substance from which our planet takes its name. Little of the soil composition of planet Earth is older than the Tertiary and most of the soil composits on us no older than the Pleistocene. In engineering, soil is referred to as regolith, or loose rock material.

The soil also provides a medium in which an astounding variety of organisms live. These organisms not only use the soil as a habitat and a source of energy, but also contribute to its formation, strongly influencing the soil's physical and chemical properties and the nature of the vegetation that grows on it. Indeed, along with vegetation, the soil biota is one of five interactive soil forming factors: parent material, climate, biota, relief, and time.

2.3 HISTORICAL PERSPECTIVE

Human's use of soil for food production began two or three thousand years after the close of the last ice age, which occurred about 11,000 years before present. Neolithic people and their primitive agriculture spread outwards from settlements in the fertile crescent embracing the ancient lands of Mesopotamia, Canaan and southern Turkey and reached as far as China and the Americas within a few thousand years. In China, for example, the earliest records of soil survey (4000 years before present) show how soil fertility was used as a basis for levying taxes on landholders. To study the soil was a practical exercise of everyday life, and the knowledge of soil husbandry that had been acquired by Roman times was passed on by peasants and landlords, with little innovation, until the early 18th century.

19th century was the period of great discoveries in physics and chemistry, the implications of which largely influenced agriculture. In 1840, Von Liebig established that plants absorbed nutrients as inorganic compounds from the soil, although he insisted that plants obtained their nitrogen (N) from the atmosphere. Lawes and Gilbert at Rothamsted, subsequently demonstrated that plants (except legumes) absorbed inorganic N from the soil. During the years from 1860 to 1890, eminent bacteriologists including Pasteur, Warington and Winogradsky elucidated the role of microorganisms in the decomposition of plant residues and the conversion of ammonia to nitrate. Over the same period, botanists such as Von Sachs and Knop, identified the major elements that were essential for healthy plant growth. That time, the soil was regarded as a relatively inert medium providing water, mineral ions and physical support for plants.

Up to mid of the twentieth century, more and more land was brought into cultivation, much of which was marginal for crop production because of limitations of climate, soil and topography. Since 1950s, demand for food, fiber and forest products from an escalating world population (now > 6 billion) has led to increased use of fertilizers to improve yields, and pesticides to control pests and diseases. More recently, however, scientists, producers and planners have acknowledged the need to compromise between maximizing crop production and conserving a valuable natural resource. Emphasis is now placed on maintaining the soil's natural condition by minimizing the disturbance, when crops are grown, matching fertilizer additions more closely to crop demand in order to reduce losses, using legumes to fix N_2 from the air, and returning plant residues and waste materials to the soil to supply some of a crop's nutrient requirements.

2.4 SOIL FORMATION

Soil formation is a very long process. A combination of physical, chemical and biotic forces acts on weathered rock and organic materials to produce soil through the process of pedogenesis. It begins with the weathering of rocks into small fragments. The rocks are also worn away by the agents of erosion like river, wind, sea and glacier. The sediments and tiny rock particles are then deposited by the agents of erosion. The accumulation of such sediments over the ages forms soil. Eventually, the plants that grow on the soil, shed their leaves which decay to form the topmost layer of soil called 'humus'.

Soil are formed by the weathering of in situ consolidated rock, or unconsolidated superficial deposits which have been transported by ice, water, wind or gravity. Consolidated rocks are of igneous, sedimentary or metamorphic origin. Igneous rocks are formed by the solidification of molten magma in or on the Earth's crust, and are the ultimate source of all other rocks. Sedimentary rocks are composed of the weathering products of igneous, metamorphic and older sedimentary rocks, and are formed after deposition by wind and water. Igneous and sedimentary rocks that are subjected to intense heat and great pressures are transformed into metamorphic rocks.

Most parts of the Earth's surface have undergone several cycles of submergence, uplift, erosion and denudation over hundreds of millions of years. During the mobile and depositional phases there is much opportunity for materials from different rock formations to be mixed, and soil genesis on heterogeneous parent material. Soils are the result of the interactions of several factors e.g. climate, organisms, parent material, and topography (relief) all acting through time. These factors affect major ecosystem processes (e.g., primary production, decomposition, and nutrient cycling), which lead to the development of ecosystem properties unique to that soil type, given its previous history . Thus such characteristics as cation exchange capacity, texture, structure, organic matter status, etc., are the outcomes of the aforementioned processes, operating as constrained by the controlling factors. Different arrays of processes may predominate in various ecosystems.

2.5 SOIL PROFILE

Digging down through the soil, one comes across a series of layers of different colours, compositions and physical properties. The number of layers and thickness of each vary across the regions. These layers are called soil horizons and vertical pattern of these layers is called soil profile. From top to down, O, A, B and C horizons are observed in most of the soils. In the forest soil or wherever organic matter is found in good amount, there are three layers above the A-horizon. These are litter (L), fermentation (F), and humification (H) zones (Oi, Oe, and Oa, respectively). These are collectively called top soil. These layers are, in fact, soil organic matter in various stages of decomposition and hardly contain mineral soil. Majority of the biological and chemical activities occur in these layers.

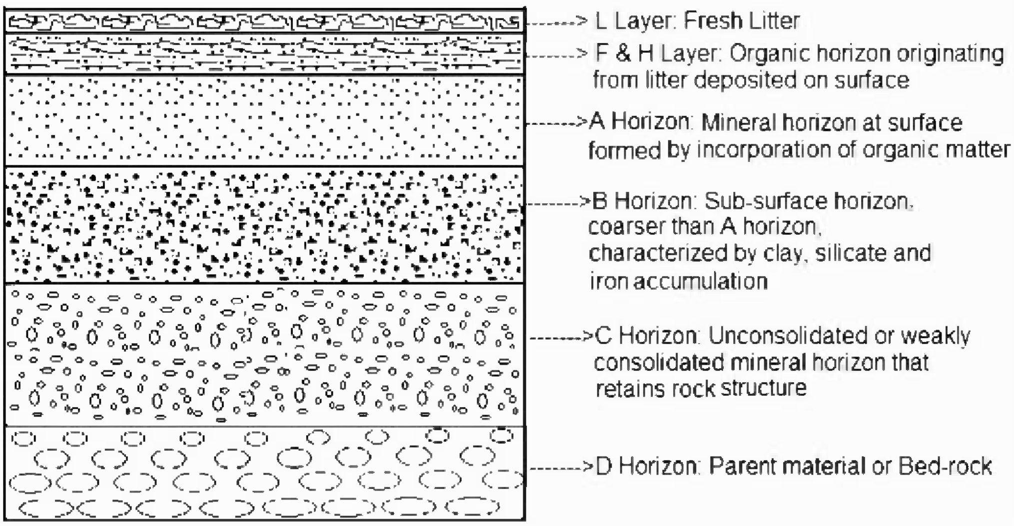

Fig. 2.1: Soil profile showing different soil horizons and parent material

A horizon is considered as top layer of mineral soil. It consists of the most intensively weathered rock material, being most exposed to surface processes. It also contains most of the organic matter. The upper portion of the A horizon is termed the topsoil, and under conditions of cultivation, the upper 12–25 centimeters (cm) is called the plow layer or furrow slice. This is followed by the layer of maximum leaching, known as the E horizon. In this horizon the water dissolves soluble minerals and carries them away with it. This process is known as leaching, and the A horizon is also termed the zone of leaching.

Many of the minerals leached from the A horizon accumulate in the layer below, the B horizon, also known as the zone of accumulation or deposition. Soil in the B horizon is coarser than the A-horizon soil because, it has been protected from the surface processes. Organic matter from the surface has also been less well mixed into the B horizon. Below the B horizon is a zone consisting principally of very coarsely broke-up bedrock and little else. This is the C horizon and does not resemble our usual idea of soil at all. Sometimes the bedrock or parent material itself is called D horizon.

2.6 SOIL COMPONENTS AND SOIL STRUCTURE

Four major components constitute soil viz., mineral matter, soil organic matter, water and air. The relative proportions of the four major components, mineral matter (40-60%), organic matter (<5%), water (20-50%) and air (10-25%), may vary widely. While mineral matter, water and gases are described in the following paragraphs, soil organic matter is described in separate section since, it bears special significances with respect to soil fertility.

The mineral matter derived from weathered rock consists of particles of different size. There is a continuous distribution of particle sizes in soil from boulders and stones down to fine clay particles. Soil that passes through a 2 mm sieve, the fine earth, is divided into sand, silt and clay. Soil texture denotes the relative proportions of sand, silt, or clay in a soil. Soils with the finest texture are called clay soils, while soils with the coarsest texture are called sandy soils. A soil that has a relatively even mixture of sand, silt, and clay is called loam. Finer textured soils tend to have greater ability to store soil nutrients.

While soil texture denotes the relative proportions of sand, silt, or clay in a soil, soil structure refers to the ways in which soil particles are arranged or grouped spatially. The groupings may occur at any size level ranging from single grained material like loose sand to massive aggregates like soil lump. Stabilization of soil aggregates is significant for soil fertility as it determine pattern of nutrient release from minerals. Stabilization is the result of various binding agents. A variety of other organic compounds act as binding agents, and some biological agents such as microbes, plant roots and fungi play a similar role.

Soil structure has strong implications for ecosystem management, particularly for Agroecosystems. A good soil structure provides a favourable environment for root growth and beneficial microbial activity. Soil structural quality can be measured in terms of available water capacity, aeration and water-stable aggregation. Deterioration of soil structure is revealed through inadequate soil aeration, decreased available water, impedance to root penetration because of soil compaction, and surface sealing.

Soil is a porous fabric that retains water and gases. Water is essential for sustaining life in soil as it mediates almost all the process supporting life in the biosphere. Soil water contains dissolved organic and inorganic solutes and is called the soil solution. Plants absorb this solution to get nutrients. While the soil air consists primarily of N_2 and O_2, it usually contains higher concentrations of CO_2 than the atmosphere, and traces of other gases that are by products of microbial activity.

2.7 SOIL ORGANIC MATTER AND SOIL ORGANISMS

The organic matter of the soil arises from the debris of green plants, animal residues and excreta deposited on the surface and mixed to a variable extent with the mineral component. The dead organic matter is colonized by a variety of soil organisms, most importantly micro organisms, which derive energy for growth from the oxidative decomposition of complex organic molecules. The combination of living and dead organic matter, irrespective of its source or stage of decomposition (but excluding the living parts of plants above ground), is called soil organic matter (SOM).

During decomposition, essential elements are converted from or ganic combination to simple inorganic forms through a process called mineralization. The remainder of the substrate C used by the micro organisms is incorporated into their cell substance or microbial biomass, together with a variable proportion of other essential elements such as Nitrogen (N), Phosphorus (P) and Sulfur (S). This incorporation makes these elements unavailable for plant growth, until the organisms die and decay, so the process is called immobilization. Whether or not there is net immobilization or mineralization depends on the nature of the decomposing substrate and the species composition of the soil or ganisms. Generally, Carbon to Nitrogen (C: N) ratios > 20 favour an increase in microbial biomass and net immobilization of N, whereas C: N ratios < 20 favour net mineralization.

The various interlocking processes of synthesis and decomposition, by which C is circulated through soil, plants, animals and air, comprise the carbon cycle. For the past 200 years or so, the release of CO_2 from the combustion of fossil fuels, respiration by organisms, land clearing and burning has exceeded the sequestration of C in living and dead organisms on land and in water. This has led to a steady rise in the CO_2 concentration in the atmosphere. This is often described as the enhanced 'greenhouse effect'. Globally, soil organic matter is a very large sink of carbon. Hence, changes in the dynamic soil organic matter can significantly affect the net flux of CO_2 to the atmosphere.

Organic matter in soil performs several important functions. It helps to build up a loose soil structure with a large number of pores. This allows easier root penetration, better aeration and allows water to infiltrate more easily into the soil. The larger visible particles of organic matter act as tiny sponges in the soil (holding as much as five times their own weight in water); this can make sandy soils more drought tolerant. The smaller non visible particles act like glue sticking the soil particles together forming larger soil crumbs. This can improve the soil structure in clay and sandy soils. The organic matter acts as a food source for soil micro organisms and larger soil organisms; this allows the organic matter to decompose. The organic matter also provides a habitat for the soil organisms. The organic matter has a great capacity to retain nutrients and to release them continuously. This has the effect of increasing the nutrient supply to the plants and will reduce nutrient loss in the soil from leaching. This is important in sandy soils which have poor nutrient retention. Organic matter has a buffering capacity, preventing soils from becoming too acidic or alkaline.

Soil organisms, often termed as soil biota or below ground biodiversity, include archaea, bacteria, fungi, protozoans, algae and invertebrate animals. Among invertebrates, there are various taxonomic groups including nematodes, annelids, arthropods and mollusks. The diversity of these organisms is amazingly very high. According to recent estimations, soil organisms may represent over 2 million species or as much as 23% of the total diversity of living organisms that have been described till date. Soil organisms contribute significantly in terms of their body mass or nutrient in ecosystem. Earthworm biomass normally ranges from 5 to 3000 kg live weight per ha, whereas the microbial biomass makes up 2– 4% of the total organic C in soil, or 0.5–2 t C/ha.

The soil organisms play vital role in soil. They help decompose organic matter in the soil and produce humus. They mix the organic matter with soil particles and build up stable soil crumbs. They make tunnels in the soil opening up the soil to promote deeper rooting of the crop, and better aeration of the soil. They help to release nutrients from mineral particles in the soil. They can help to control pest and disease organisms which may affect the roots of the crop.

Check Your Progress 1

Note: a) Use the space given below for your answer.

b) Compare your answers with those given at the end of the unit.

1) How does mineralization differ from immobilization?

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2) What is the role of organic matter in soil?

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2.8 SOIL NUTRIENTS, SOIL FERTILITY AND SOIL QUALITY

There are 17 elements without which green plants cannot grow normally and reproduce. On the basis of their concentration in plants, these essential elements are subdivided into: the macronutrients C, H, O, N, P, S, Ca, Mg, K and Cl which occur at concentrations > 1000 mg/kg (plant dry matter basis); and the micronutrients Fe, Mn, Zn, Cu, B, Ni and Mo which are generally < 100 mg/kg. Out of different nutrients, C, H and O are supplied as CO_2 and H_2O, which are abundant in the atmosphere and hydrosphere; likewise Cl, which is abundant and very mobile as the Cl^- ion. Of the others, with the exception of N which comprises 78% of the atmosphere, the major sources of the essential elements are weathering minerals in the soil and parent material.

Soil fertility is a connotation of the nutrient status or ability of soil to supply nutrients for plant growth under favourable environmental conditions such as light, temperature and physical conditions of soil. Fertile soil contains sufficient nutrients to ensure plant growth and yield and is able to maintain appropriate moisture and components in the soil. Soil fertility is the foundation of sustainable agriculture. Fertile or healthy soils have a shielding capacity that allows a balanced intake of nutrients and can improve water retention; thereby creating a healthy plant that is less susceptible to pest attack and will be more resistant to pest damage.

Often land productivity, as measured by the yield of crop or animal product per hectare soil, is taken as indicator of soil fertility. In fact, land productivity is governed by a number of other factors besides soil fertility. These factors include climate, pests, disease, genetic potential of the crop, and man's management. Soil fertility connotes primarily, the combined effect of chemical and biological properties, and is probably the most important single soil factor affecting land productivity.

Soil quality is another term which is used to specify soil attributes in more comprehensive sense. Soil quality is often defined as 'the capacity of a soil to function within ecosystem boundaries to sustain biological productivity, maintain environmental quality, and promote plant and animal health'. Conventionally soil quality and soil fertility have been used almost synonymously. However, in recent years, due to increasing concern for environmental protection across the globe, a more comprehensive description of soil quality is demanded. In fact soil is increasingly being recognized as a vital component of environment along with air and water.

Quality of soil is experienced directly or indirectly through the diversity and health of the natural ecosystems it supports, the quality and quantity of crops (and animals) grown, the water (and sometimes sediment) that runs off and drains from a soil, and the gases absorbed or released by a soil. Whereas the desirable qualities of air and water for human and animal life can be adequately defined and monitored, the same is not true of soil for several reasons. Soil is continuously variable in space and, being a complex, dynamic biological system, is variable in time. The rate of change of individual soil properties is itself very variable.

The quality of a soil depends on the soil's use and its fitness for that use or function. This premise underlies the assessment of land use capability (called land evaluation) in which land is classed according to its suitability for various uses. Agriculture has traditionally been a key use, and soil quality is a major factor determining the land capability class (ranging from the best class – no limitations, to the worst class – severe limitations). The land use capability approach has been adapted to determine the suitability of soils for a range of crops, usually based on a correlation between crop yield and a set of biophysical criteria (e.g. climate, soil physical properties, soil acidity and organic matter content) to derive a soil quality index.

The definition of soil quality becomes more specific, when contaminated land is considered. Soil contamination by organic and inorganic chemicals occurs in urban and rural areas from various causes such as: mining activities (including exploration, extraction and processing); industrial activities (including defence, and the disposal of industrial waste); urban living (including motor transport, and the concentration of urban waste through storm water runoff, sewage effluent and sewage sludge); and agriculture, forestry and horticulture, through over use of fertilizers and pesticides.

Although we ideally aspire to defining soil quality in objective terms, in reality the concept is diffuse and must reflect a range of social, cultural and economic factors as well as biophysical properties. For these reasons, soil quality is often assessed by the management practices that are designed to improve, or at least maintain, a soil's performance for specific purposes, e.g. minimizing erosion, supporting a variety of crops, storing good quality water under ground, or minimizing the movement of heavy metals applied in industrial wastes.

2.9 MANAGEMENT OF SOIL FERTILITY

Soil fertility management is a long term strategy aimed at reducing the loss of nutrients and building soil fertility through the continuous nourishment of the soil. The aim is to minimize the need, to bring in external inputs from outside the farm. In simple words, soil fertility management means methods of farming or agriculture. Soil management practices greatly vary across the countries and are guided by numerous factors including crop types, geography, climate, traditional practices, economic development, modernization etc.

Out of numerous soil fertility management practices, here we are describing organic agriculture as one model. Organic agriculture, sometimes described as 'biological farming,' has, in fact, emerged as an alternative to the conventional agriculture which is based on the use of chemicals for intensive production. Organic agriculture, which is more labour intensive as compared to conventional agriculture, is based on the adoption of several strategies, as crop rotation, conservation of biodiversity, use of organic manure, crop residues and green manure etc.

Crop rotation involves a planned succession of crops on each farm field to achieve control over weeds, diseases and insects, and to promote efficient nutrient cycling and good soil structure. By appropriate sequencing of crops and management of residues, the populations of natural predators of pest organisms can increase, allowing pesticide use to be scaled back. This concept is the basis of integrated pest management (IPM). By conserving biodiversity through rearing diversity of crops and livestock, farm income can be buffered against market, climatic and biological risks, in contrast to crop monoculture (e.g. cotton) or single enterprise animal farming (e.g. sheep for wool), where income is particularly vulnerable to fluctuations in commodity prices, extremes of weather and the incidence of pests and disease.

By the use of organic manures and crop residues to a soil, nutrient cycling is improved and soil organic matter is maintained or increased. The later effect is beneficial for soil structure, increases water infiltration and storage, and improves soil tilth. Good tilth promotes seed germination and seedling emergence. Organic matter encourages soil micro organisms and soil fauna, especially earthworms. Green manures are especially important in organic farming, not only for the return of residues, but also for the incorporation of legumes that contribute N_2 fixed from the air. Green manuring is often advocated to prevent leaching of surplus soil NO_3^- during winter or the non cash crop period.

2.10 AGRICULTURE, SOIL QUALITY AND SUSTAINABILITY

Since humans are terrestrial creatures and largely dependent on land based food resources, their survival on the planet, to a great extent depends on maintenance of fertility of soil to grow enough food for the huge population of over 6.5 billion people. Already only 10% area of the total land is under cultivation and that too has deteriorated in the past several decades due to faulty agricultural practices. Concern over soil health remained in focus in global development issues such as food security, land degradation and the provision of ecosystem services.

Traditional farming practices, based on rotational cropping, mixed farming and use of farm yard manure, were generally sustainable over a long period in past. However, because of population pressure, the cost of labour and the demand for land for non-agricultural use, traditional methods have gradually been displaced by intensive mono cultural systems, such as continuous cereal cropping, and livestock farming. This trend has resulted in varying degrees of soil nutrient depletion, soil structural decline, salinization, accelerated acidification, erosion and overall environmental degradation in many countries. Modern intensive farming requires substantial inputs of fertilizers and organic manures to maintain soil fertility.

For the last 60 years, demand for food, fibre and forest products from an escalating world population has led to increased use of fertilizers to improve yields, and pesticides to control pests and diseases. Such practices have resulted in some accumulation of undesirable pesticide residues in soil, and in increased losses of soluble constituents such as nitrate and phosphates to surface waters and groundwater. For example, nitrate when applied to agricultural land in excess amount leaches from soil and mixes in ground water. When this water is used to make bottled-milk feed for babies, it leads to methaemoglobinaemia or 'blue-baby disease among infants. Similarly agricultural run-off containing nitrates and phosphate causes eutrophication of lakes and ponds.

The ideal pesticide is one, that controls only the target organism and persists long enough to achieve this purpose before degrading into harmless products. In practice, however, the ideal is not always achieved and chemicals have been used in agriculture that are 'broad spectrum' in their activity; that is, they kill harmless and beneficial organisms as well as the target organisms. Pesticides, such as the organochlorine, are very stable and have high lipid solubility. They therefore, accumulate in the fatty tissues of animals. Extensive use of these and other persistent chemicals has led to their residues and breakdown products becoming widely disseminated, and there have been many instances of their detrimental effect on beneficial insects and plants, domestic animals and wildlife.

More recently, however, scientists, producers and planners have acknowledged the need to compromise between maximizing crop production and conserving a valuable natural resource. As a response to these concerns, organic agriculture is emerging as an alternative to the conventional agriculture. Emphasis is now placed on maintaining the soil's natural condition by minimizing the disturbance when crops are grown, matching fertilizer additions more closely to crop demand in order to reduce losses, using legumes to fix N_2 from the air, and returning plant residues and waste materials to the soil to supply some of a crop's nutrient requirements.

Precision agriculture has evolved as response, to prevailing challenge of nutrient imbalance in soil. In this agriculture, instead of 'blanket' recommendations for a nutrient for a particular field, fertilizer applications can be adjusted to the specific need of parts of individual fields, based on crop yield maps or spatially referenced data for soil tests. Similar to precision agriculture, new tillage methods have been designed to maintain soil structure and minimize erosion losses. They have gained widespread popularity, compared mainly on soils, where high surface temperatures, high evapotranspiration, surface sealing, and water and wind erosion pose problems. These methods range from reduced or minimum tillage (fewer passes with cultivating implements) to direct drilling or no-till, where the only disturbance is injecting fertilizers and sowing seeds.

There are still great lacunae in our current understanding about optimal use of soil resources and sustainability implications of various land management practices. Nevertheless, with the continuous research work in agricultural and associated sciences, a number of soil fertility management strategies are being evolved, tested and implemented by scientists, planners and farmers across the globe to maintain a balance between economic gains and environmental quality.

2.11 SOIL TYPES IN INDIA

India has a wide range of soils, each type being particular of a specific locality. The Indian Council of Agricultural Research (ICAR) has made major contributions on the study of Indian soils. As per ICAR, Indian soils can be broadly grouped in eight categories, namely, alluvial soil, black soil, red soils, laterite soil, forest & mountain soils, arid & desert soils, saline & alkali soils and peaty & marshy soils.

Alluvial soils cover about 24% of the total land of India. They occupy most of the Indo-Gangetic Plains (from Punjab to West Bengal) and also occur in the valleys of Narmada and Tapti in Madhya Pradesh & Gujarat, Mahanadi in Orissa, Godawari in Andhra Pradesh and Cauvery in Tamilnadu. These soils are formed by the deposition of fine sediments and silt carried by the rivers along their banks. These soils respond well to irrigation and manuring. They are good for both rabi and kharif crops and suitable for wheat, sugarcane, rice, cotton and oilseeds. In delta region, they are ideal for jute cultivation. The economics of India, Pakistan and Bangladesh are dependent on alluvial soils.

The black cotton soils cover about 16% of the total land. These soils are found in the States of Maharashtra, Gujarat, Madhya Pradesh, Karnataka, Andhra Pradesh, Tamil Nadu, Uttar Pradesh and Rajasthan. These soils have been formed due to the weathering of the lava rocks. This is also known as the Regur soil and Cotton soil. These soils are rich in lime, iron, magnesia and alumina but lack in the phosphorus, nitrogen and organic matter. These are ideal for cultivation of cotton and also good for cultivation of cereals, pulses, oil seeds, citrus fruits, vegetables, etc.

Red soils have been estimated to occur in about 16% of the total land. These soils are found in Chhotanagpur plateau, Telangana, Nilgiris, Tamil Nadu, Karnataka, Andhra Pradesh and periphery areas of Deccan Plateau. Red soils are reddish in colour due to the presence of iron. These soils have been formed due to decomposition of underlying igneous rocks under heavy rainfall. They have less humus. These are suitable for the cultivation of millets, pulses, linseed, tobacco etc.

Laterite soils occur in about 4% of the total land. These soils are formed under conditions of high temperature and heavy rainfall with alternate wet and dry periods. Laterite soils are found in elevated areas which receive very high rainfall. As a result of heavy rainfall, top soil gets washed away. This process is called leaching. The soil, therefore, loses its fertility to a great extent. These soils are found in the north- eastern state in India. Their colour is red due to the presence of iron oxide which is formed by leaching. These soils are good for cultivation of tea, coffee, rubber, cinchona and coconut.

Forest and mountain soils are mainly found on the hill slopes covered by forests. The formation of these soils is mainly governed by the characteristic deposition of organic matter derived from forest growth. In the Himalayan region, such soils are mainly found in valley basins, depressions and less steeply inclined slopes. Apart from the Himalayan region, the forest soils occur in higher hills in south and the peninsular region. Very rich in humus but are deficient in potash, phosphorous and lime and needs fertilizers. These are good for plantation of tea, coffee, spices, tropical fruits and vegetables.

The arid and desert soils occupy about 11% of the total land. These soils are found in dry areas of Rajasthan, Gujarat, Punjab, and Haryana. These soils are chiefly found in areas receiving less than 50 cm of annual rainfall and hence these are affected by desert conditions. These areas are covered by a mantle of sand which inhibits soil growth. These coarse soils are suitable for cultivation of jowar, bajara, cotton etc.

Soils with high proportion of salts and alkalis are called saline and alkali soils. They are formed due to accumulation of tidal water in adjoining coasts where drainage is poor. They are also found in drier parts of Bihar, Rajasthan, U.P., Punjab, Haryana, Maharashtra. These soils contain many salts like sodium, magnesium and calcium which make them infertile and render unfit for agriculture.

Marshy and peaty soils are found in continuously water-logged areas, or marshy areas. These originate in the humid regions as a result of accumulation of large amounts of organic matter in the soil. They contain considerable amounts of soluble salts and 10 to 40% of organic matter. These soils are found in some parts of Kerala, Bihar, Orissa, Tamil Nadu, West Bengal and UP.

Check Your Progress 2

Note: a) Use the space given below for your answer.

b) Compare your answers with those given at the end of the unit.

1) What is the difference between soil fertility and soil quality?

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2) What are the major impacts of conventional agriculture on soil health?

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2.12 LET US SUM UP

- Soil is technically defined as the layer of unconsolidated particles derived from weathered rocks, organic material, water and air that supports plant growth. A combination of physical, chemical and biotic forces acts on weathered rock and organic materials to produce soil.
- Four major components constitute soil viz., mineral matter, soil organic matter, water and air. The relative proportions of the four major components, however, vary widely. Soil organic matter plays important role in maintaining soil fertility.
- Soil fertility is a connotation of the nutrient status or ability of soil to supply nutrients for plant growth under favourable environmental conditions.
- Soil fertility management is a long term strategy aimed at reducing the loss of nutrients and building soil fertility through the continuous nourishment of the soil.
- More recently scientists, producers and planners have acknowledged the need to compromise between maximizing crop production and conserving a valuable natural resource.
- India has a wide range of soils. Eight major soil types have been identified by ICAR. Each type has certain characteristic features.

2.13 KEY WORDS

Weathering : Break down of rocks into smaller fragments that ultimately form soil.

Eutrophication : Excessive growth of algae and weeds in water-bodies due to high concentration of nutrients.

Pedogenesis : Process of formation of soil from rocks.

Leaching : Dissolving of minerals in water and their escape from that soil layer.

Soil erosion : Gradual removal of particles from soil leading to thinning of soil column.

Ecosystem : A piece of vegetated land or water-body where life can continue without external support.

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2.15 KEY TO CHECK YOUR PROGRESS

Check Your Progress 1

1) Your answer must include the following points:

   - Mineralization means conversions of elements from or ganic combinations to simple inorganic forms
   - Immobilization means incorporation of elements by microorganisms in their cell

2) Your answer must include the following points:

   - It helps to build up a loose and son soil structure with a large number of pores
   - It acts as a food source for soil micro -organisms and larger soil organisms.

Check Your Progress 2

1) Your answer must include the following points:

   - Soil fertility connotes ability of soil to supply nutrients for plant growth
   - Soil quality connotes soil attributes in more comprehensive sense

2) Your answer must include the following points

   - This resulted in varying degrees of soil nutrient imbalance
   - Pesticide residue present in soil and ecosystem

UNIT 3 WATER: STATUS, DISTRIBUTION AND QUALITY

Structure

3.0 INTRODUCTION

Life without water would probably never have developed on our planet. Water is the major constituent of almost all life forms. More than 70% of the earth's surface is covered with this simple molecule and most animals and plants contain more than 60% water by volume. Scientists estimate that the hydrosphere contains about 1.36 billion cubic kilometers of this substance, mostly in the form of a liquid (water) that occupies topographic depressions on the earth. But 98% of water is sea water and it's too salty for us to use. Moreover, since most of this remaining 2% freshwater is ice, less than 0.3% of water on earth is directly available to us. Prediction says that in near future the urban population in developing countries will grow dramatically, generating demand well beyond the capacity of already inadequate water supply and sanitation infrastructure and services. According to the UN World Water Development Report (year), by 2050, at least one in four people are likely to live in a country affected by chronic or recurring shortages of freshwater. Therefore it seems there are more than few reasons to put water and sanitation at the top of the world's agenda.

3.1 OBJECTIVES

After reading this unit, you will be able to:

- state about the importance of water as a precious resource;
- describe the physical and chemical unique properties of water and their distribution; and
- define the different types of pollution of water, their consumption and impacts of pollution both within states/countries and transboundary.

3.2 WATER AS A RESOURCE

Water is the second most essential material for human survival. Life as we know it would not be possible without water. However, availability of pure water for human use is a major issue worldwide. The sad fact is that pollution of fresh water (drinking water) is a problem for about half of the world's population The United Nations estimates that 2.7 billion people will face a water shortage by 2025. Over 80 countries in the world suffer from a water deficit, and an estimated 1.2 billion people drink unclean water. Each year there are about 250 million cases of water related diseases, which result in roughly 5 million to 10 million deaths. A significant number of these deaths are caused by the ingestion of water contaminated with pathogenic bacteria, viruses, or parasites responsible for cholera, typhoid, schistosomiasis, dysentery, and other diarrheal diseases.

3.2.1 Water as a Basic Need of Life

Water is our lifeline that bathes us and feeds us. Water provides the Earth with the capacity of supporting life. Human life, as with all animal and plant life on the planet, is dependent upon water. Not only do we need water to grow our food, generate our power and run our industries, but we need it as a basic part of our daily lives, our bodies need to ingest water every day to continue functioning. Communities and individuals can exist without many things if they have to - they can be deprived of comfort, of shelter, even of food for a period, but they cannot be deprived of water and survive for more than a few days. Because of the intimate relationship between water and life, water is woven into the fabric of all cultures, religions and societies in myriad ways. We need water to maintain a basic standard of personal and domestic hygiene sufficient to maintain health. It is not sufficient merely to have access to water in adequate quantities; the water also needs to be of adequate quality to maintain health and it must be free of harmful biological and chemical contamination. Water gathered from unprotected sources often does not meet these criteria and places the users at risk. Often water which is of a sufficiently high quality at the point of collection, is contaminated before it is used because, it has to be carried and stored before use or because of unhygienic practices.

Water provision cannot be separated from two other interrelated factors - sanitation and health. This is because, one of the primary causes of contamination of water is the inadequate or improper disposal of human (and animal) excreta. This often leads to a cycle of infection (resulting primarily in diarrhoeal diseases) and contamination which remains one of the leading causes of illness and death in the developing world. Providing for daily water needs is a burden on households with inadequate services in a number of ways, in addition to the direct health threats. Often water has to be carried long distances to the house which takes time and effort, a burden borne mainly by women and children. Provision of basic daily water needs is yet to be regarded by many countries as a human right. It is right to conclude here that, at the point of twenty first Century, we are surrounded by the marvels of modern communications, electronics and bio-mechanics; we have charted the human genome and yet we have not mustered the skills, resources and will to provide the global population with something as basic as safe water supply and adequate sanitation.

3.2.2 Exceptional Properties of Water

Water is one of the most wonderful compounds known to humans. Water is composed of two hydrogen atoms and a single oxygen atom; there are a total of two chemical bonds in the molecule. Each of the hydrogen atoms is bound to the oxygen by a covalent bond a bond formed by the sharing of one or more electrons between two atoms. In the case of the oxygen-hydrogen covalent bond, the electrons are not shared equally between the two atoms. In a water molecule, the oxygen atom can be described as having a net negative charge and the hydrogen atom as having a net positive charge. The attraction between these two atoms of different molecules is an example of hydrogen bonding. Hydrogen bonding isn't as strong as bonds, where electrons are shared or exchanged and can only happen when the molecules are fairly close together. Nevertheless, it is water's propensity to engage in hydrogen bonding that gives it some of its unique character. Hydrogen bonding is responsible for the fact that ice in liquid water floats, that water remains liquid over a large range of temperatures, that water has a high specific heat, and that strands of DNA stay "zipped" together. Without these molecules, life would have a very difficult time, perpetuating itself on the planet.

Water has a high specific heat. Specific heat is the amount of energy required to change the temperature of a substance. Since water has a high specific heat, it can absorb large amounts of heat energy before it begins to get hot. It also means that water releases heat energy slowly when situations cause it to cool. Water's high specific heat allows for the moderation of the Earth's climate and helps organisms regulate their body temperature more effectively.

Water in a pure state has a neutral pH. Pure water is neither acidic nor basic. Water changes its pH when substances are dissolved in it. Rain has a naturally acidic pH of about 5.6 because it contains natural derived carbon dioxide and sulfur dioxide.

Water conducts heat more easily than any liquid except mercury. This characteristic features causes large bodies of liquid water like lakes and oceans to have essentially a uniform vertical temperature profile.

Water molecules exist in liquid form over an important range of temperature from 0 - 100 Celsius. This range allows water molecules to exist as a liquid in most places on our planet.

Water is a universal solvent. It is able to dissolve a large number of different chemical compounds. This feature also enables water to carry solvent nutrients in runoff, infiltration, groundwater flow, and also in living organisms.

Water has a high surface tension. Water is adhesive and elastic, and tends to aggregate in drops rather than spread out over a surface as a thin film. This phenomenon also causes water to stick to the sides of vertical structures despite gravity's downward pull. Water's high surface tension allows for the formation of water droplets and waves, allows plants to move water (and dissolved nutrients) from their roots to their leaves, and the movement of blood through tiny vessels in the bodies of some animals.

Water molecules are the only substance on Earth that exists in all three physical states of matter: solid, liquid, and gas. Incorporated in the changes of state are massive amounts of heat exchange. This feature plays an important role in the redistribution of heat energy in the Earth's atmosphere. In terms of heat being transferred into the atmosphere, approximately 75 percent of this process is accomplished by the evaporation and condensation of water.

The freezing of water molecules causes their mass to occupy a larger volume. When water freezes, it expands rapidly adding about 9% by volume. Fresh water has a maximum density at around 4° Celsius. Water is the only substance on this planet where the maximum density of its mass does not occur when it becomes solidified.

Finally water can act as a shield, if enough of it is present. For example, during the history of early Earth there was not a protective layer in the atmosphere that blocked harmful ultraviolet (UV) radiation.

3.2.3 Uses of Water

Water resources are sources of water that are useful or potentially useful to humans. According to a report published by State hydrological institute, St. Petersburg) and UNESCO, Paris, 1999 the worldwide agricultural water withdrawal is about 2600 Km^3, Domestic 800 Km^3, industrial 400 Km^3 and evaporation 200 Km^3 (refer to Fig 3.1.)

Uses of water include agricultural, industrial, household, recreational and environmental activities. Virtually all of these human uses require fresh water. Uses of fresh water can be categorized as consumptive and non-consumptive (sometimes called "renewable"). A use of water is consumptive, if that water is not immediately available for another use. Losses to sub-surface seepage and evaporation are considered consumptive, as is water incorporated into a product (such as farm produce). The uses of water are many, from drinking and cleaning to irrigating crops and landscapes. Water is used for cooling, for recreation, and dust control. Water is needed for restaurants, most industrial processes, and even some religious ceremonies. On another level, the splash and flow of water in streams and fountains soothes and inspires. In one way or another, water is a part of almost everything humans make and do. Some of the prominent uses of water are as listed below.

Agricultural

It is estimated that 69% of worldwide water use is for irrigation, with 15-35% of irrigation withdrawals being unsustainable. In some areas of the world irrigation is necessary to grow any crop at all, in other areas it permits more profitable crops to be grown or enhances crop yield. Aquaculture is a small but growing agricultural use of water. Freshwater commercial fisheries may also be considered as agricultural uses of water, but have generally been assigned a lower priority than irrigation.

Industrial

It is estimated that 22% of worldwide water use is industrial. Major industrial users include power plants, which use water for cooling or as a power source (i.e. hydroelectric plants), ore and oil refineries, which use water in chemical processes, and manufacturing plants, which use water as a solvent. Water is used in power generation. Hydroelectricity is electricity obtained from hydropower. Hydroelectric power comes from water driving a water turbine connected to a generator. Pressurized water is used in water blasting and water jet cutters. It is also used in the cooling of machinery to prevent over-heating, or prevent saw blades from over-heating. Water is also used in many industrial processes and machines, such as the steam turbine and heat exchanger, in addition to its use as a chemical solvent.

Household

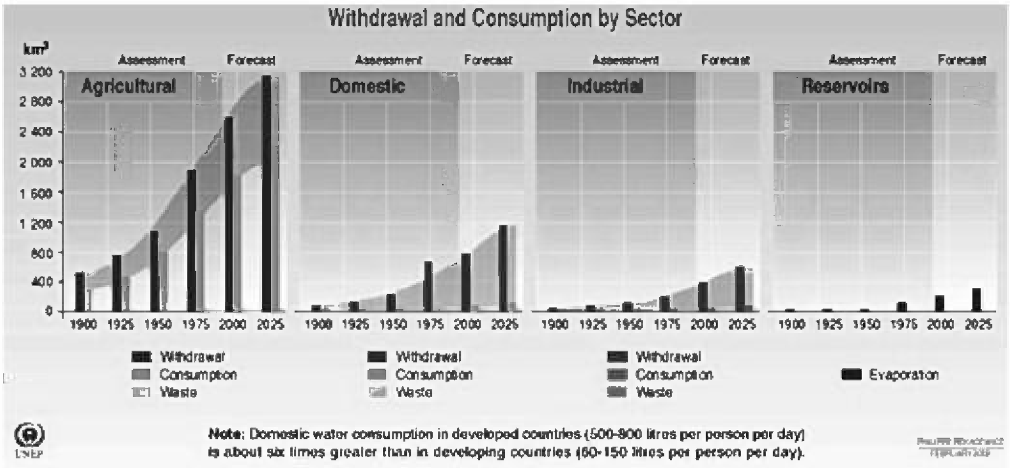
It is estimated that 8% of worldwide water use is for household purposes. These include drinking water, bathing, cooking, sanitation, and gardening. Drinking water is water that is of sufficiently high quality so that it can be consumed or used without risk of immediate or long term harm.

Recreation

Recreational water use is usually a very small but growing percentage of total water use for activities like whitewater boating, angling, water skiing, nature enthusiasts and swimmers. Recreational usage is usually non-consumptive. Recreational usage may reduce the availability of water for other users at specific times and places. For example, water retained in a reservoir to allow boating in the late summer is not available to farmers during the spring planting season.

Environmental

Explicit environmental water use is also a very small but growing percentage of total water use. Environmental water usage includes artificial wetlands, artificial lakes intended to create wildlife habitat, fish ladders, and water releases from reservoirs timed to help fish spawn.Like recreational usage, environmental usage is non-consumptive but may reduce the availability of water for other users at specific times and places. For example, water release from a reservoir to help fish spawn may not be available to farms upstream.



Source: Igor A. Shiklomanov, State Hydrological Institute (SHI, St. Petersburg) and United Nations Educational Scientific and Cultural Organisation (UNESCO, Paris), 1999

Fig.3.1. Global withdrawal and consumptive water use

Check Your Progress 1

Note: a) use the space given below for your answer.

b) Compare your answers with those given at the end of the unit.

1) Why water is considered to be an immensely important resource for life?

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2) Elaborate the unique properties of water and their significance.

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3.3 DISTRIBUTION AND AVAILABILITY OF GLOBAL WATER RESOURCE

Water is widely distributed on earth as freshwater and saline water in the oceans. The planet's fresh water is also very unevenly distributed. Although in warm periods such as the Mesozoic and Paleogene when there were no glaciers anywhere on the planet all fresh water was found in rivers and streams, however today the distribution is approximately as shown in fig 3.2. Out of world' s total water resources about 97.5% is salt found water mainly in oceans, and only 2.5% is available as fresh water at any time on the planet earth. Out of this 2.5% of fresh water, about 0.4% is available as surface water and 30.1% as ground water.

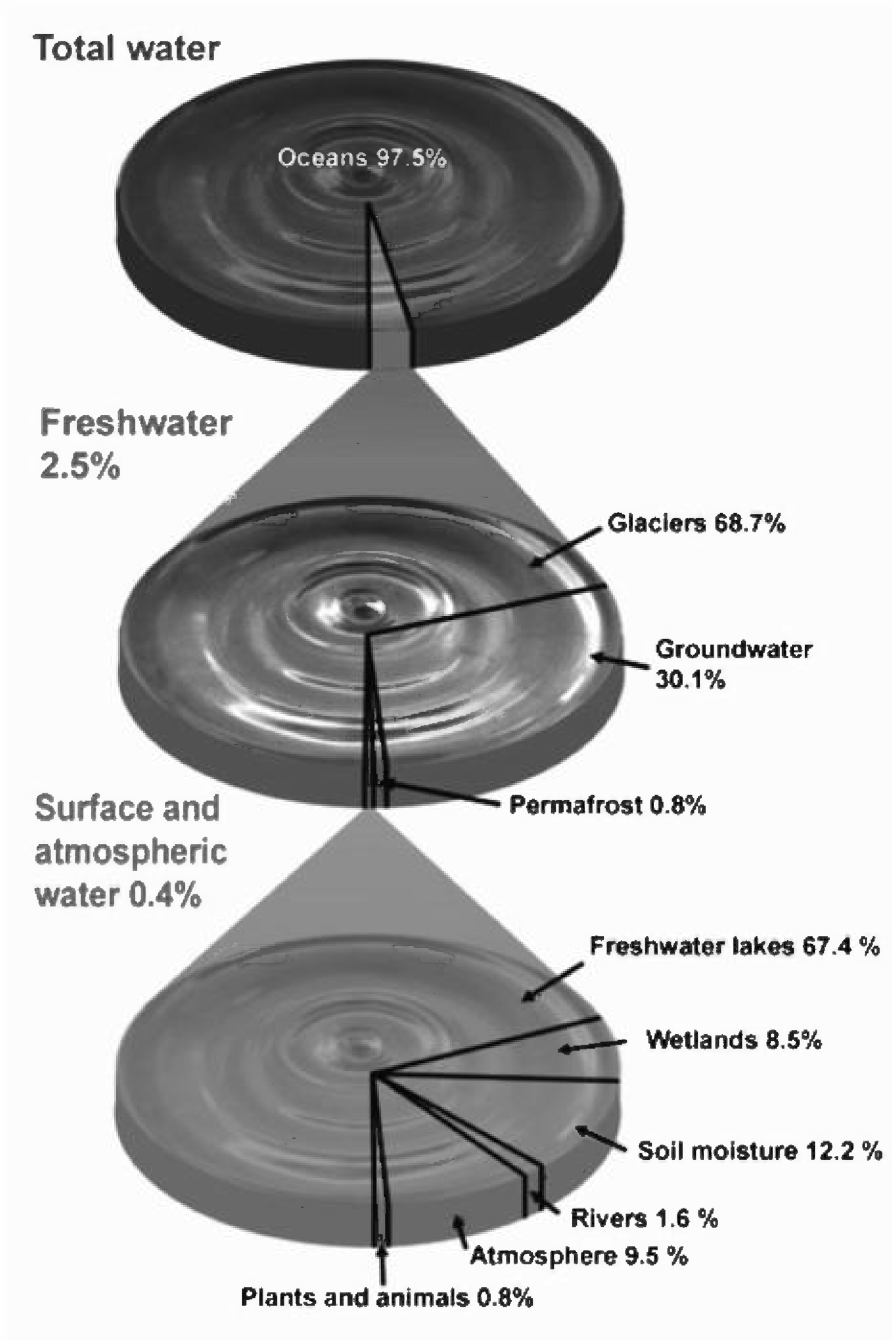

Fig.3.2: Global water distribution

As a result, the vast bulk of the water on Earth is regarded as saline or salt water, with an average salinity of 3.5%, though this varies slightly according to the amount of runoff received from surrounding land. In all, oceanic water, saline water from marginal seas and water from saline *closed* lakes amounts to over 98% of the water on Earth, though no closed lake stores a globally significant amount of water. Renewable *saline* groundwater is believed to total at least 100 km³ globally, but is seldom considered except when evaluating water quality in arid regions. Typically, fresh water is defined as water with a salinity of less than 1 percent that of the oceans - ie. below around 0.035%. Water with salinity between this level and 1% is typically referred to as marginal water because it is marginal for many uses by humans and animals.

The continent wise distribution of world water resources is best depicted by the fig 3.3.

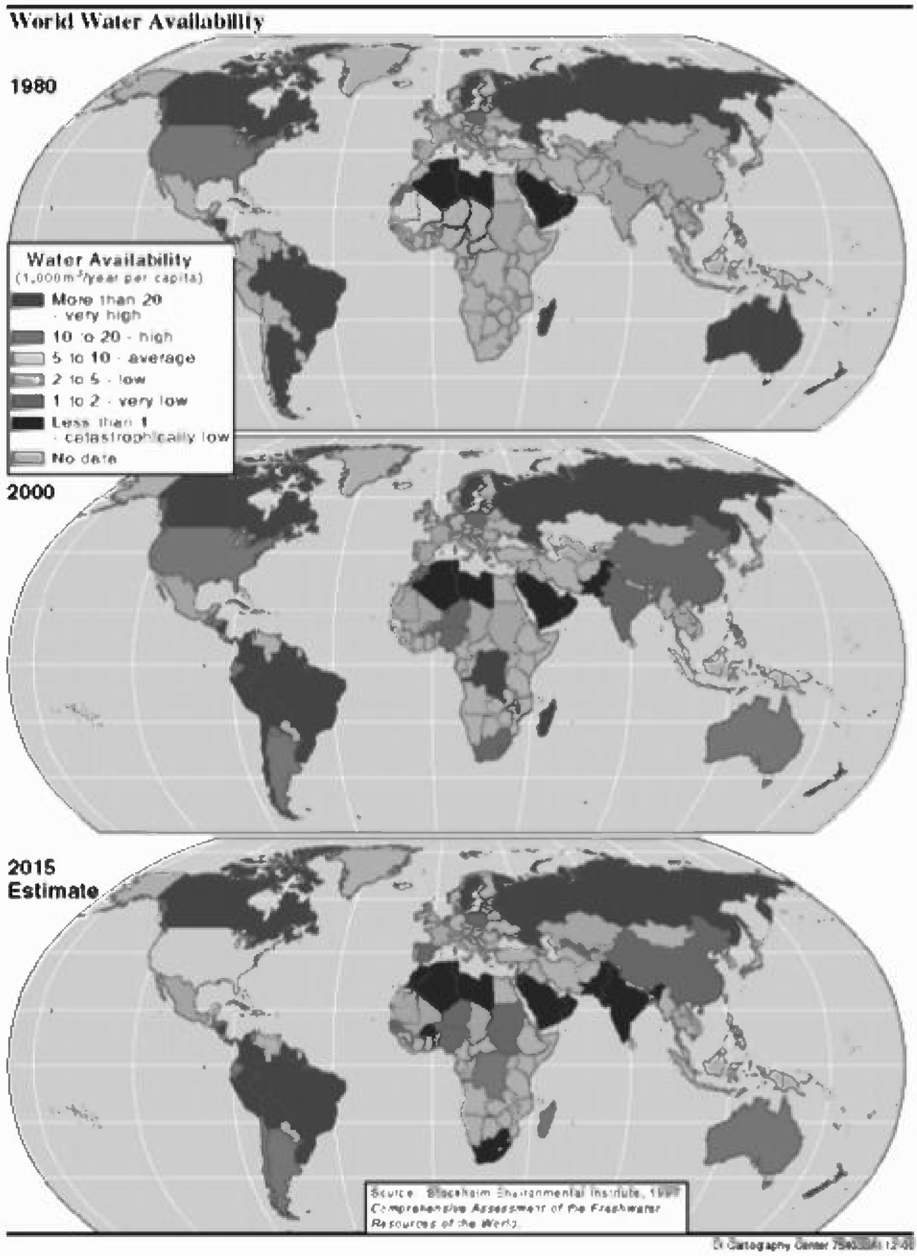

Fig.3.3: World water availability

Source: National Intelligence Council, Global Trends 2015, Dec. 2000, p. 29 citing original source as Stockholm Environmental Institute, 1997: Comprehensive Assessment of the Freshwater Resources of the World.

3.3.1 Importance of Glaciers in World Water Availability

Glaciers store about 69% of the world's freshwater, and if all land ice melted the seas would rise about 70 meters (about 230 feet). Though, most (97%) is not considered as a water resource as it is inaccessible, located in the Antarctic, Arctic and Greenland ice sheets. However, land based glaciers and permanent snow and ice, found on all continents except Australia, cover approximately 680,000 km^2 and are critical to many nations' water resources. Even in situations where ice covers only a small percent of a basin's upland mountainous terrain (e.g. in the Himalayas, Rockies, Urals, Alps, Andes), glaciers can supply water resources to distant lowland regions. Thus, glacial ice and snow represents a highly valuable natural water reservoir. Glacier melt buffers other ecosystems against climate variability. Very often, it provides the only source of water for humans and biodiversity during dry seasons. The Himalayas have the largest concentration of glaciers outside the polar caps. With glacier coverage of 33,000 km^2, the region is aptly called the "Water Tower of Asia" as it provides around $8.6 \times 106\ m^3$ of water annually. These Himalayan glaciers feed seven of Asia's great rivers: the Ganga, Indus, Brahmaputra, Salween, Mekong, Yangtze and Huang Ho. It ensures a year round water supply to millions of people. However, fresh groundwater is of great value, especially in arid countries such as India. Its distribution is broadly similar to that of surface river water, but it is easier to store in hot and dry climates, because groundwater storages are much more shielded from evaporation than are dams.

3.3.2 Hydrological Cycle

Hydrologic cycle is the water transfer cycle, which occurs continuously in nature (Fig 3.4.). The three important phases of the hydrologic cycle are:

a) Evaporation and evapotranspiration

b) precipitation and

c) runoff.

The globe has one third land and two third oceans. Evaporation from the surfaces of ponds, lakes, reservoirs, ocean surfaces, etc. and transpiration from surface vegetation i.e., from plant leaves of cropped land and forests, etc. take place. These vapours rise to the sky and are condensed at higher altitudes by condensation nuclei and form clouds, resulting in droplet growth. The clouds melt and sometimes burst resulting in precipitation of different forms like rain, snow, hail, sleet, mist, dew and frost. A part of this precipitation flows over the land called runoff and part infilters into the soil which builds up the ground water table. The surface runoff joins the streams and the water is stored in reservoirs. A portion of surface runoff and ground water flows back to ocean. Again evaporation starts from the surfaces of lakes, reservoirs and ocean, and the cycle repeats.

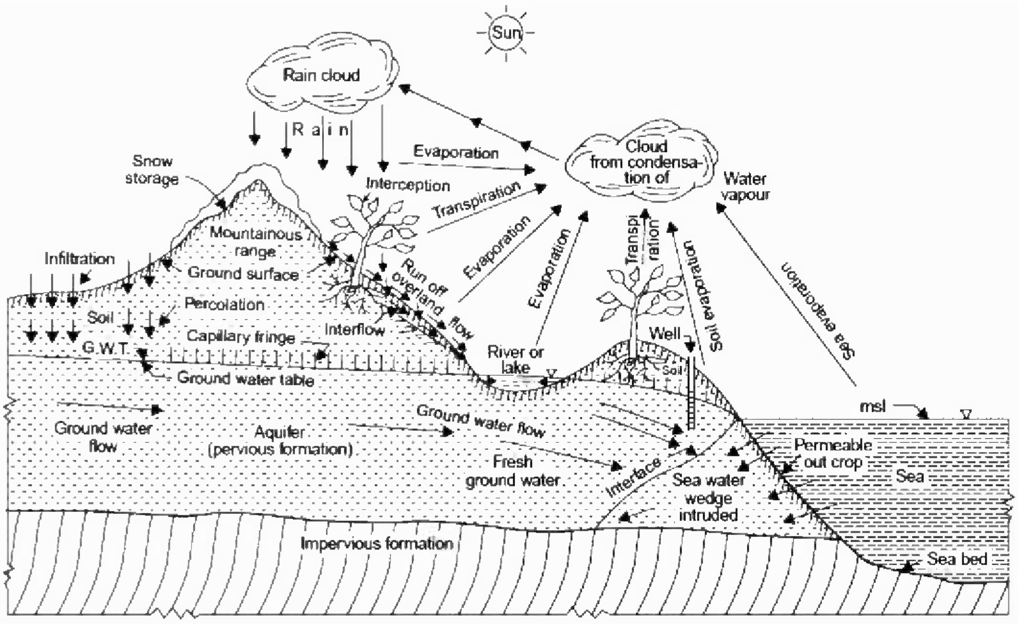

Fig.3.4. Hydrological cycle

The process begins with condensation, when water vapor condenses in the atmosphere to form clouds. Condensation occurs when the temperature of the air or earth changes. Water changes states when temperatures fluctuate. So when the air cools enough, water vapor has to condense on particles in the air to form clouds. This process is very noticeable on plants as they dew in the morning. As clouds form, winds move them across the globe, spreading out the water vapor. When eventually the clouds can't hold the moisture, they release it in the form of precipitation, which can be snow, rain, hail, etc. The next three stages: infiltration, runoff, and evaporation occur simultaneously. Infiltration occurs when precipitation seeps into the ground. This depends a lot on the permeability of the ground. Permeability is the measure of how easily something flows through a substance. The more permeable, the more precipitation seeps into the ground. If precipitation occurs faster than it can infiltrate the ground, it becomes runoff. Runoff remains on the surface and flows into streams, rivers, and eventually large bodies such as lakes or the ocean. Infiltrated groundwater moves similarly, as it recharges rivers and heads towards large bodies of water. As both of these processes are happening, the power of the sun is driving this cycle by causing evaporation. Evaporation is the change of liquid water to a vapor. Sunlight aids this process as it raises the temperature of liquid water in oceans and lakes. As the liquid heats, molecules are released and change into a gas. Warm air rises up into the atmosphere and becomes the vapor involved in condensation.

Considering so little of the water on earth is drinkable to people, it is amazing the supply has survived as long as it has. The hydrologic cycle continues to move water and keep sources fresh. It is estimated that 100 million billion gallons a year are cycled through this process. Without this process life on Earth would be impossible. We need it to sustain us and for all of our life processes to function. Without water, life would not be possible on Earth.

3.3.2.1 Role of Vegetation in Hydrological Cycle

Vegetation has immense importance in the hydrological cycle phenomena (Fig 3.5), its cover affects precipitation. During cloud-free daytime conditions, heat fluxes near the ground surface are affected by the partitioning of absorbed radiative energy into sensible and latent heat. On bare dry land, this results in a strong heating of the surface, a strong sensible heat flux in the atmospheric surface layer and a large soil heat flux. Evaporation is limited. By contrast, in wet/ vegetated land the incoming radiation is mostly used for evaporation. In that case, the sensible heat flux and the soil heat flux are usually much smaller than the latent heat flux. Such differences lead to significantly different atmospheric boundary layers above dry and wet (vegetated) land.

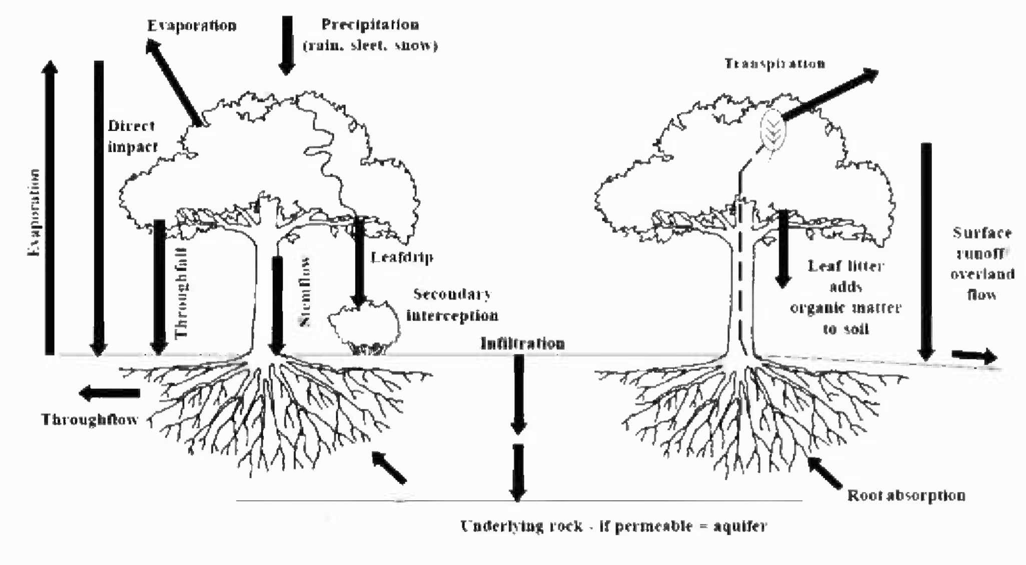

Fig.3.5: Role of vegetation in hydrological cycle

Interception

When precipitation lands on vegetation it is said to have been **intercepted**. The volume of water which is intercepted is dependent on the nature of the vegetation; woodlands will intercept more than patchy grassland.

Leafdrip

The total volume of water which drips from leaves is influenced by the shape of the leaf, the presence or absence of any waxy cuticle and the surface form of the leaf. Hairy leaves will retain more water which may then evaporate. **Secondary interception** of rainfall may be more important in preventing rainsplash erosion than the original interception by the trees.

Stemflow

Stemflow is greatest on trees which have smooth barked and steeply angled branches. The leaves, branches and stems of trees may be covered in acid pollutants, e.g. sulphur particles. The pH of rainfall may therefore be decreased between the point of initial interception and the point when it reaches the ground.

Throughfall

This refers to intercepted water dripping off leaves and branches to the ground.

Direct impact

Raindrops possess considerable kinetic energy. The total amount of energy transmitted to the soil surface is proportional to the product of rainfall intensity and duration. Accumulating leaf litter dissipates the energy of falling raindrops.

Transpiration

This is the loss of water through microscopic pores (stomata) in leaves. The combination of evaporation and transpiration is known as **evapotranspiration** and in temperate zones such losses will be greater in summer. Transpiration loss from trees is greater than that from crops because humid air adjacent to the leaves is more rapidly removed by air currents. This maintains a steeper diffusion gradient between the stomata and the atmosphere. The loss of water from the plant by transpiration effectively 'pulls' water up through the xylem tubes of the entire plant. This is known as the **transpiration stream**. This movement encourages water to be absorbed from the soil by the root hairs.

Infiltration

Infiltration refers to the absorption of water into the soil. The infiltration rate is influenced by soil porosity, which is itself determined by the nature and arrangement of the soil peds. Decomposed leaf litter adds organic matter to the soil, improving it's **structure**, hence permeability, encouraging more efficient infiltration.

Throughflow

Water will always move downwards as a result of gravity but water may be deflected laterally by soil particles and impermeable soil components.

Overland flow/surface runoff

Water which is unable to enter the soil (infiltrate) will collect on the soil surface and at some point in time, begin to flow away over the surface, a process known as surface runoff.

3.3.3 Rainfall Pattern and its Ecological Implications

Precipitation is the primary source of freshwater for rivers, lakes, groundwater, and glaciers on the Earth's terrestrial surface. The average annual precipitation of the world is estimated to be 1050 millimeters per year or 2.9 millimeters per day.

Areas of high precipitation are found near the equator, west coast of North America between latitudes of 35 to 60 degrees North, southeastern United States, coast of southeast Asia, and eastern Australia. Areas deficient of precipitation include the continental deserts at the subtropical high belts, central Eurasia and North America, and the Polar Regions above a latitude of 60 degrees.

The reasons for these patterns are as follows:

- The deserts in the subtropical regions occur because these areas do not contain any mechanism for lifting air masses. In fact, these areas are dominated by subsiding air that results from global circulation patterns.
- Continental areas tend to be dry because of their distance from moisture sources.
- Polar areas are dry because cold air cannot hold as much moisture as warm air.
- Areas near the equator achieve high rainfall amounts because constant solar heating encourages convection, and global circulation patterns cause northern and southern air masses to converge here causing frontal lifting.
- Mid latitudes experience cyclonic activity and frontal lifting when polar and subtropical air masses meet at the polar front. Further, the air masses in this region generally move from West to East, causing levels of precipitation to decrease East of source regions.
- Mountain ranges near water sources can receive high rainfalls because of orographic uplift, if and only if the prevailing winds are in their favor. This can also result in a sharp reduction in rainfall in regions adjacent or on the leeward slopes of these areas. This phenomenon is commonly known as the rain shadow effect.

Check Your Progress 2

Note: a) Use the space given below for your answer

b) Compare your answers with those given at the end of the unit

1) Define Hydrological cycle

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2) Write a note on Global rainfall pattern and its ecological implications.

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3.4 WATER QUALITY AND ITS IMPAIRMENT

Water quality is a term used to express the suitability of water to sustain various uses or processes. The composition of surface and underground is dependent on natural factors (geological, topographical, meteorological, hydrological and biological) in the drainage basin and varies with seasonal differences in runoff volumes, weather conditions and water levels. Human intervention also has significant effects on water quality. Although the natural ecosystem is in harmony with natural water quality, any significant changes to water quality will usually be disruptive to the ecosystem. The quality of water may be described in terms of the concentration and state (dissolved or particulate) of some or all of the organic and inorganic material present in the water, together with certain physical characteristics of the water. It is determined by *in situ* measurements and by examination of water samples on site or in the laboratory.

3.4.1 Parameters of Water Quality

Water Temperature

Water temperature is not only important to fisherman and industries, but also to the growth of fish and algae. A lot of water is used for cooling purposes in power plants that generate electricity. The temperature of the released water can affect downstream habitats. Temperature also can affect the ability of water to hold oxygen as well as the ability of organisms to resist certain pollutants.

pH

The pH is a measure of how acidic/basic a water sample is. The range goes from 0 - 14, with 7 being neutral. The pH of less than 7 indicates acidity, whereas a pH of greater than 7 indicates a base. The pH is really a measure of the relative amount of free hydrogen and hydroxyl ions in the water. Since pH can be affected by chemicals in the water, pH is an important indicator of water and in turn can harm animals and plants living in the water.

Specific Conductance

Specific conductance is a measure of the ability of water to conduct an electrical current. It is highly dependent on the amount of dissolved solids (such as salt) in the water. Pure water, such as distilled water, will have a very low specific conductance, and sea water will have a high specific conductance. Rainwater often dissolves airborne gasses and airborne dust while it is in the air, and thus often has a higher specific conductance than distilled water. Specific conductance is an important water quality measurement, because it gives a good idea of the amount of dissolved material in the water.

Turbidity

Turbidity is the amount of particulate matter that is suspended in water. Turbidity measures the scattering effect that suspended solids have on light: the higher the intensity of scattered light, the higher the turbidity. Material that causes water to be turbid includes:

- clay
- silt
- finely divided organic and inorganic matter
- soluble coloured organic compounds
- plankton
- microscopic organisms

Turbidity makes the water cloudy or opaque. Turbidity is measured by shining a light through the water and is reported in Nephelometric Turbidity Units (NTU).

Dissolved Oxygen

A small amount of oxygen, upto about ten molecules of oxygen per million of water, is actually dissolved in water. This dissolved oxygen is breathed by fish and zooplankton and is needed by them to survive. Rapidly moving water, such as in a mountain stream or large river, tends to contain a lot of dissolved oxygen, while stagnant water contains little. Bacteria in water can consume oxygen as organic matter decays. Thus, excess organic material in the tanks, lakes and rivers can cause an oxygen deficient situation to occur. Aquatic life can have a hard time in stagnant water that has a lot of rotting, organic material in it, especially in summer, when dissolved oxygen levels are at a seasonal low.

Hardness

The amount of dissolved calcium and magnesium in water determines its 'hardness'. Where the water is relatively hard, it is difficult to get lather up when washing hands or clothes and, industries in these areas have to spend money to soften their water, as hard water can damage equipment. Hard water can even shorten the life of fabrics and clothes.

Suspended Sediment

Suspended sediment is the amount of soil moving along in a stream. It is highly dependent on the speed of the water flow, as fast flowing water can pick up and suspend more soil than calm water. If land is disturbed along a stream and protection measures are not taken, then excess sediment can harm the water quality of a stream. Sediment coming into a reservoir is always a concern; once it enters it cannot get out most of it will settle to the bottom. Reservoirs can 'silt in' if too much sediment enters them. The volume of the reservoir is reduced, resulting in less area for water storage for agriculture as well as reducing the power-generation capability of the power plant in the dam.

3.4.2 Water Pollution and its Impacts

Water pollution occurs when a body of water is adversely affected due to the addition of large amounts of materials to the water. Two types of water pollutants exist; point source and non-point source. Point sources of pollution occur when harmful substances are emitted directly into a body of water. Many causes of pollution including sewage and fertilizers contain nutrients such as nitrates and phosphates. Water is essential for life, but it can and does transmit diseases in countries in all continents, from the poorest to the wealthiest. It can be classified into three types as domestic pollution, industrial and agricultural pollution.

Domestic pollution

Important source of water pollution is domestic sewage system, which pollutes well and rivers, which are important source of drinking water. The problem of excreta disposal is clearly as old as mankind itself. It directly influences disease transmission through person to person contact, water and the food chain. At least 2500 million people in developing countries lack an adequate system for disposing of their faeces. The potable water contaminated with faeces is the chief cause of some important diseases of human beings. They consist primarily of intestinal bacteria. Deteriorating water quality is a particular threat in developing countries, where hundreds of millions of people lack access to clean drinking water and the vast majority of sewage are discharged into surface waters without wastewater treatment. When untreated or inadequately treated wastewater or excreta (faecal sludge) is applied to soil and crops, disease transmission can occur. The persons at risk are the farmers, farm workers and their families as well as consumers of crops produced in such a way.

Industrial Pollution

Industrial waste is also a significant polluter, giving rise to contamination with heavy metals. The chemicals discharged by the factories are more harmful than the sewerage that flows into the river. The effluent discharged by the factories contains detergents, non biodegradable materials and toxic chemicals hazardous to health and hygiene. Other sources of water pollution are distilleries potassic fertilizers, electroplating plant, which contains harmful heavy metals, and cyanides which causes excessive acidity in water, which is harmful for aquatic life. Intensive use of pesticides and fertilizers has increased the level of nitrates in water. Water pollution ranged from moderate to very high in case of textiles, jute, leather, vegetables fats and brewery. Moderate pollution was noted from dairy and canning establishments.

Agricultural Pollution

In addition to problems of water logging, desertification, salinization, erosion, etc., that affect irrigated areas; the problem of downstream degradation of water quality by salts, agrochemicals and toxic leachates is a serious environmental problem. In the past few years has it become apparent that trace toxic constituents, such as Se, Mo and As in agricultural drainage waters may cause pollution problems that threaten the continuation of irrigation in some projects.

The construction industry is also at fault for contaminating our water resources with cement, lubricants, plastics and metals. Rivers and lakes are also polluted from heavy silt or sediment run-off from construction sites.

Natural catastrophes are the cause of water pollution effects as well. Major upheavals such as storms, earthquakes, acid rain, floods, and volcano eruptions have been known to disrupt the ecological system and pollute water.

Littering on the land or on the water is a source of water pollution. Debris tossed onto land eventually makes its way into storm drains and then returns to surface water. Ships and boats discharging human waste or chemicals into the water directly are simply speeding up the pollution process.

Ground water pollution occurs when chemicals, debris, garbage, oil or other harmful contaminants enter the ground water supply over time. Ground water is often a resource for our drinking water. If it is not treated properly, those harmful elements can cause serious health issues for human beings and domestic animals.

Impacts of water pollution

The effects of water pollution are far reaching and affect not only the environment, but human beings and animals as well. Water pollution affects our oceans, lakes, rivers, and drinking water, making it a widespread and global concern. Numerous diseases, health problems, and even fatalities have been associated with water pollution.

Some water pollution effects are recognized immediately, whereas others don't show up for months or years. Additional effects of water pollution include:

1) The food chain is damaged. When toxins are in the water, the toxins travel from the water the animals drink to humans when the animals' meat is eaten.

2) Diseases can spread via polluted water. Infectious diseases such as typhoid and cholera can be contracted from drinking contaminated water. This is called microbial water pollution. The human heart and kidneys can be adversely affected if polluted water is consumed regularly. Other health problems associated with polluted water are poor blood circulation, skin lesions, vomiting, and damage to the nervous system. In fact, the effects of water pollution are said to be the leading cause of death for humans across the globe.

3) Acid rain contains sulfate particles, which can harm fish or plant life in lakes and rivers.

4) Pollutants in the water will alter the overall chemistry of the water, causing changes in acidity, temperature and conductivity. These factors all have an effect on the marine life.

5) Marine food sources are contaminated or eliminated by water pollution.

6) Altered water temperatures (due to human actions) can kill the marine life and affect the delicate ecological balance in bodies of water, especially lakes and rivers.

3.4.3 Ganga Action Plan

The river Ganga occupies a unique position in the cultural ethos of India. The river is not just a legend, it is also a life-support system for the people of India because the basin is inhabited by 37 per cent of India's population including eight states of India and 47 per cent of the total irrigated area in India. It has also been a major source of navigation and communication since ancient times. However In the recent past, due to rapid progress in communications and commerce, the river is no longer only a source of water but is also a channel, receiving and transporting urban wastes away from the towns. It has been assessed that more than 80 per cent of the total pollution load (in terms of organic pollution expressed as biochemical oxygen demand (BOD)) arises from domestic sources, i.e. from the settlements along the river course, Solid garbage thrown directly into the river, non-point sources of pollution from agricultural run-off containing residues of harmful pesticides and fertilisers, animal carcasses and half-burned and unburned human corpses thrown into the river, defecation on the banks by the low income people along with mass bathing and ritualistic practices.

The Central Pollution Control Board (CPCB), undertook a comprehensive scientific survey in 1981-82, in order to classify river waters according to their designated best uses. This report was the first systematic document that formed the basis of the Ganga Action Plan (GAP). It detailed land use patterns, domestic and industrial pollution loads, fertiliser and pesticide use, hydrological aspects and river classifications. Realizing the need for urgent intervention the Central Ganga Authority (CGA) was set up in 1985, under the chairmanship of the Prime Minister. The Ganga Project Directorate (GPD) was established in June 1985, as a national body operating within the National Ministry of Environment and Forest. Finally the GAP plan was formally launched on 14 June, 1986. The main thrust was to intercept and divert the wastes from urban settlements away from the river. Treatment and economical use of waste, as a means of assisting resource recovery, were made an integral part of the plan. One outcome of this initiative was a multi disciplinary study of the river in which the 14 universities located in the basin participated in a well coordinated, integrated research programme. The mandate of GAP was limited to quick and effective, but sustainable, interventions to contain the damage. The studies carried out by the CPCB in 1981-82 revealed that pollution of the Ganga was increasing, but had not assumed serious proportions, except at certain main towns on the river such as industrial Kanpur and Calcutta on the Hoogly, together with a few other towns. These locations were identified and designated as the "hot-spots" where urgent interventions were warranted. The causative factors responsible for these situations were targeted for swift and effective control measures. This strategy was adopted for urgent implementation during the first phase of the plan under which only 25 towns identified on the main river were to be included.

The studies had revealed that:

- 75 percent of the pollution load was from untreated municipal sewage.
- 88 percent of the municipal sewage was from the 25 Class I towns on the main river.
- Only a few of these cities had sewage treatment facilities (these were very inadequate and were often not functional).
- All the industries accounted for only 25 percent of the total pollution (in some areas, such as Calcutta and Kanpur, the industrial waste was very toxic and hard to treat).

As a result apart from the visible improvement in the water quality, the awareness generated by the project is an indicator of its success. It has resulted in the expansion of the programme over the entire Ganga basin to cover the other polluted tributaries. The GAP has further evolved to cover all the polluted stretches of the major national rivers, and including a few lakes. Considering the huge costs involved the central and state governments have agreed in principle to each share half of the costs of the projects under the "National Rivers Action Plan". The state governments are also required to organise funds for the GAP is a successful example of timely action due to environmental awareness at the governmental level.

3.4.4 Transboundary Impacts of Water Pollution

Geographical position and terrain topography have affected the dispersion of river system in many nations of the world into their neighbouring countries. This has given rise to the terminology "transboundary waters". "Transboundary waters" means any surface or ground waters which mark, cross or are located on the boundaries between two or more States or nations. Another terminology which has emerged from this transboundary water is "transboundary impact" which means any significant adverse effect on the environment resulting from a change in the conditions of transboundary waters caused by a human activity, the physical origin of which is situated wholly or in part within an area under the jurisdiction of another Party. Effects include effects on human health and safety, flora, fauna, air, climate, etc. Sometimes some environmental pollutants and toxicants which are carcinogenic, mutagenic, teratogenic or bioaccumulative, especially when they are persistent may be released from one place but the effect is felt in another location either downstream in a moving water body or by dispersion via wind.

Management of transboundary impacts requires measure to avoid the release of hazardous substances and equitable so that the needs of the present generation are met without compromising the ability of future generations to meet their own needs.

The means of reducing transboundary impact are legal, administrative, economic, technical and financial measures. The Parties may adopt water quality criteria and introduce emission limits for discharges into surface waters. This type of pollution may be avoided or reduced by using low pollution technology. The States must establish programmes for monitoring the condition of transboundary waters. In heavily industrialized, heavily populated areas like China, the possibility of polluted water making it way across international boundaries, as well as unrecognized water pollution within a poorer country brings up questions of human rights, allowing for international input on water pollution.

Unilateralism and lack of collaboration between cobasin States often affect water availability, producing harmful consequences to inland water biodiversity and thus to human activities, vital human needs, and livelihoods. For example, reductions in river flows due to diversions upstream can increase the concentrations of pollutants above safe levels; water diversions from one basin to another can relocate entire aquatic faunas, resulting in significant problems with invasive alien species. Therefore, it is crucial that coriparians agree on mechanisms of collaboration and dialogue that enable the integrated management of transboundary inland water systems. In most situations, especially where different types of water uses compete with one another, such management will depend on the establishment of agreed substantive and procedural rules and principles governing water allocation and management across international borders.

Check Your Progress 3

Note: a) Use the space given below for your answer.

b) Compare your answers with those given at the end of the unit.

1) Describe the different types of water quality parameters.

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2) State the impacts of water pollution.

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3.5 LET US SUM UP

- Water is the most important resource on our planet to support existence of plants, animals and human beings.
- Precipitation is the primary source of freshwater for rivers, lakes, groundwater, and glaciers on the Earth's terrestrial surface.
- Uses of water include agricultural, industrial, household, recreational and environmental activities.
- Hydrologic cycle is the water transfer cycle, which occurs continuously in nature. The three important phases of the hydrologic cycle are: Evaporation and evapotranspiration ,precipitation and runoff.
- This is for the multipurpose use owing to the unique properties of walls, but without realizing its importance and geographical distribution, it has been used incessantly and contaminated, which has finally given rise to several deleterious ecological, health, economic and political impacts around the globe.
- Immediate attention is required to conserve this inevitable resource with policies, scientific backup and above all willingness from every citizen on this earth.

3.6 KEY WORDS

Water Resource : An inevitable nature gifted resources which is a basic need for life processes of plants, animals and human beings.

Unique Properties of Water : The chemical structure gives rise to certain unique properties of water in both physical and chemical terms, which make it a wonderful liquid of the earth and as known an universal solvent.

Global Distribution : Latitudinal and altitudinal differences of rainfall create a horizontal distribution of water around the globe.

Water Pollution : Addition of certain unwanted substances into water which impairs its normal physical and chemical properties.

Impacts : Effects of water pollution.

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3.8 KEY TO CHECK YOUR PROGRESS

Check Your Progress 1

1) Your answer must include the following points:
   - Water requirement for daily life processes
   - Agricultural, Industrial, Recreational and environmental uses

2) Your answer must include the following points.
   - Chemical structure of water molecule
   - Physical properties of water

Check Your Progress 2

1) Your answer must include the following points:
   - Processes that help in this cycle like evaporation, precipitation, runoff, infiltration
   - Digramatic representation of the hydrological cycle
2) Your answer must include the following points:
   - Global pattern of annual precipitation
   - Reasons for this pattern (latitudinal and altitudinal)

Check Your Progress 3

1) Your answer must include the following points:
   - Water parameters that certifies its quality
2) Your answer must include the following points
   - Ecological impacts
   - Water borne diseases
   - Ground water pollution
   - Impairment of water quality parameters

UNIT 4 WATER: COMPETITIVE USES

Structure

4.0 INTRODUCTION

Earth is composed largely of water, but freshwater comprises only 3% of the total water available to us, of that, only 0.06% is easily accessible. As human populations continue to expand and an increasing number of people use finite resources, future availability of adequate supplies of freshwater for human and agricultural needs may become critical in many regions. According to the United Nations Population Fund (UNFPA, 2005), while the global population tripled over the past 70 years, the water use has grown six fold, a result of industrial development and expansion of irrigation. Even as demand for water by all users grows, groundwater is being depleted, other water ecosystems are becoming polluted and degraded, and developing new sources of water is becoming more costly.

So all that needs to be addressed by the water sector today in order to promote sustainable and equitable water management. Many of these challenges are interconnected, requiring integrated and holistic solutions.

4.1 OBJECTIVES

After reading this unit, you will be able to:

- describe the impact of economic development on global water resources;

- underline the individual, national and international efforts and conflicts regarding water sharing and conservation throughout the world;
- recognise the impacts of climate change on water resources; and
- discuss the conservation methods options from our ancient civilizations till today for water conservation.

4.2 WATER RESOURCES AND ECONOMIC DEVELOPMENT: CHALLENGES

There have been three major drivers to the enormous expansion of water resources infrastructure in the past century: (1) population growth; (2) changing standards of living and (3) expansion of irrigated agriculture. All these factors have increased dramatically. Between 1900 and 2000, the population of the world has grown from 1.600 million to 6,000 million people. Land under irrigation increased from around 50 million hectares at the turn of the century to over 267 million hectares today. These facters other factors have led to a nearly seven fold increase in freshwater withdrawals. Rapid population growth and increased water consumption are quickly depleting the available water and also degrading water quality. Demand for water will surpass accessible water by 2014 (at around 10,000 cubic Km/yr). It is said that actual consumption is lower than demand because water sources may be inaccessible to population centers. Consumption will be forced to level off by 2030 due to limits on accessible water (refer to Fig 4.1). Many factors significantly impact the increasing water demand, including population growth, economic growth, technological development, land use and urbanization, rate of environmental degradation, government programs, climate change, and others. In 1990, 43.5% of the world's population lived in urban areas by 2000 the proportion had grown to 47%. Simultaneously business activity ranging from industrialization to services such as tourism and entertainment continues to expand rapidly. This expansion requires increased water services including both supply and sanitation, which can lead to more pressure on water resources and natural ecosystems.

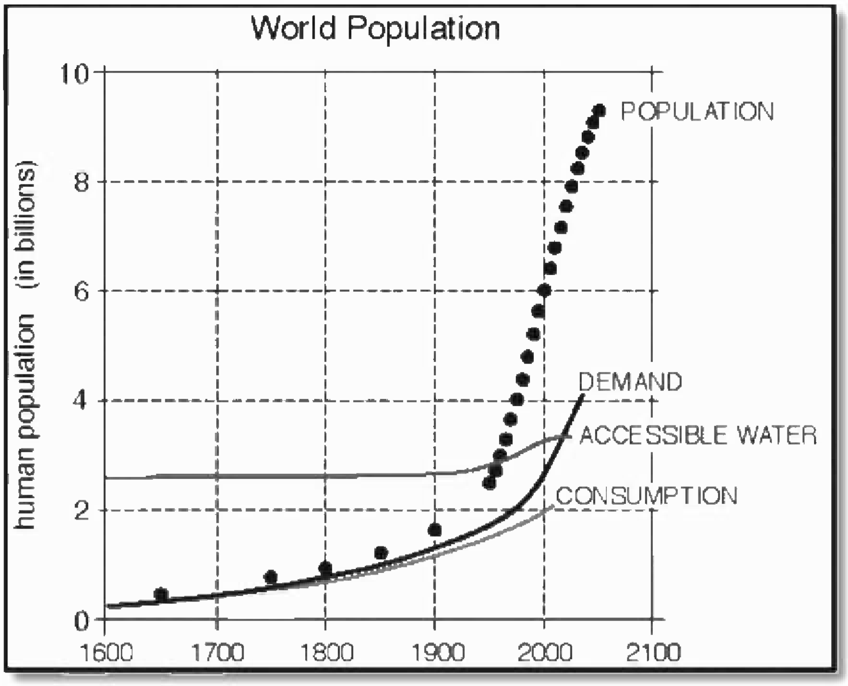


Fig.4.1: Estimated global water demand and consumption

4.3 WATER: AVAILABILITY VS. DEMAND

Water availability, as well as the amount of water used, is a significant factor for social (and economic) activities. Various countries in the world are at different levels of demographic and economic development which may determine a region's (country's) vulnerability to water resources.

4.3.1 Availability

Water resource availability in different parts of the world varies significantly, in part due to the size of the country and in part as a result of differences in the natural conditions. Of all of the countries in the world, only 13 counties have water resources exceeding 500 km^3. Most of these countries also have a large surface area. Many countries, particularly in Europe, Africa, and Middle East Asia, have a relatively small amount of water resources; the annual availability of water is less than 100 km^3. Water supply in a country (region) consists of internal surface water, net inflow of surface water, and annual recharge of groundwater in its aquifers. On average, for the world as a whole, groundwater contributes roughly 29 percent to the total world water supply.

Per capita water availability

On a per capita basis, the availability of water resources is different from the availability of total water resources. On average, we have 7,824 m^3 of water for every individual inhabitant in the world. This water is available in plentiful quantities in the other Pacific region, the Southwest Pacific, Northern South America, and Southern South America.

However, the situation in Northern Africa, the Middle East region of Asia, and the Eastern Asian region is remarkably different. In these regions the availability of water on a per capita basis is less than 800 m^3 per annum (Fig. 4.2).

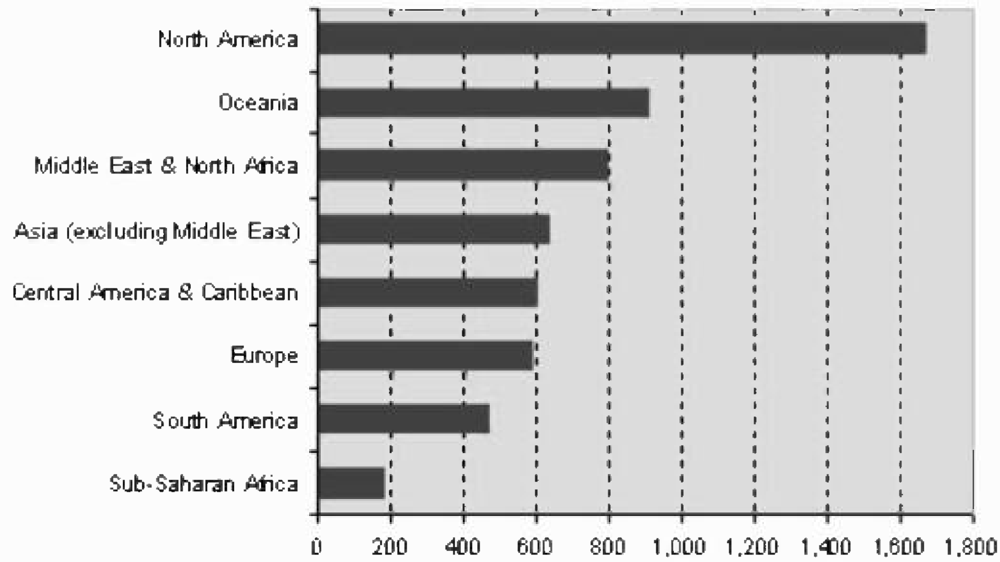


Fig.4.2 : Per Capita Water Use, 2000 (cubic meters per year),

Source: EarthTrends, 2007

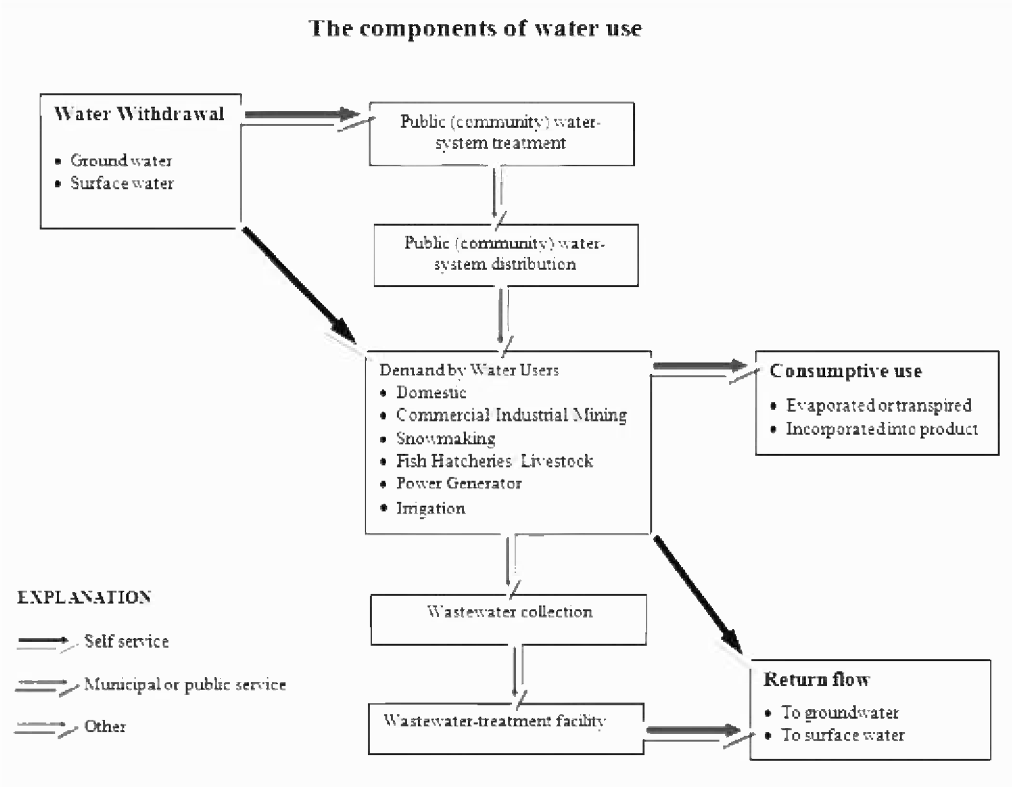
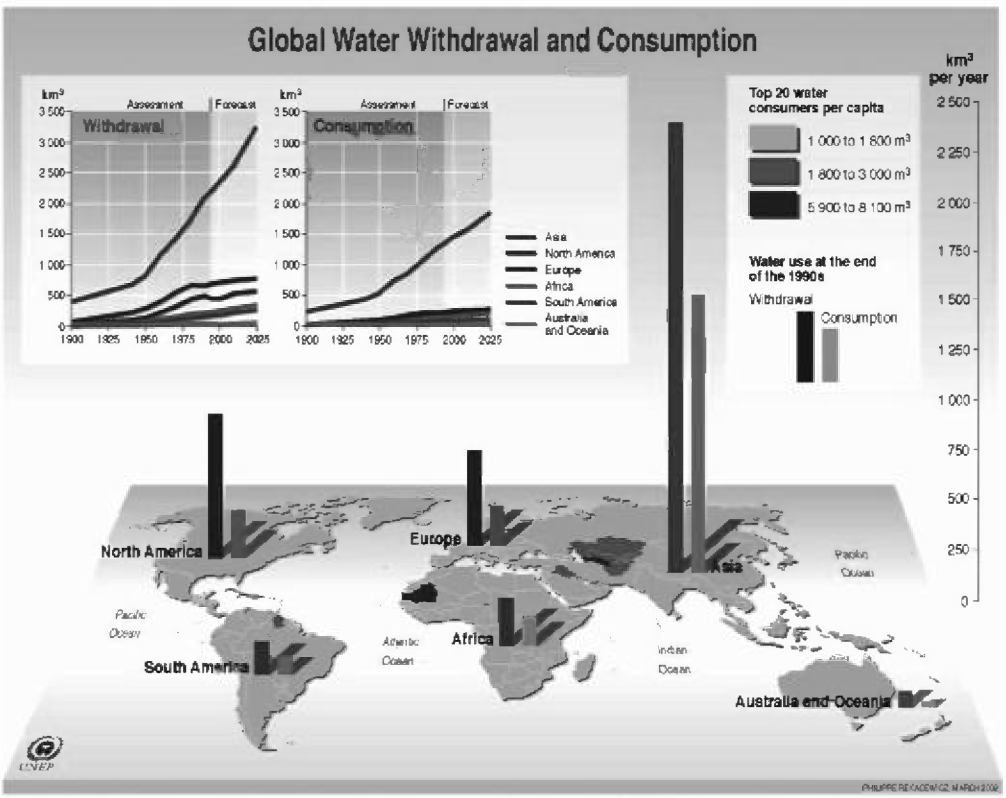


Fig.4.3: The component of water use

4.3.2 Competitive Uses and Increasing Demand

Recent estimates of water stocks and flows through the world's hydrologic cycle and their spatiotemporal variability illustrate the nature of current and projected water disparities throughout the world (Fig. 4.3). Water is used for three major purposes - domestic, industrial, and agricultural. On average, in the world, we use almost 3,609 km^3 of water annually or 9,888 m^3 of water every day.



Source: Igor A. Shiklomanov, State Hydrological Institute (SHI, St. Petersburg) and United Nations Educational, Scientific and Cultural Organisation (UNESCO, Paris), 1999; *World Resources 2000-2001. People and Ecosystems: The Fraying Web of Life*. World Resources Institute (WRI), Washington DC, 2000; Paul Harrison and Fred Pearce, *AAAS Atlas of Population 2001*, American Association for the Advancement of Science, University of California Press, Berkeley.

Fig. 4.4: Water consumption pattern throughout the world

4.3.3 Water Scarcity Scenario

One of the most pressing global issues currently facing mankind is the increase in world population and its impact on the availability of freshwater. Water resources are under increasing stress due to patterns of over exploitation, conflicts over rights, and broader anthropogenic environmental change. The quality and quantity of regional water resources are under stress due to increasing variability and scarcity, compounded by pressure on ground and surface water resources to meet intensified agricultural outputs and industrial needs. The water crisis would lead to a breakdown in domestic water service for hundreds of millions of people, a devastating loss of wetlands, serious reductions in food production and skyrocketing food prices, that would force declining per capita food consumption in much of the world.

While the world's population tripled in the 20th century, the use of renewable water resources has grown six-fold. Within the next fifty years, the world population will increase by another 40 to 50 %. This population growth coupled with industrialization and urbanization will result in an increasing demand for water and will have serious consequences on the environment. By 2025, 1.8 billion people will live in countries or regions with absolute water scarcity (Fig. 4.4). Most countries in the Middle East and North Africa can be classified as having absolute water scarcity today. By 2025, these countries will be joined by Pakistan, South Africa, and large parts of India and China. This means that they will not have sufficient water resources to maintain their current level of per capita food production from irrigated agriculture even at high levels of irrigation efficiency and also to meet reasonable water needs for domestic, industrial, and environmental purposes. To sustain their needs, water will have to be transferred out of agriculture into other sectors, making these countries or regions increasingly dependent on imported food. Many African countries, with a population of nearly 200 million people, are facing serious water shortages. By the year 2025, it is estimated that nearly 230 million Africans will be facing water scarcity, and 460 million will live in water-stressed countries.

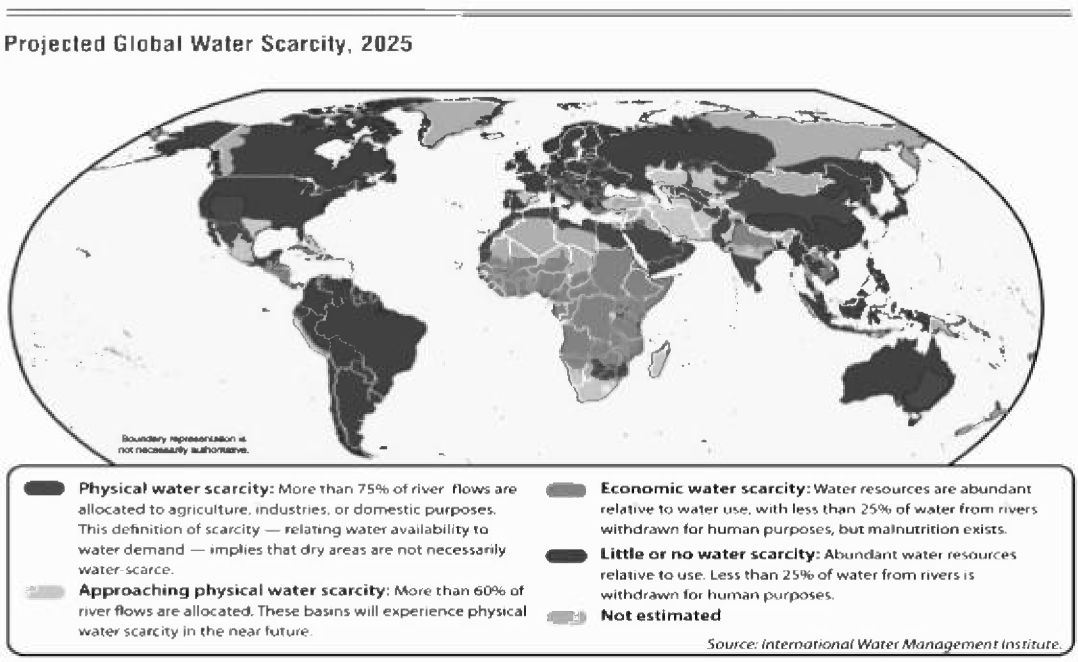


Fig. 4.5: Global water scarcity scenario

4.4 DYNAMICS OF WATER USE: SPATIAL AND TEMPORAL

Knowledge about spatial dynamics of land use and its irrigation water use, under changing water availabilities helps in the determination of suitable solutions in finding the best way to allocate the scarce and strongly varying amount of available water. To get more knowledge about the spatial dynamics of agricultural land use and irrigation water use under different situations of water availability around strategic water reservoirs in the semi-arid regions of the world could be done by analyzing the aspects in a spatial way, using GIS and Remote Sensing-techniques, for a research area during a time frame.

1) Firstly a downscaling has to be carried out to areas of interest each mainly supplied by one source of water availability. Four aspects of water availability could be distinguished in the research area: rainfall, river discharges/reservoir releases, reservoir volumes and locally stored runoff. Each type of water availability is quantified for each area of interest.

2) Secondly the agricultural land use, as largest water user, has to be determined by applying a land cover classification to satellite images of each year.

3) Thirdly the irrigation water use of each area of interest in each dry season within the research period has to be estimated by using the Cropwat model, a model able to calculate crop irrigation requirements.

The results of these three components could be analyzed in a inter annual way (how are the components evolving during the research period in a particular area of interest) and in a spatial way (how do the components of different areas of interest influence each other during the research period. The analysis of the result will show that the different types of water sources have different spatial and temporal ranges and different water availabilities.

Check Your Progress 1

Note: a) Use the space given below for your answer.

b) Compare your answers with those given at the end of the unit.

1) Write a note on the relation between economic development and water scarcity scenario.

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2) Discuss the spatio temporal fluctuation of water consumption pattern.

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4.5 SHARING OF WATER RESOURCES BETWEEN COMMUNITIES AND NATIONS

More than 260 river basins, covering almost 50% of the earth's land area are shared by at least two countries, making many countries dependent on the use of common water resources for national development. Unilateral action by any one country concerning international basins is often ineffective (fish ladders in an upstream country only), inefficient (hydropower development in a flat downstream country), or impossible (many developments on boundary stretches).

However, cooperation in managing transboundary water resources is the most effective way to harness this mammoth resource of fresh water. 'Benefit sharing' has been proposed as one approach to bypass the contentious issue of property rights. The idea is that, if the focus is switched from physical volumes of water to the various values derived from water use in multiple spheres, including economic, social, political, and environmental, riparians will correctly view the problem as one of positive outcomes associated with optimising benefits, rather than the zero outcomes associated with dividing water.

4.5.1 Equitable Access and Partnership to Conserve Shared Water

The case for sharing benefits is a compelling one. A river basin is a common pool resource, meaning that use of it by one riparian (or indeed individual) will necessarily diminish the benefits available to others. In other words, water use in one part of the basin creates external effects in other parts. If these externalities are not 'internalised', the overall benefits are reduced and the outcome is suboptimal. Thus, both hydrology and economics concur that a river basin should be treated as a single unit to maintain the physical integrity of the system and to internalise externalities. In the last decades of the past century, in global level, are registered phenomenon of violence between states regarding with transboundary waters. However, at the same time are recorded over 200 bilateral and multilateral agreements related to transboundary waters. Due to the importance of transboundary waters, the United Nations World Water Day (March 22nd, 2009) focused cross border waters topic entitled "Shared Water, Shared Opportunities.

4.5.2 Conflicts Arising due to Water Resource Sharing

Water is our right, but it is not a secured right. It is fraudulent for anyone to claim legitimate ownership of the air, the sea, or space itself. Yet we can see from historical events that these claims are inevitable. Water conflict is a term describing a conflict between countries, states, or groups over an access to water resources. A wide range of water conflicts appear throughout history, though rarely are traditional wars waged over water alone. Instead, water has historically been a source of tension and a factor in conflicts that start for other reasons. However, water conflicts arise for several reasons, including territorial disputes, a fight for resources, and strategic advantage.

Water's viability as a commercial resource, which includes fishing, agriculture, manufacturing, recreation and tourism, among other possibilities, can create dispute even, when access to potable water is not necessarily an issue.

Historically, fisheries have been the main sources of question, as nations expanded and claimed portions of oceans and seas as territory for 'domestic' commercial fishing. Certain lucrative areas, such as the Bering Sea, have a history of dispute; in 1886 Great Britain and the United States clashed over sealing fisheries, and today Russia surrounds a pocket of international water known as the Bering Sea Donut Hole.

Corporate interest often crosses opposing commercial interest, as well as environmental concerns, leading to another form of dispute. Water pollution poses a significant health risk, especially in heavily industrialized, heavily populated areas like China. The possibility of polluted water making it way across international boundaries, as well as unrecognized water pollution within a poorer country brings up questions of human rights, allowing for international input on water pollution. There is no single framework for dealing with pollution disputes local to a nation

4.6 CLIMATE CHANGE AND WATER RESOURCES OF THE WORLD

The effect of changing climate on water resources is one of the most difficult global environmental changes to assess. Problems arise because:

1) A changing climate may affect both availability and use.
2) A changing level of water availability would have an impact on water quality.
3) The distribution of climate induced impacts would differ significantly from region to region.
4) The available results of climate models are not consistent with their predictions.

Four attributes of climate change are particularly relevant in the context of regional vulnerability:

1) Changes in atmospheric variables, such as temperature, precipitation, and wind speed.
2) Inter year variability in precipitation and temperature, leading to extreme events such as droughts and floods.
3) Intra year variability in precipitation and temperature.
4) A rise in sea level.

The change in the atmospheric variables would affect the relationships that govern water needs, as well as river flow. Occurrences of droughts and floods can also alter a region's water availability and demands. The IPCC, in cooperation with new partners, has begun to address this issue in addition to their more traditional focus on greenhouse gases and temperature changes. IPCC expert meeting (IPCC, 2004, p. 27) identified two issues related to water and the impacts from global warming: one related to impacts and the other to knowledge gaps. These two issues, as taken from the IPCC report, are as follows:

- The extreme event frequency and magnitude will increase even with a small increase in temperature and will become greater at higher temperatures.
- The impacts of such events are often large locally and could strongly affect specific sectors and regions. Increased extreme events can cause critical design values or natural thresholds to be exceeded, beyond which the impacts magnitudes increase rapidly.

Although climate change may be perceived as a long-term problem, it needs to be addressed now because decisions today will affect society's ability to adapt to increasing variability in tomorrow's climate. If we are to balance freshwater supply with demand, and also protect the integrity of aquatic ecosystems, a fundamental change in current wasteful patterns of production and consumption is needed. Recognition of the links between rapidly growing populations and shrinking freshwater supplies is the essential first step in making water use sustainable.

4.7 INTERNATIONAL EFFORTS TO CONSERVE WATER AND TO PROTECT ITS QUALITY

Authority for managing the world's fresh water resources is fragmented amongst the world's nations, hundreds of thousands of local governments, and countless non-governmental and private organizations, as well as a large number of international bodies. Management issues have been subjected to numerous studies and debates in the international arena to promote awareness, build political commitment and trigger action on critical water issues at all levels, including the highest decision-making level, to facilitate the efficient management and use of water in all its dimensions and on an environmentally sustainable basis.

In 1977, The Mar del Plata United Nations Conference on Water was the first and only intergovernmental conference devoted exclusively to water-a milestone in the history of water development. In 1980, it led the UN General Assembly to proclaim the Declaration of the International Drinking Water Supply and Sanitation Decade. In 1992, the idea of forming a world water council was first proposed in 1992 at the UN's International Conference on Environment and Development in Dublin and at the Rio de Janeiro Earth Summit. Later on in 1994, The International Water Resources Association (IWRA) organized a special session on the topic in its Eighth World Water Congress held in Cairo in November 1994, which resulted in a resolution to create the World Water Council and a committee to accomplish the preparatory work for this task. Consensus was established around the need for the creation of a common umbrella organisation to unite the disparate, fragmented, and ineffectual efforts in global water management. In 1995, the Founding Committee of the World Water Council was formed and convened its first meeting in Montreal, Canada, in March 1995, and again in Bari, Italy in September, 1995. These two meetings defined the mission and objectives of the World Water Council. Again in June 1996, the World Water Council was legally incorporated and its headquarters established in Marseille, France. In July 1996, the First Interim Board of Governors met in Grenada, Spain. In March 1997, the success of the First World Water Forum in Marrakech, Morocco, and the issuing of the Marrakech Declaration firmly established the leadership of the Council in water affairs. The World Water Council received the mandate to develop the World Water Vision for Life and Environment for the 21st Century. In September 1997, the First Meeting of the General Assembly of members of the World Water Council was held in Montreal, during the Ninth World Water Congress of the IWRA. The Constitution of the Council was approved and the members of the first Board of Governors were elected. Again in March 1998, the World Water Council, in cooperation with the Government of France, participated in organizing the International Conference on Water and Sustainable Development in Paris. In March 2000, the Second World Water Forum, was successfully held in the Netherlands. The results of the Vision were presented to some 5,700 participants from all parts of the world. The Ministerial Conference gathered 120 Ministers and resulted in the Declaration of the Hague on Water Security in the 21st Century. In March 2003, the Third World Water Forum took place in Kyoto, Shiga and Osaka, Japan. Following up on its commitments from the 2nd Forum, the WWC launched the World Water Actions report, an inventory of over 3,000 local water actions. This Forum was the largest water conference in history, gathering 24,000 participants. A Ministerial Conference was held in parallel and brought together 130 Ministers. Participants made hundreds of commitments to action, and each session organizer was asked to state, what concrete output would follow his or her respective session. In march 2006, the Fourth World Water Forum was held in Mexico City, gathering some 20,000 people from throughout the world who participated in 206 working sessions, under the theme "local actions for a global challenge". In December 2010, the United Nations General Assembly declared the year 2013 as the United Nations International Year of Water Cooperation. As rapid urbanization, climate change and growing food needs put ever – increasing pressure on freshwater resources, the objective of the Year was to draw attention to the benefits of cooperation in water management.

4.8 INDIVIDUAL AND COMMUNITY LEVEL EFFORTS REQUIRED TO CONSERVE WATER

The daily action or inaction of each individual across the globe, has a continual and exponential effect on the earth's ability to remain sustainable. The excess consumption of valuable natural resources occurring in developed countries has a direct impact on the growth and sustainability of underdeveloped countries. "Sustainable development encourages us to conserve and enhance our resource base, by gradually changing the ways in which we develop and use technologies. In developed nations the necessary effort that each of us puts forth to conserve water and prevent unnecessary waste can have immense financial and environmental impacts across the globe. Water is essential for everyone. We are sharing this precious water with all life on Earth. So we have to share the responsibility of keeping the water clean. A little bit of environmentally friendly behavior can make a difference. We must all keep Earth safe and clean for everyone in the world and for our future generations. At community level Water conservation programs are typically initiated at the local level, by either municipal water utilities or regional governments.

4.9 WATER RESOURCES OF INDIA: STATUS, USE AND MANAGEMENT

Although India occupies only 3.29 million km^2 geographical area, which forms 2.4% of the world's land area, it supports over 15% of the world's population. The total utilizable water resources of the country are assessed as 1122 km^3 (Fig.4.5).

Precipitation pattern

India receives annual precipitation of about 4000 km^3, including snowfall. Out of this, monsoon rainfall is of the order of 3000 km^3. Rainfall in India is dependent on the south-west and north-east monsoons, on shallow cyclonic depressions and disturbances and on local storms. Most of it takes place under the influence of south-west monsoon between June and September except in Tamil Nadu, where it is under the influence of north-east monsoon during October and November. The annual potential natural groundwater recharge from rainfall in India is about 342.43 km^3, which is 8.56% of total annual rainfall of the country.

Surface and Groundwater

India is gifted with a river system comprising more than 20 major rivers with several tributaries. Many of these rivers are perennial and some of these are seasonal. The rivers like Ganges, Brahmaputra and Indus originate from the Himalayas and carry water throughout the year. The snow and ice melt of the Himalayas and the base flow contribute the flows during the lean season.

Apart from the water available in the various rivers of the country, the groundwater is also an important source of water for drinking, irrigation, industrial uses, etc. The annual potential groundwater recharge augmentation from canal irrigation system is about 89.46 km^3. Thus, total replenishable groundwater resource of the country is assessed as 431.89%. Thus, the available groundwater resource for irrigation is 361 km^3, of which utilizable quantity (90%) is 325 km^3. It accounts for about 80% of domestic water requirement and more than 45% of the total irrigation in the country.

Table 4.1: Water Resources of India

Sl. No.	Items	Quantity (Cu.Km)
1	Annual Precipitation Volume (Including snowfall)	4000
2	Average Annual Potential flow in Rivers	1869
3	Per Capita Water Availability (2001) in cubic meter	1820
4	Estimated Utilizable Water Resources	1122
	i) Surface Water Resources	690
	ii) Ground Water Resources	432

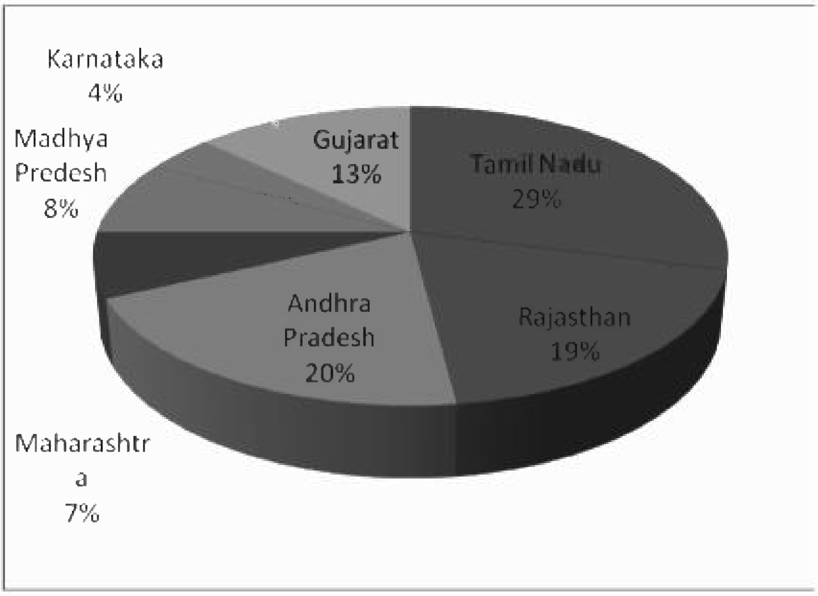

Fig. 4.6: Water resources of India (Source: Ministry of water resources, GoI, Down to Earth Mag.)

Water use in India

Community water supply is the most important requirement and it is about 5% of the total water use. About 7 km^3 of surface water and 18 km^3 of groundwater are being used for community water supply in urban and rural areas. Along with the increase in population, it is expected that nearly 61% of the population will be living in urban areas by the year 2050, in high growth scenario as against 48% in low growth scenario.

Sectoral consumption pattern of water in India indicates an all time highest consumption in agriculture from 1980 to 2010, followed by municipal and industrial consumption (Fig.4.6). In India per capita surface water availability in the years 1991 and 2001 were 2309 and 1902 m^3 and these are projected to reduce to 1401 and 1191 m^3 by the years 2025 and 2050 respectively. Hence, there is a need for proper planning, development and management of water resources for raising the standards of living of the millions of people, particularly in the rural areas.

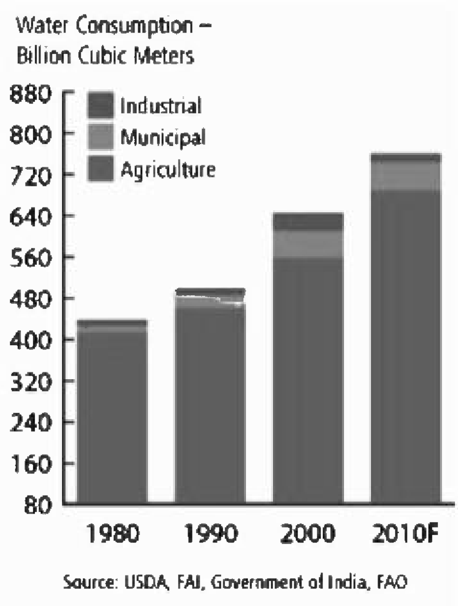

Fig.4.7: Sectoral water consumption pattern of India

Some ancient Indian methods of water conservation

The Indus Valley Civilization, that flourished along the banks of the river Indus and other parts of western and northern India about 5,000 years ago, had one of the most sophisticated urban water supply and sewage systems in the world. Another very good example is the well planned city of Dholavira, on Khadir Bet, a low plateau in the Rann in Gujarat.

Rainwater harvesting

In urban areas, the construction of houses, footpaths and roads has left little exposed earth for water to soak in. In parts of the rural areas of India, floodwater quickly flows to the rivers, which then dry up soon after the rains stop. If this water can be held back, it can seep into the ground and recharge the groundwater supply.

This has become a very popular method of conserving water, especially in the urban areas. Rainwater harvesting essentially means collecting rainwater on the roofs of building and storing it underground for later use. Not only does this recharging arrest groundwater depletion, it also raises the declining water table and can help augment water supply. Rainwater harvesting and artificial recharging are becoming very important issues. It is essential to stop the decline in groundwater levels, arrest sea-water ingress, i.e. prevent sea-water from moving landward, and conserve surface water run-off during the rainy season.

Realizing the importance of recharging groundwater, the CGWB (Central Ground Water Board) is taking steps to encourage it through rainwater harvesting in the capital and elsewhere. A number of government buildings have been asked to go in for water harvesting in Delhi and other cities of India.

Typically, rain is collected on rooftops and other surfaces, and the water is carried down to where it can be used immediately or stored. You can direct water run-off from this surface to plants, trees or lawns or even to the aquifer.

Some of the benefits of rainwater harvesting are as follows

- Increases water availability
- Checks the declining water table
- Is environmentally friendly
- Improves the quality of groundwater through the dilution of fluoride, nitrate, and salinity
- Prevents soil erosion and flooding especially in urban areas

Agriculture

Conservation of water in the agricultural sector is essential since water is necessary for the growth of plants and crops. A depleting water table and a rise in salinity due to overuse of chemical fertilizers and pesticides has made matters serious. Various methods of water harvesting and recharging have been and are being applied all over the world to tackle the problem. In areas where rainfall is low and water is scarce, the local people have used simple techniques that are suited to their region and reduce the demand for water.

- In India's arid and semi-arid areas, the 'tank' system is traditionally the backbone of agricultural production. Tanks are constructed either by bunding or by excavating the ground and collecting rainwater.
- Rajasthan, located in the Great Indian Desert, receives hardly any rainfall, but people have adapted to the harsh conditions by collecting whatever rain falls. Large bunds to create reservoirs known as khadin, dams called johads, tanks, and other methods were applied to check water flow and accumulate run-off. At the end of the monsoon season, water from these structures was used to cultivate crops. Similar systems were developed in other parts of the country. These are known by various local names jal talais in Uttar Pradesh, the haveli system in Madhya Pradesh, ahar in Bihar, and so on.

Reducing water demand

Simple techniques can be used to reduce the demand for water. The underlying principle is that only part of the rainfall or irrigation water is taken up by plants, the rest percolates into the deep groundwater, or is lost by evaporation from the surface. Therefore, by improving the efficiency of water use, and by reducing its loss due to evaporation, we can reduce water demand. There are numerous methods to reduce such losses and to improve soil moisture. Some of them are listed below.

- Mulching i.e., the application of organic or inorganic material such as plant debris, compost, etc., slows down the surface run-off, improves the soil moisture, reduces evaporation losses and improves soil fertility.
- Soil covered by crops, slows down run-off and minimizes evaporation losses. Hence, fields should not be left bare for long periods of time.
- Ploughing helps to move the soil around. As a consequence it retains more water thereby reducing evaporation.
- Shelter belts of trees and bushes along the edge of agricultural fields slow down the wind speed and reduce evaporation and erosion.
- Planting of trees, grass, and bushes breaks the force of rain and helps rainwater penetrate the soil.
- Fog and dew contain substantial amounts of water that can be used directly by adapted plant species. Artificial surfaces such as netting-surfaced traps or polyethylene sheets can be exposed to fog and dew. The resulting water can be used for crops.
- Contour farming is adopted in hilly areas and in lowland areas for paddy fields. Farmers recognize the efficiency of contour-based systems for conserving soil and water.
- Salt resistant varieties of crops have also been developed recently. Because these grow in saline areas, overall agricultural productivity is increased without making additional demands on freshwater sources. Thus, this is a good water conservation strategy.
- Transfer of water from surplus areas to deficit areas by inter-linking water systems through canals, etc.
- Desalination technologies such as distillation, electrodialysis and reverse osmosis are available.

- Use of efficient watering systems such as drip irrigation and sprinklers will reduce the water consumption by plants.

Check Your Progress 2

Note: a) Use the space given below for your answer.

b) Compare your answers with those given at the end of the unit.

1) Comment on opportunities and conflicts from Trans boundary water sharing.

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2) Discuss the water distribution, consumption, scarcity and management options of water resources in India.

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4.10 LET US SUM UP

- Demand for the world's increasingly scarce water supply is rising rapidly, challenging its availability for food production and putting global food security at risk. Therefore one of the most pressing global issues currently facing mankind is the increase in world population and its impact on the availability of freshwater.
- Water resources are under increasing stress due to patterns of over - exploitation, conflicts over rights, and broader anthropogenic environmental change. The quality and quantity of regional water resources are under stress due to increasing variability and scarcity, compounded by pressure on ground and surface water resources to meet intensified agricultural outputs and industrial needs.
- Knowledge about spatial dynamics of land use and its irrigation water use under changing water availabilities helps in the determination of suitable solutions in finding the best way to allocate the scarce and strongly varying amount of available water.

- The effect of changing climate on water resources is one of the most difficult global environmental changes to assess.
- The solution remains in cooperation in managing transboundary water resources is the most effective way without conflicts.
- Like international efforts, even community based and individual efforts are also required and for that prior to any management strategy, what is required is the change in vision towards water resources and developing attitude for conserving them.

4.11 KEY WORDS

Water scarcity : Water scarcity involves water stress, water shortage or deficits, and water crisis

Water conservation : Water conservation encompasses the policies, strategies and activities to manage fresh water as a sustainable resource to protect the water environment and to meet current and future human demand.

Transboundary Water issues : International waters (the open seas of the world outside the territorial waters of any nation

Climate Change : A change in the world's climate

4.12 REFERENCES AND SUGGESTED FURTHER READINGS

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4.13 KEY TO CHECK YOUR PROGRESS

Check Your Progress 1

1) Your answer must include the following points:
   - Rapid urbanisation, Population growth
   - Per capita water availability and demand
2) Your answer must include the following points:
   - Spatial and temporal water consumption variability
   - Monitoring methods

Check Your Progress 2

1) Your answer must include the following points:
   - Water sharing
   - Equitable access
   - Conflicts
2) Your answer must include the following points:
   - Water distribution statistics
   - Consumption pattern
   - Conservation strategies in tune to the primitive eco friendly methods