स्वाध्याय स्वमन्थन स्वावलम्बन

UTTAR PRADESH RAJARSHI TANDON OPEN UNIVERSITY

(Established vide U.P. Govt. Act No. 10, of 1999)

Indira Gandhi National Open University UP Rajarshi Tandon Open University

PGD-ESD-03
Agriculture and Environment

RST BLOCK	:	Environment - Agriculture Relationship
ECOND BLOCK	:	Agro-Environmental Resources : Issues & Challenges
HIRD BLOCK	:	Strategies For Eco-Friendly Agriculture
OURTH BLOCK	:	Towards A Greener Future

Shantipuram (Sector-F), Phaphamau, Allahabad - 211013

SAFLI
South Asia Foundation
Learning Initiative

Towards Participatory Management

Department of Environmental Science
Allama Iqbal Open University Islamabad

PGD-ESD-03(1A)

Uttar Pradesh
Rajarshi Tandon Open University

PGD-ESD - 03

Agriculture and Environment

Block

1

ENVIRONMENT-AGRICULTURE RELATIONSHIP

AGRICULTURE AND ENVIRONMENT

Agriculture forms the backbone of economic activity in South Asian countries. The major challenge facing all countries in this region today is to feed an ever growing population without degrading the environment further and without further increasing pressures on a finite resource base. In the next 25 years, South Asia's food requirements are likely to double, while its natural resource base is likely to shrink. The Indian subcontinent itself accounts for 21 percent of the world's population on just 3 percent of its land area.

South Asian countries already have a high proportion of their land under cultivation and relatively little under forest and pastures: the share of arable and permanent crop land in total agricultural land is the largest (91.5%). Within the region, India and Bangladesh have very high shares - 94.0% and 93.3%, respectively. Continuous diversion of prime agricultural lands to non-agricultural purposes is likely to lead to a decrease in this share. The only recourse for these countries is to increase agricultural productivity from existing lands through environment-friendly practices.

Modern agriculture encompasses the science and art of growing food, fibre, forage and energy crops and fruit and ornamental trees, raising of livestock for milk (dairying) and meat, and rearing of sheep, goats and pigs. It also includes fisheries and poultry. Issues and policies relating to the marketing (including exports and imports) of agricultural produce have become very important globally after the World Trade Agreement. The introduction of high yielding varieties in the developing countries in the past few decades led to a remarkable increase in agricultural productivity. However, it required an intensive use of resources like water, fertilizers and pesticides that created a host of environmental problems such as depletion of soil nutrients and water reserves, increased incidences of soil salinity and water-logging, decline in productivity, resurgence of pests and diseases and increased environmental pollution. It is in fact due to these pressing problems that the sustainability of agricultural production systems and environment has emerged as a serious concern.

Safety of natural resources is of prime concern in order to ensure productivity, profitability and sustainability of agriculture for the present and future. The need of the hour is to strike a balance between the two diametrically opposite processes of exploitation and conservation. To achieve this, environmental protection, resource conservation and its rational utilization must form an integral part of all agricultural activities and processes.

This optional course on Agriculture and Environment is being offered as a part of the PG Diploma Programme to address these very concerns. The objectives of this course are to:

- Generate awareness about various issues related to agriculture and environment, e.g., natural resource management, policies and practices for sustainable agriculture, globalization and agriculture, appropriate technologies for agriculture;
- Develop and promote a shared vision and consensus for action for meeting food needs while protecting the environment; and
- Encourage debate to influence action by national governments, nongovernmental organizations, the private sector, international development institutions, and other elements of civil society.

We hope that after studying this course, you will gain useful insights about the issues pertaining to agriculture and environment in your own context. We have also given **additional references** at the end of the units for further reading. We hope you enjoy studying the course and wish you good luck!

BLOCK 1 ENVIRONMENT-AGRICULTURE RELATIONSHIP

We begin this course by helping you develop an understanding of the relationship between agriculture and environment in our specific context. During the three closing decades of the 20th century, countries in the South Asian region have passed through the most remarkable transition in the history of agriculture. Before this time almost all the increases in agricultural production occurred as a result of increases in the area cultivated. You would perhaps know that modern agricultural practices are remarkably different from those of the pre-industrial era. The significant changes in agriculture in the post-industrial era can best be appreciated if we understand the evolution of agriculture in the pre-industrial era. Therefore, in Unit 1of this block, we describe how agriculture emerged in human societies and how it developed through the ages.

In Unit 2, we deal with the concept of agro-ecosystems. Like any natural system, agricultural enterprises also receive inputs from the environment (both natural and created by human beings), and lose energy and matter as outputs. It is through these inputs that we control the agricultural systems and maintain their ability to give the high outputs that characterize modern agriculture. A number of factors have, however, combined to refocus our attention on the problems of agricultural productivity in developing countries. In Unit 3 we take up the problems of agricultural development in relation to environmental degradation most of which arose from the over-exploitation of natural resources. In Unit 4 we discuss how changes in the environment such as increase in greenhouse gases, global warming, ozone layer depletion etc. are affecting agricultural productivity.

The problems of sustainability of highly productive agriculture – also referred to as 'green revolution', have now been well documented and analysed. The pressing need to develop more productive and sustainable agricultural practices is taken up in Unit 5 of the block. We hope that by the end of the block you would be able to appreciate why sustainable advances in agricultural productivity must be achieved without associated ecological harm.

One final word about how to study this and the other blocks of the course. We suggest that you focus on the concepts being explained here and apply them to your own regional or national context. Make your notes and write your comments in the margin of the unit as you study each unit. We have given many self-assessment questions (SAQs) within each unit and terminal questions at the end of each unit. Since this course is at the postgraduate level, we have refrained from giving you any set answers to these questions. We expect you to reflect upon them and arrive at your own understanding of the issues involved. We hope that you will find this block useful for understanding the relationship between agriculture and environment. We wish you good luck!

UNIT 1 THE EVOLUTION OF AGRICULTURE

Structure

1.1 INTRODUCTION

Agriculture as we understand today is the science and art of growing food, fibre, forage and energy crops and fruit and ornamental trees, raising of livestock for milk (dairying) and meat and rearing of sheep, goats and pigs. It also includes fisheries and poultry. Modern agriculture also includes issues and policies relating to its marketing including exports and imports, which has become very important globally after the World Trade Agreement. Thus agricultural products have to be produced at an international competitive price.

Modern agricultural practices are remarkably different from those of the pre-industrial era. The significant changes in agriculture in the post-industrial era can best be appreciated if we understand the evolution of agriculture in the pre-industrial era. Therefore, in the first unit of the course, you will study about how agriculture emerged in human societies and how it developed through the ages. The Industrial Revolution in Europe marks a distinct phase in the evolution of agriculture. With the development of science, population growth and shrinking of available land and resources, agriculture in modern times has undergone revolutionary changes. In the final section of the unit, we look at some features of modern agriculture. In the next unit, we introduce the concept of Agro-Ecosystem so that a sound foundation is built for understanding the environment-agriculture relationship.

Objectives

After studying this unit, you should be able to:

- enunciate the hypotheses regarding the evolution of agriculture;
- describe developments in agriculture through various periods in human history, viz. Neolithic age, Chalcolithic age, middle ages and industrial era;
- discuss the post-Neolithic development of agriculture in the Indian subcontinent;
- describe the main features of the Agricultural Revolution in England and the developments in USA; and
- discuss the main facets of modern agriculture.

1.2 AGRICULTURE IN THE PRE-INDUSTRIAL ERA

Evolution and development of agriculture especially during the pre-Christian era and before the Industrial Revolution, was very slow. Domestication of animals and plants moved at a snail's speed in the *Neolithic* (*New Stone Age*) and *Chalcolithic* (*Bronze*) *ages*. According to Sauer (1952), an American biographer, primitive agriculture began in forested uplands and not in the river valleys and the hearths of domestication are to be sought in marked diversity of plants and animals. A significant contribution to the present knowledge of the main centres of cultivated plants has been made by the Russian biographer Vavilov (Fig.1.1). He suggested that agriculture evolved in several regions of the world at the same or different periods of time. He identified eight such **geocentres** (geographical locations of wild ancestors of modern cultivated plants). We list them in Table 1.1 along with the regions/countries covered, plants domesticated and the possible periods. It reveals that a number of crop plants were domesticated in more than one geocentre. However, opinions differ on the regions of domestication of several crop plants among biographers and biologists. This information should, therefore, be taken with caution and is subject to modification.

Fig.1.1: Nikolai Ivanovich Vavilov, born in 1887 was a Russian botanist and geneticist. In 1918 he discovered in Transcaucasia a variety of wheat that grows at an altitude of nearly 3,000 ft (914 m) and is resistant to rust and mildew. His genetic study of wheat variations led to an attempt to trace the locales of origin of various crops by determining the areas in which the greatest number and diversity of their species are to be found. In 1936 he reported that his studies indicated Ethiopia and Afghanistan as the birthplaces of agriculture and hence of civilization. Vavilov divided cultivated plants into those that were domesticated from wild forms, e.g., oats and rye, and those known only in the cultivated form, e.g., corn.

Table 1.1: Geocentres of the world

Sl. No.	Geocentre (Period)	Regions/Countries	Crop Plants Domesticated
1.	Southwest Asia (7500-1700 BC)	Asia Minor, Turkey, Iraq, Iran, Israel, Jordan, Syria, Lebanon, Cyprus, Crete, Greece, Arabian Peninsula, Afghanistan, Egypt	Wheat, barley, lentil, pea, chickpea, broad bean, flax melons, several vegetables
2.	Central Asia (4000-3000 BC)	Tajikistan, Kazakhstan, Kirigizistan, Turkmenistan & area lying to west of Tien Shan	Peas, flax, carrots, onion, garlic, radish, spinach, alfalfa, almond, walnut, Pistachio and grapes
3.	Southeast Asia (9000-1700 BC)	India, Pakistan, Bangladesh, Sri Lanka, Myanmar, Thailand, Cambodia, Vietnam and Philippines	Rice, sugarcane, legumes, coconut, bamboo, taro, yam, durian, mango and cucumber
4.	China-Japan (6000-5000 BC)	China and Japan	Soybean, sorghum, millet, corn, sweet potato, barley, peanuts, cotton, tobacco, tea, sericulture, several fruits and vegetables
5.	Mediterranean (By 4000 BC)	Iberian Peninsula, Coastal areas of Spain, France, Italy, Albania, Bosnia, Serbia, Croatia, Crete, Cyprus and coastal strips of Africa	Flax, olive, figs, vines, rutabagas, lupines, oak and lavender
6.	Africa (By 5000 BC)	Nile Valley and other parts of Africa	Wheat, cotton, oats, flax, African rice, castor beans, cowpea, coffee, oil-palm, kola nut
7.	South America (7000-3000 BC)	Peru, Brazil, Bolivia, Chile, Ecuador, Argentina	Manioc, arrowroots, water-nuts, sweet potato, pumpkin, potato, tomato, lima beans
8.	Central America (7000-3000 BC)	Mexico, Guatemala, Costa-Rica, Honduras, Nicaragua, Panama and El-Salvador	Corn, cacao, tomato, potato, kidney beans, pumpkin, sunflower, red pepper, tobacco and avocado

ı addition to geocentres, which tell us about the domestication of cultivated plants ıat made the beginning of agriculture, there are a number of hypotheses regarding the volution of agriculture mainly based on the archaeological findings including C^{14} ating. On the basis of their findings and evidences, archaeologists tend to describe ıe life of the past societies within a temporal and spatial framework and attempt to xplain the changes that occurred. These include the kinds of plants grown and the nimals used for movement and transport. We give below five of the hypotheses elated to the evolution of agriculture:

. *South-East hearth hypothesis:* As cited by Bender (1975) South-East Asia was the ideal hearth for the evolution of agriculture because it had the ideal conditions for transition from hunting-gathering to farming. These conditions were:

a) flourishing economy,

b) orientation towards food-gathering rather than hunting,

c) sedentary nature,

d) living in forest areas,

e) being away from large river valleys subject to frequent floods, and

f) availability of a wide variety of plants and animals. This theory is closely linked to the existence of geocentres.

. *Migration hypothesis:* According to this theory, when life became harsh in places of their origin and enough food was not available, people moved to newer areas taking with them already developed agricultural practices and tools. Various combinations of crops that originated in the Southwest Asia formed the basis of agricultural systems in Europe, the Nile valley, Central Asia, the Indus valley and the Gangetic plains of India mainly due to migration.

. *Climatic hypothesis:* Nomadic hunters and gatherers migrated from relatively cold and warm and wet regions to the areas of mild temperatures and temperate climates, where there was great diversity of plants and they camped for longer times and for their sustenance they developed agriculture.

. *Rubbish heap theory:* This hypothesis was suggested by Hawkes and Woolley (1963) based on the symbiosis between plants, animals and people. The rubbish heaps made of animal droppings and house wastage were spots richer in plant nutrients and allowed a variety of plants to grow from which a selection of useful plants suitable for cultivation was made.

. *City theory:* According to Jacobs, an economist (cited by Bender, 1975), the evolution of agriculture began in the trade centres (cities) that provided a place of exchange of information and produce of animal and plant origin. This was transmitted to smaller settlements (villages) around which agriculture evolved.

Ve now describe the emergence and evolution of agriculture through the ages, from rehistoric times. However, you may like to fix the concepts discussed so far in your nind. Attempt the following SAQ.

Radio-carbon or C^{14} dating is a method of obtaining age estimates on organic materials such as wood, charcoal, marine and fresh-water shells, bone and antler, peat and organic-bearing sediments and dissolved carbon dioxide and carbonates in ocean, lake and ground-water sources. It has been used to date samples as old as 50,000 years.

Radioactive carbon, produced when nitrogen 14 is bombarded by cosmic rays in the atmosphere, drifts down to earth and is absorbed from the air by plants. Animals eat the plants and take C^{14} into their bodies. Humans in turn take carbon 14 into their bodies by eating both plants and animals. When a living organism dies, it stops absorbing C^{14} and the C^{14} that is already in the object begins to disintegrate. Scientists can use this fact to measure how much C^{14} has disintegrated and how much is left in the object. Carbon 14 decays at a slow but steady rate and reverts to nitrogen 14. The rate at which Carbon decays (Half-life) is known: C^{14} has a half-life of 5730 years. Basically this means that half of the original amount of C^{14} in organic matter will have disintegrated 5730 years after the organism's death; half of the remaining C^{14} will have disintegrated after another 5730 years and so forth. After about 50,000 years, the amount of C^{14} remaining will be so small that the fossil can't be dated reliably.

SAQ 1

a) What do you understand by, a geocentre?
b) Which crop plants were domesticated in ancient times in India ?
c) Complete the table given below:

Sl. No.	Hypothesis	Main Feature
1.	Migration hypothesis	
2.		Agriculture evolved in areas of mild temperatures and temperate climates.
3.	Rubbish heap theory	
4.	City theory	
5.		Agriculture evolved in South-east Asia as it had the ideal conditions for farming.

1.2.1 Emergence of Agriculture

It is by and large agreed that modern man (*Homo sapiens*) first appeared about 30000 to 40000 years ago. The most famous sites of *Homo sapiens* are Cro-Magnon and Combe Capelle in France, Oberkassel in Germany and Predmosti, Mladec and Dolni Vestonica in Moravia (Randhawa, 1980).

With the arrival of modern man began the Mesolithic age about 10000 BC and ended by 7500 BC, when the Neolithic (New stone) age began. In the Mesolithic age, man was a hunter and gatherer of food. He mostly used tools made of stone for hunting, such as spears made of wooden sticks having a sharp stone head. Stones were also used in slings. Fire had been discovered by then and was used to cook the meat. The domestication of dog was the major achievement of Mesolithic hunters. Once the dog had become the member of the human society, control and domestication of small ruminants became possible. Sheepherders even today keep dogs for controlling their herds.

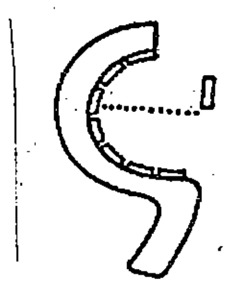


Fig.1.2: Microliths were hafted in a bone or a wooden piece to make a compound tool, like a sickle.

Neolithic or New Stone Age (7500-6500 BC)

Agriculture emerged between 7500-6500 BC in West Asian hilly regions embracing Israel, Jordan, Iraq, the Caspian basin and the adjoining Iranian Plateau (Braidwood, 1960). The Natufians named after a campsite in Wadi-el-Natuf in Jordan used sickles of small flint blades set with gum into the grooved shafts of bone. The blades were finely notched and set in a line to make a continuous saw edge. Continuous cutting of grass or corn stalks polished the edges of the flints into a bright lustre (see Fig.1.2).

It is in this Western Asian region that the wild ancestors of barley and wheat and of domesticated animals like goat, sheep, pig and cattle are found. Thus, apart from a fertile soil all other essentials of mixed farming (crop production and stock raising) were present in this region.

The oldest Neolithic settlement sites known are Ali Kosh, Bus Mordeh phase in Iran (7500 BC), Jericho in Jordan (7000 BC), Jarmo in Iraq (6750 BC) and Belt Cave below the Caspian (6500 BC) in northern Iraq (Randhawa, 1980).

The important achievements of Neolithic agriculture are:

- *Growing of cereals*: Wheat, barley, corn (maize), millets, and rice.
- *Domestication of animals*: a) goat and sheep b) cattle and pigs c) horse and ass (in that order).
- *Housing*: Houses were made of sun-dried bricks and stone. Lime plastering of walls was also done.
- *Pottery*: Baking of pots was done.
- *Basket making*: Baskets of tree branches, straw and other materials were made.
- *Spinning and Weaving*: Flax and wool.

Fig. 1.3 shows some implements used towards the end of Stone Age.

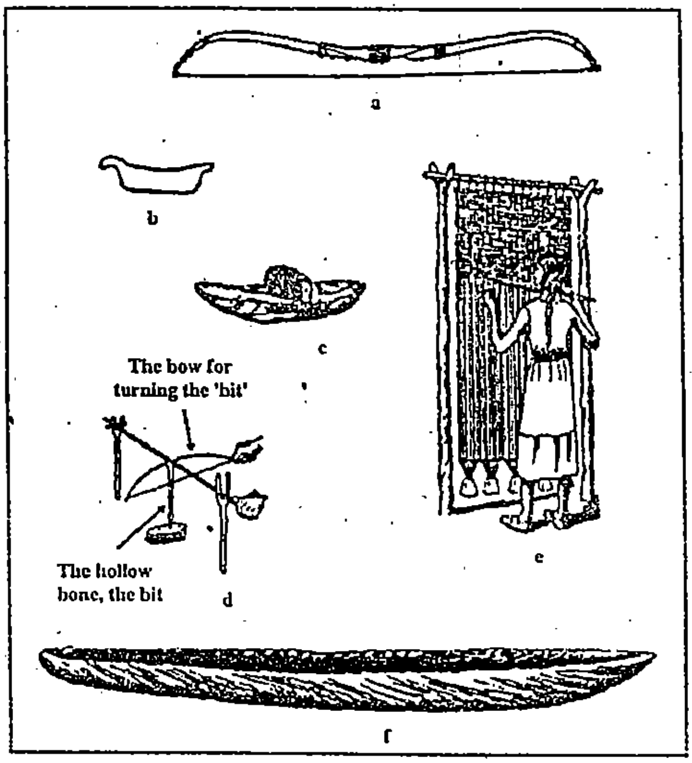


Fig.1.3: Implements used towards the end of the Stone Age: a) composite bow; b) skin boat, outline from Norway; c) grain milling stone; d) bow drill for boring stone; e) weaving loom, reconstructed according to available remains and descriptions; f) boat made out of a tree trunk.

1.2.2 Development of Agriculture up to the Middle Ages

The emergence of agriculture in the Neolithic age gave rise to tiny settlements. The discovery of copper in the later period changed the way agriculture was practiced. This period is known as the Chalocolithic age.

Chalcolithic or Bronze Age (3000 BC-1700 BC)

The term Chalcolithic is applied to communities using stone implements along with copper or bronze implements. This occurred mostly between 3000 BC and 1700 BC. The Chalcolithic revolution began in Mesopotamia (The valleys of Tigris and Euphrates rivers, now Iraq) and from there it spread to Egypt and subsequently to the Indus valley. The people who settled in Mesopotamia were Sumerians, who had just emerged from the Neolithic stage. By 3000 BC, Sumerian civilization was fully developed. Copper in Mesopotamia was imported from Oman or the Persian Gulf.

Cereal-fallow system is a system of growing crops in which the land is left fallow after growing a cereal crop.

Sumerians developed the technique of making bronze. In this period the basic agricultural techniques, which were developed in hilly uplands shifted to river valleys. The nomadic shifting cultivation gave way to the *cereal-fallow system*. The main achievements of the Chalcolithic period in relation to agriculture were:

- *Invention of the plough* – The Sumerians developed the plough by 2900 BC. In other parts of the world, cultivation of small plots with hoes was a common practice.
- *Invention of the bullock cart* – Development of wheel was a great achievement of pre-historic carpentry. Wheeled vehicles are represented in Sumerian art as early as 3500 BC. In the Indus valley wheeled carts were in use in 2300 BC.
- *Development of sailing boats* – It helped in transporting agricultural produce to far off markets.
- *Development of irrigation.*
- *Discovery of chemical processes* involving smelting of copper ore and study of the physical properties of metals.
- *Working out an accurate solar calendar.*
- *Art of growing of additional crops* viz. melons, forage crops of Lucerne and Egyptian clover, flax, beans (vicia), Kabli chickpea and fruit crops such as grapevines, fig, date palm and citrus.

The above achievements changed the tiny villages of the Neolithic period into populous cities with some industry and foreign trade. According to Braidwood (1960) the life of human beings during the Chalcolithic or Bronze Age changed more radically than in all preceding years. Before the emergence and evolution of agriculture, most human beings spent their waking moments seeking their next meal except when they had a great kill.

The first environmental hazard encountered at that time was water logging and salinity due to long period of irrigation without adequate drainage. According to Whyte (1960) salinity caused by 1000 to 1500 years of agriculture was the cause of the decline of the Sumerian civilization. By 1700 BC, wheat had completely disappeared from Mesopotamia and barley which is more salinity tolerant survived but gave lower yields.

With this brief overview of developments in agriculture in the rest of the world, we now turn our attention to the Indian subcontinent. But before studying the next section you may like to reinforce what you have studied so far by trying the following SAQ.

SAQ 2

a) List the crops (cereals, fruits and vegetables) grown in:

New Stone Age
Bronze Age

b) What agricultural implements were used in these eras?

Development of Agriculture in the Indian Subcontinent in the Pre-Christian Era

The great cities of Harappa and Mohen-jo-daro, now in Pakistan, were discovered in the 1920s. They were the first evidence of a fairly advanced river valley civilisation in the Indian Subcontinent (Fig. 1.4). It is known as the Indus Valley or Harappan Civilisation.

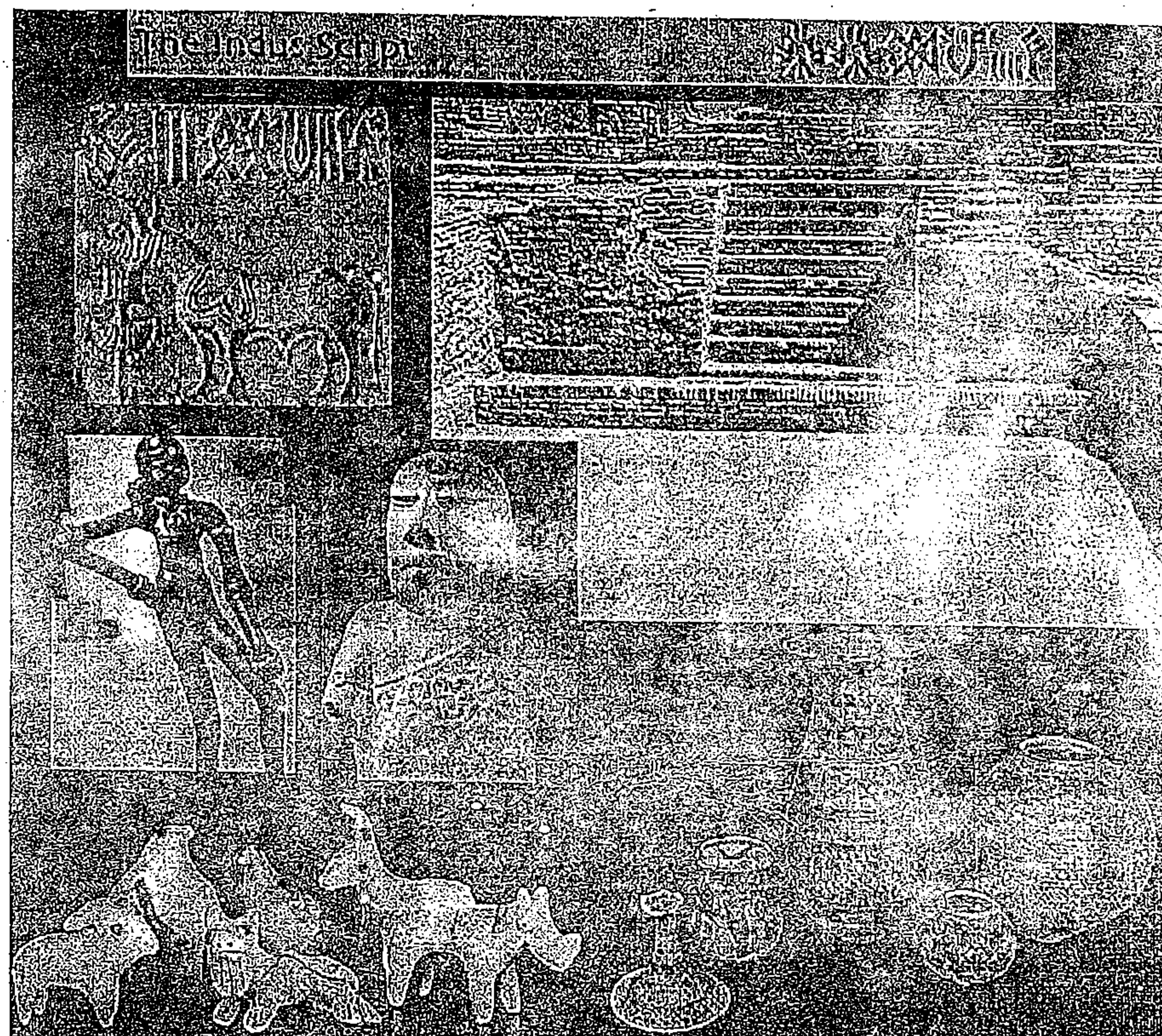


Fig.1.4: Some images and artefacts from Indus Valley civilisation

Harappan agriculture was Chalcolithic in nature and from Harappa it spread to neighbouring parts of India such as Punjab, Haryana, Jammu and western Uttar Pradesh. The crops grown were wheat, barley, gram, sesame, peas, rapeseed-mustard, and cotton. Fruit crops grown were date-palm, pomegranate, lemon and plough was used for land cultivation and bullock carts for transporting goods. The excavations in Mohen-jo-daro show that the harvested grain was stored in special granaries.

The Aryans (1500-600 BC)

The home of Aryans is believed to be South Russia. They left their homeland about 1800-1600 BC perhaps due to drought and famine and dispersed east and westwards in large groups. One group conquered and occupied northern Iran, the other Asia

Minor and the third entered the Indian subcontinent through Afghanistan and Baluchistan. As quoted by Randhawa (1980), Sanskrit, Greek, Latin and Zend are sister languages derived from a common ancestral language, which was spoken by Aryans in their homeland. Vedas were composed by Indo-Aryans during 1500 to 1200 BC and were handed over orally from father to son: The deities invoked for good crops and betterment were *Agni*, *Surya*, *Marut*, *Prithvi*, *Varun* and *Indra*.

Aryans are credited for domestication of horse, which took place in the region now occupied by Ukraine, Kazakhstan and Turkmenistan. They used a horse chariot, which made the movement of people and agricultural goods much faster than bullock cart.

The Vedic Aryans were primarily pastoral. When they settled in Punjab, they cut the forests and built their villages. They grazed their cattle and grew barley. The land was ploughed by bullocks and fields were irrigated when required. Milk formed an important part of their diet and *ghee* (clarified butter) was also prepared.

The Aryans developed the art of smelting iron and made ploughshares and other tools from it. The iron ploughshares permitted cultivation of heavier soils found in Uttar Pradesh in India. Cow dung was used as manure for enriching the soil. In addition to barley they grew wheat, pearl millet, small millets, rice and linseed.

The Buddhist and Later Periods (500 to 200 BC)

In the sixth century BC four great religions of the world were born. These were Confucianism in China, Zoroastrianism in Iran, and Buddhism and Jainism in India. Of these Buddhism had a universal appeal. The Vedic practice of animal sacrifices was given up under the influence of Buddhism and the bullocks became companions of man in the conquest of virgin lands. Iron Age was well established and in addition to ploughshares and sickles, iron was used for making spearheads, arrowheads, axes, daggers and knives.

Buddhism adopted the cult of tree-worship from the older religions and this helped in increasing vegetation. Stories abound that Gautama Buddha was born under an *asoka* (*Saraca asoka*) tree, received enlightenment under a *pipal* (*Ficus religiosa*) tree, preached his new gospel in mango (*Mangifera indica*) groves and under shady banyan (*Ficus benghalensis*) tree and died under a *sal* (*Shorea robusta*) tree. Emperor Asoka, whose reign extended up to regions of Afghanistan, adopted Buddhism after the Kalinga war and promoted growing of trees for fruits and decoration. The fruit trees encouraged included mango, banana, jackfruit and grapevines.

During the Mauryan rule (322 BC-232 BC) in India, agriculture received considerable importance. Animal husbandry was developed and the importance of feed and fodder was recognized. Pastures were developed and veterinary service was established.

Thus, at the beginning of the Christian era there had been considerable interchange of plants between South Asia, Southwest Asia, Europe, Africa, India and China due to significant trade and interaction between these regions.

Crop production and domestication of animals were well established in Western Europe by Roman times. Crop-fallow was the common practice. Wheat and barley were sown in autumn and harvested in spring. Legumes (pulses) were also grown. Soil fertility was judged by colour, taste and smell. Crops were grown on the basis of soil fertility. We will now discuss how agriculture developed during medieval times. But before that, you may like to attempt the following SAQ.

SAQ 3

Compare the level of development of agriculture in the Indus Valley civilization and the Vedic times in the Indian subcontinent pointing out the similarities and differences.

Development of Agriculture in the Medieval Period

The Arab traders played an important role in spreading crops during the medieval times. They carried wheat, barley, rice, cotton, sugarcane, flax, peas and beans from Mesopotamia to Portugal and Spain, North and West Africa and even to China and its neighbouring countries. They introduced rice, citrus fruits, mango, coconut and banana from Southeast Asia to East African countries in eighth and ninth centuries. Traders from Southeast Asia (Indonesia, Malaysia and Thailand) crossed the Indian Ocean and carried rice, banana and yam to Madagascar from where it spread to other neighbouring mainland countries.

The European navigators especially those from Spain, Portugal, Italy, Netherlands (Holland), Britain and Scandinavian countries discovered sea routes to Southeast Asia and the Far-east. They also discovered the New World (North and South America). Columbus discovered America in 1492, Vasco de Gama reached India via Cape of Good Hope in 1498 and Magellan circumvented the world in 1521. These navigators took European and Asian crops to Americas and American crops such as corn (maize) and potatoes to Europe. Asia and Africa.

1.3 AGRICULTURE IN THE POST- INDUSTRIAL ERA

During the eighteenth century, a number of scientific discoveries were made and the stage was set for the Industrial Revolution in England. The scientific discoveries and the Industrial Revolution had far reaching influences on the evolution of agriculture and paved the way for modern agriculture. Therefore, we discuss them briefly.

The Great Age of Discovery

James Hutton (1785) in his 'Principles of Earth' systemized the knowledge of geology, which brought out the importance of fossils and rock strata in interpreting the origin and development of earth. Benjamin Franklin (1706-1790), an American genius proved that lightning in the clouds is due to electricity. Volta (1745-1827) constructed the first electric battery. Joseph Priestley (1733-1786) and Scheele (1742-1786) independently discovered oxygen and Cavendish (1731-1810) discovered the chemical composition of water. Lavoisier showed that oxygen was involved in the burning of a material and that breathing in animals is an oxidation process. Edward Jenner (1749-1823) invented the process of vaccination. These are only a few of the important discoveries made in the eighteenth century (Randhawa, 1980).

As regards plants and animals, which form the basis of agriculture, Carlos Linnaeus (1707-1778) invented the bionomical nomenclature, the modern system of naming plants and animals. He used *Latin* for this purpose. According to this system each plant or animal species has two words to describe it; the first word refers to genus while the second word refers to the species. For example, in *Homo sapiens*, *Homo* is the genus, while *sapiens* is the species. Similarly, for mango the biological nomenclature is *Mangifera indica*. Here *Mangifera* is the genus and *indica* is the species name; *indica* indicates its linkage to India.

Benjamin Franklin

Joseph Priestley

Henry Cavendish

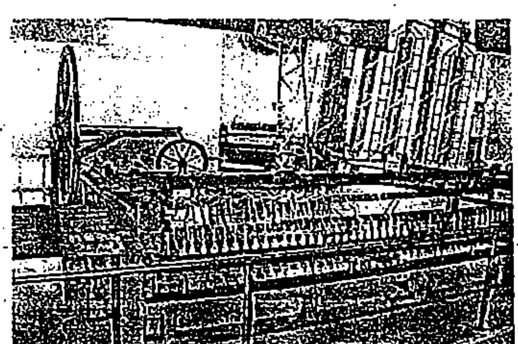
Carlos Linnaeus

Fig.1.5: Scientists of the Great Age of discovery

The Industrial Revolution

The Industrial Revolution in England began with the textile industry. Until 1764, spinning was done with the spinning wheel, where one person could take only one thread at a time. Three great inventions, Hargreaves' spinning-Jenny of 1764, Arkwright's water frame of 1769 and Crompton's mule of 1779 made the first real breach in the old hand techniques, first by multiplying the action of the hand and by using the power in the primary process of spinning. Thus, machinery substituted manual work in spinning and weaving leading to a manifold increase in production.

In 1784 Cartwright invented a new improved loom and by the end of the eighteenth century power driven machines had been invented, permitting the spinning of 200 threads at a time. The engineers who sparked off the Industrial Revolution in England were the lineal descendents of the millwrights and metal workers. They included men such as, James Watt (1736-1819), the discoverer of steam engine, Murdock (1754-1839), the inventor of coal gas lightening and Mathew Boulton (1728-1809), who became the first manufacturer of steam engine (Randhawa, 1980).



(a)

(b)

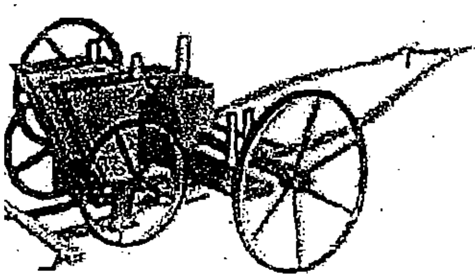
Fig.1.6: Inventions that set the stage for the Industrial Revolution; a) Hargreaves' spinning-Jenny, b) Arkwright's water frame

'he Industrial Revolution had a harmful effect on rural artisans and craftsmen in ;ngland and adversely affected the cottage textile industry in India. Much of the gricultural development in cotton production in India by the British was primarily irected towards providing adequate cotton to spinning mills in England. The large :ale cultivation of indigo in the eastern states in India was also controlled by the ritish and was meant to supply indigo to cotton mills in England.

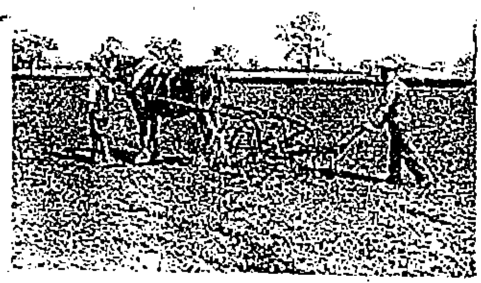
'he Industrial Revolution caused profound social upheavals, but it also made England ie workshop of the world. Apart from promoting its textile trade it provided British :my with the artillery and other war materials that were superior to other countries in ie world. It put many technologies and scientific knowledge at the disposal of human ocieties. When some of these were applied to agriculture, it underwent a significant ansformation, which we take up in the next section.

.4 MODERN AGRICULTURE

he agricultural revolution in England began in the early eighteenth century. ecognizing the soil fertility restoring value of legumes, the cereal-fallow cropping 'stem was replaced by the cereal-legume rotation. Jethro Tull (1647-1741) invented horse drawn hoe and a seed-drill with tines at right distance to sow the row crops.



(a)



(b)

Fig.1.7: a) Seed drill; b) Horse Drawn Hoe

'inter crops of turnip and clover were introduced from Flemish agriculture. Before e introduction of these crops, lack of winter feed for the animals was a nightmare at returned every year and the farmers could keep only as many animals as their pply of grass, straw and hay would feed. The rest of the animals were slaughtered d their meat was salted and during the long winter months, farm families in England 'ed mostly on salted meat.

›bert Blackwell (1725-1795) brought about a revolutionary change in stock-eeding. He bred horses for draught purposes, cattle for beef and milk, and sheep for ›ol and mutton. The rise in prices of the agricultural products during the volutionary and Napoleonic wars (1793-1815) gave stimulus to British agriculture d the use of new implements and farm machinery made progress. Societies for the iprovement of agriculture were formed in Scotland in 1723 and a Professorship in riculture was established at the University of Edinburgh in 1790. The Farmers agazine, a monthly, was established in 1776.

ie manufacture of chemical fertilizers started in the middle of the nineteenth ntury, when Lawes and Gilbert (1847) developed single super phosphate in igland. The funds from the sale of this fertilizer were donated for establishing the ›thamsted Experimental Station in England.

SAQ 4

Describe the impact of Industrial Revolution on agriculture.

Many other developments in the New World were giving an impetus to farm mechanization, improved breeds of crops and animals, and synthetic fertilizers in agriculture. We describe now the development of agriculture in the United States of America.

Developments in Agriculture in the USA

American farmers had big farms and in the horse husbandry period needed many farm hands, which were difficult to get in the mid-west and northwest US. In 1890, a steam driven tractor was developed in the northwest US. This was followed by the development of a gasoline driven tractor by an Iowa (a state in US) farmer. The tractor with internal combustion engine was developed in 1910. The development of other tractor driven machines followed. Soon the tractors replaced horses and mules and crop harvesters replaced sickles in the US farms. These developments in farm machinery in the US soon reached Europe. Thus developed the modern mechanized agriculture. The increase in agricultural yields, however, was accompanied by environmental problems.

In order to get a soft seed bed and more and more nutrients released from the soil organic matter, farmers practiced repeated ploughing and over the years, the surface soil became too loose and this led to severe wind erosion popularly known as "the famous dust bowl" of the Great Plains of the 1930s. So damaging was the effect of this wide-spread wind erosion that the Soil Erosion Act of 1935 and Soil Conservation and Domestic Allotment Act of 1936 were passed by the US House of Representatives (Rasmussen, 1973).

Considerable research was done at the State Agricultural Experiment Stations in the US to develop what is now known as 'Conservation tillage' or 'Stubble mulch farming'. In this kind of farming, sowing of crops is done in the field without land preparatory ploughing using special equipment which cuts the stubbles of maize, sorghum etc. at the soil surface and spreads them in the field, while a special tine makes a slit in the soil and sows the seed at the desired depth in a single operation. The stubbles left in the field accumulate at the soil surface and form a layer of undecomposed or partly decomposed organic matter mulch, which prevents soil erosion, conserves soil moisture and improves soil fertility (McCalla and Army, 1961 and Prasad and Powar, 1991).

Many changes in the world agriculture since 1914 are directly traceable to the World War I. The most important effect was the stimulation to agricultural production outside Europe to meet its food demands. The area devoted to cereals in Canada, USA, Argentina and Australia in 1921 was 19% more than the pre-war period. The production of pork in USA, beef in Argentina and butter and cheese in New Zealand and Argentina also increased (Rasmussen, 1973).

Another major contribution of American Agricultural Scientists was the development of hybrid corn during 1905-1920. The first corn hybrid to be produced commercially was 'Burr-Learning' double cross by the Connecticut Agricultural Experiment Station in 1917. Hybrid corn yields were very high and demanded heavy application of fertilizer, especially nitrogen. Although the first synthetic ammonia plant was built in Germany in 1910, a fertilizer plant was built by the US Govt. at Sheffield Alabama just prior to the close of the World War I to manufacture ammonium nitrate. It was followed by another fertilizer plant at Syracuse (New York state) in 1921 and yet another at Hopewell (Virginia state) in 1929. All these 3 fertilizer plants manufactured nitrogen fertilizers (ammonium nitrate/sodium nitrate).

In addition to encouraging the establishment of fertilizer plants, development of hybrid corn also led to the development of seed industry, because the farmers needed to buy hybrid seed each year. The first seed company for commercial production was established in 1926, but large-scale hybrid corn seed production was started in 1932.

These developments in agriculture in USA had an impact on global agriculture. Hybrid corn (maize) is now produced the world over including India. Furthermore the principle of hybridisation has been extended to other crops such as sorghum and pearl millet. China was the first to produce hybrid rice, which is now being produced in India also.

One of the latest advances made in agriculture is the development of genetically modified (GM) plants. In this case the crosses are made in laboratory across genomes to transfer a desired trait from one organism to another. GM maize and other food crops are being grown in US and some other countries. During the crop years 2002 and 2003 Gm Bt cotton was grown in India with only partial success against cotton boll worm. As yet there is no global acceptance of GM food plants. Nevertheless the GM technology offers a way for overcoming serious pest problems without the use of pesticides and may play an important role in modern agriculture.

The worldwide changes in agricultural techniques and practices were to impact South Asian countries in a significant manner. The Green Revolution in India is a good case study of how the developments in modern agriculture have proved to be a double-edged sword.

Green Revolution in India: A Case Study

After achieving independence, India's first priority was to achieve self-sufficiency in food. A number of programmes were initiated to improve the country's agricultural production but the real success came in mid 1960s when a large amount of the seed of high yielding varieties of wheat was imported from Mexico. They were sown on the farmers' fields in the crop year 1967-68 and that year wheat production in India showed a quantum jump; it increased from 11.4 million tonnes (one tonne – 1000 kg) in 1966-67 to 16.5 million tonnes in 1967-68. This ushered in what is called the *Green Revolution in India.*

Wheat production in India in the year 2002-03 was 78 million tonnes and per hectare yield increased from 887 kg/ha in 1966-67 to 2743 kg/ha in the year 2000-2001, a three-fold increase. India now ranks second in wheat production in the world. There has also been an increase in the productivity of other crops. The high yielding varieties of cereals (e.g., rice and the hybrids and synthetics of maize, sorghum, and pearl millet in India) give yields that are 2 to 3 times of those obtained with local tall varieties and therefore need heavy fertilization. The major problem with the local tall wheat and rice varieties was that when high amounts of fertilizer were applied they lodged and there was no yield increase, on the contrary lodging reduced yield. On the other hand, dwarf wheat and rice varieties did not lodge when heavily fertilized and this finally resulted in high yields.

The point to be noted is that modern agriculture is highly input intensive. For high yields, good quality seed is required, which in the case of hybrids has to be purchased each year from seed producing companies. Moreover, high yielding cereal varieties demand heavy fertilization and thus investment in fertilizer has increased. The consumption of chemical fertilizers in India increased from a mere 65 thousand tonnes of plant nutrients (N+P205+K20) in 1951-52 to 17.3 million tonnes in 2000-01 (FAI, 2002).

Since well fertilized crop plants remain greener and more succulent they invite more insect pests and thus with high yielding varieties the demand for pesticides

1 lakh = 10^5

(insecticides, fungicides, herbicides, rodenticides) increased from 24305 tonnes in 1971 to 85030 tonnes in 1994-95 (ICAR, 2001). Due to intensive agriculture (growing of 2 or more crops a year) the need for irrigation and farm mechanization has also increased. Due to heavy and over-irrigation, the water table particularly in the rice-wheat belt of north India has gone down to alarming levels. The number of tractors in India has increased from 1.5 lakhs in 1972 to 22.2 lakhs in 1998, while that of threshers has increased from 2 lakhs in 1972 to 32.3 lakhs in 1998 (ICAR, 2001).

Excessive use of chemical fertilizer leads to several environmental problems which include eutrophication of lakes, ponds and estuaries, nitrate enrichment of ground water, ammonia and nitrous oxide enrichment of the atmosphere, the latter is involved in depletion of ozone layer (Prasad, 1998). Similarly pesticides can persist in soil and edibles and are a health hazard (Edwards, 1973). Increased use of tractors on the farm leads to increased emission of smoke and CO_2. Thus modern agriculture creates several environmental problems and sustainability issues in agricultural production system. These are discussed in detail in later units.

Safety of natural resources is of prime concern so as to ensure productivity, profitability and sustainability of our major farming systems for the present and future. In this mission scientists are striving to strike a balance between the two diametrically opposite processes of exploitation and conservation. To achieve this, the extent of environmental protection, resource conservation and its rational utilization must form an integral part of agricultural research and developmental processes. Integrated farming systems have been considered a promising and potential pathway.

With this brief overview of the evolution of agriculture, and a discussion of various facets of modern agriculture, we would like to end the unit by summarizing its contents.

1.5 SUMMARY

- It is widely accepted that agriculture evolved in Southwest Asia during the Neolithic Age (7500-6500 BC).
- The important achievements related to agriculture during the Neolithic Age are:

  1) Growing of crops (wheat, barley, millets, maize); 2) Domestication of animals (goat, sheep, cattle, pig, ass); 3) Building of houses; 4) Pottery; 5) Basket weaving; and 6) Spinning and weaving.
- The important achievements of the Chalcolithic Age (3000-1700 BC) are: 1) Invention of the plough, 2) Invention of the bullock cart, 3) Development of irrigation, 4) Sailing boats, 5) Smelting of copper and making of bronze.
- A number of new agricultural developments in India (as well in Europe) were initiated by Aryans (1500-600 BC) who came from South Russia. They domesticated horses and used horse chariots that moved faster than the bullock carts. They cleared forests and established villages in Punjab and western U.P. and they grew wheat, barley, rice, millets and linseed. They perfected the art of smelting iron and made iron ploughshares, sickles, spearheads, arrowheads and swords.
- The Buddhist period (500-200 BC) in India is credited with the planting of shady roadside trees (banyan, *pipal*, and palm) and fruit trees (mango, jackfruit). They also grew banana and grapevines. In the Mauryan period (322-232 BC) in India, animal husbandry and veterinary science were developed.

- During the medieval period, considerable interchange of plants and animals took place all over the world in which Arab and South Asian traders and European navigators played the key role.

- Soon after the Industrial Revolution in England, modern agriculture started which ushered the agricultural revolution in England. A seed-drill was developed and stockbreeding was started. The first fertilizer plant was established for manufacturing single super phosphate.

- Heavy farm machinery, the foundation of modern mechanized farming was developed in USA, where the first tractor using internal combustion engine was developed in 1910. World War I provided the stimulus to the agriculture in US, Canada, Argentina and New Zealand because food had to be produced for Europe. Hybrid corn was developed in US during 1905-20. Due to its high yield it encouraged use of large amounts of fertilizer and pesticides. Hybrid corn also laid the foundation of seed industry. These new developments in agriculture soon reached Europe and other parts of the world.

- Green revolution in India occurred in mid 1960s due to large-scale import of high yielding varieties of wheat from Mexico. Though it made the country self-sufficient in food, it has thrown up several environmental issues that need to be addressed urgently.

- Modern agriculture is input intensive and needs good quality seeds, mechanization, large amounts of fertilizers, adequate irrigation and pesticides (insecticides, fungicides, herbicides, rodenticides) and thus demands heavy expenditure and raising the input efficiency. These inputs also create environmental problems and health hazards, which call for development of optimum, sustainable and eco-friendly production systems.

1.6 TERMINAL QUESTIONS

1. What role did the traders and navigators play in the evolution of agriculture in the medieval period?

2. What do you understand by Agricultural Revolution in England?

3. Briefly discuss the agricultural developments in USA.

4. What are the main inputs required in modern agriculture? Discuss briefly their impact on the environment.

5. Outline the current status of agricultural practices in India.

6. Briefly discuss why eco-friendly agricultural technology has become important today.

REFERENCES

1. Braidwood, R.J. (1960) The Agricultural Revolution. Scientific American 203(3): 130-152.

2. Bender, B. (1975) Farming in Pre-history – from hunter gatherer to food producer. Billing & Sons Ltd., pp.268, London.

3. Edwards, C.A. (1973) Resistant Pesticides in the Environment. 2nd ed. CRC Press, Boca Raton, pp.119, USA.

4. FAI (2002) Fertilizer Statistics 2001-2002. The Fertilizer Association of India, New Delhi.

5. Hawkes, J.J. and Wooley, L. (1963) Pre-history and the Beginnings of Civilization, Allen & Unwun, London (c.f. Randhawa, 1980).

6. ICAR (2001) Agricultural Research Data Book. ICAR, New Delhi.

7. Lawes, J.B. and Gilbert, J.H. (1847): Journal of Royal Agricultural Society. 9:226-232.

8. Prasad, R. (1998) Fertilizer urea, food security, health and environment. Current Science 75:677-683.

9. Prasad, R. and Power, J.F. (1991) Crop Residue Management. Advances in Soil Science 15:205-251.

10. Randhawa, M.S. (1980) A History of Agriculture in India. Vol. 1(pp. 541) and Vol. III (pp.422), ICAR, New Delhi.

11. Rasmussen, W.D. (ed.) (1973) Agriculture in the United States – A documentary History, Greenwood Press Inc., Westport, pp. 2913.

12. Sauer, C.O. (1952): Agricultural Origins and Dispersals. American Geographical Society, New York (c.f. Randhawa, 1980).

13. Unger, P.W, and McCalla, T.M. (1980) Conservation Tillage. Advances in Agronomy. 33:2-53.

14. Vavilov, N.I. (1949-50) The Origin, Variation, Immunity and Breeding of Cultivated Plants. Chronica Botanica 13:113-120.

15. Whyte, R.O. (1960) Evolution of Land Use in South-Western Asia, FAO, Rome.

UNIT 2 AGRO-ECOSYSTEMS

Structure

2.1 INTRODUCTION

In the earlier unit you have read about the emergence and development of agriculture through the ages and learnt that agriculture was developed for a simple but fundamental purpose to provide adequate human nutrition. During the last century, modern agriculture became resource intensive and technology based and enabled the green revolution to happen. The apparent success of production agriculture depended on the world's capital held in the form of soil organic matter and nutrients. One unintentional outcome of production oriented agriculture is the recent global degradation of soil and water resources and the consequent loss of biodiversity. Further, expansion of agriculture into the forests and conversion of rangeland into cropland, have aggravated the situation. Agriculture now faces the problem of enhancing food production while simultaneously reversing the resource degradation and overcoming the harmful effects of chemicals used in agriculture. Therefore, it is necessary to view agriculture from an ecosystems perspective. The ecosystems that are used for agriculture are known as agro-ecosystems.

Odum (1984) defined agro-ecosystems as domesticated ecosystems that are in many basic ways intermediate between natural ecosystems such as grasslands and forests on one hand and fabricated ecosystems such as cities on the other. Agro-ecosystems are "areas where at least 30% of the land is used as cropland or highly managed pasture." They cover approximately 28% of Earth's land area, excluding Greenland and Antarctica — a total of 4.92 billion hectares. Of this, about 30% is cropland and 70% is pasture. Irrigated agro-ecosystems comprise little more than 5% of the total, but produce about 40% of the world's crops. These systems are also solar powered as are natural ecosystems but differ from them in various aspects.

In this unit we will explain how the concept of agro-ecosystems is used to describe a geographically and functionally coherent domain of agricultural activity. We will also discuss the various living and nonliving components and the interactions among them. The discussions related to the structural and functional components within the agro-ecosystems will provide the background for discussions in further units of this course.

You will also learn about the various agro-climatic zones of the Indian subcontinent and their influence on the productivity of the region.

Objectives

After studying this unit, you should be able to:

- define and differentiate between agro-ecosystems and natural ecosystems;
- describe the various structural and functional components of agro-ecosystems;
- enumerate the various agro-ecosystems; and
- describe the agro-climatic zones and sub-zones of the Indian region.

2.2 CONCEPT OF AGRO-ECOSYSTEMS

The agro-ecosystem is an ecological system modified by humans to produce agricultural products. Ecologically such systems are less complex than natural systems, but are made complex by the imposition of socio-economic values and defined goals.

Natural ecosystems can extend over large areas and make up large systems such as grasslands, mangroves, coral reefs, ponds, oceans, tropical forests etc. However, when farming is practiced then different ecological conditions and new ecosystems known as Agro-Ecosystems are created. Agro-ecosystems are the living communities of soil, plants, and animals that constitute our farms, croplands, orchards, pastures, and rangelands. More than 90% of all the crops and livestock we consume as well as livestock feed is produced by agro-ecosystems. They also contribute fibre crops such as cotton, flax, hemp, and jute, which we use for clothing and textile manufacturing.

The use of an agro-ecosystem approach in agricultural development requires the recognition of the existence of interactions among biological and natural resource variables, and, in all but the very lowest level, of social and economic considerations as well. People are at the centre of agro-ecosystems.

To analyse the productivity or sustainability of any agro-ecosystem requires in theory, a reference to all possible variables and their interactions, a task made possible only by a process through which the major or priority issues and interactions are identified by a community of end users and other participants appropriate to the level of reference.

Agro-ecosystems are conceived as existing in a four dimensional space, the parameters of which are **productivity, sustainability, stability** and **equitability**. The hierarchy of agro-ecosystems is presented in Fig. 2.1

No matter how they came about, our lives depend on agro-ecosystems. For they have kept pace with our demands for food, feed, and fibre over the past 4 decades as the global population doubled. In fact, agro-ecosystems provide, on average, 24% more food per person today than they did in 1961. But by 2020 agro-ecosystems will have to supply food for an estimated 1.7 billion more people.

Spatially an agro-ecosystem could vary from a system involving a crop or a farm to communities and watershed composed of many farms and even large eco-regions. Regardless of the scale, agro-ecosystems are characterized by driving variables (solar radiation, rain, water and wind), inputs such as immigration, inflow of capital, information, energy, fertilizers, chemicals and human infrastructure and knowledge. Most agro-ecosystems experience losses and outputs in the form of export of crops and livestock, loss of nutrients, water and emigration.

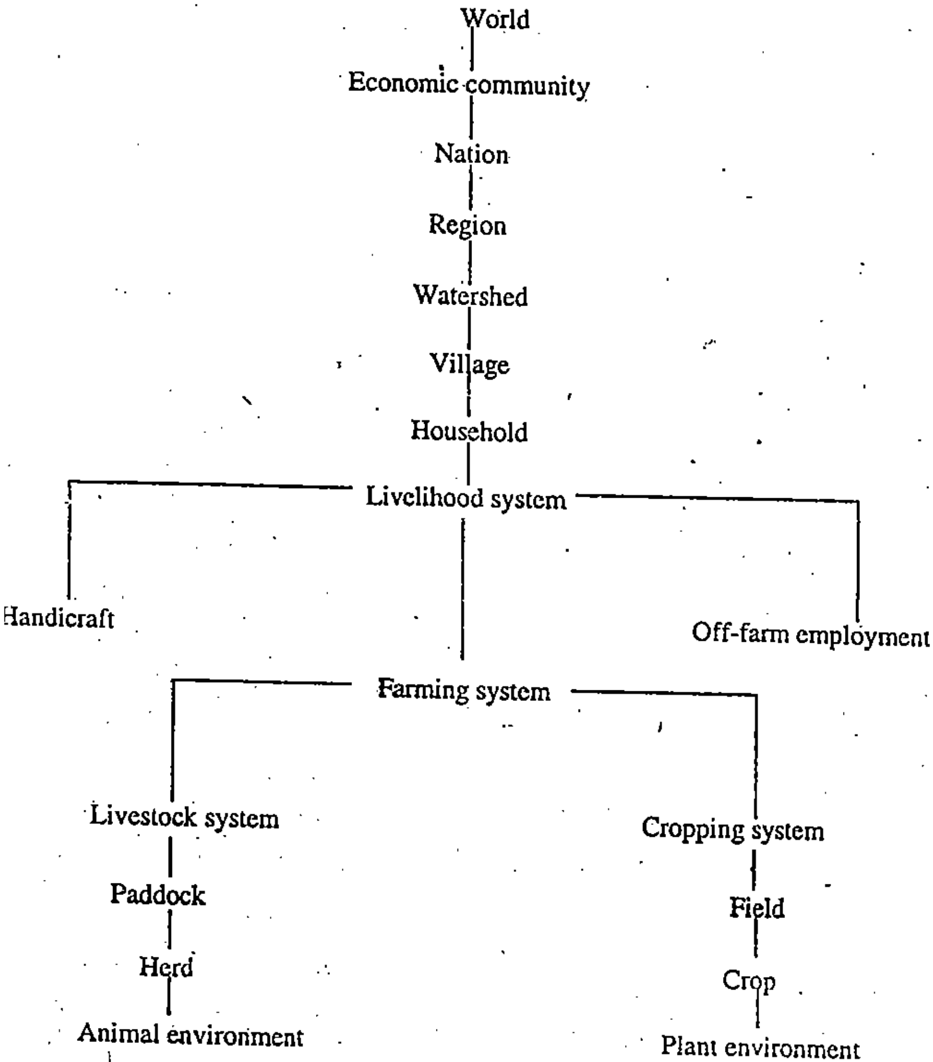


Fig.2.1: The hierarchy of agro-ecosystems (Conway, 1987)

'ome of the most important goods and services provided by agro-ecosystems are ;iven in the table below:

Table 2.1: Goods and services provided by agro-ecosystems

Goods	Services
'ood – Agro-ecosystems provided 94% f all the plant and animal protein and 9% of all the calories humans consumed ı 1997.	**Employment** – Food production employs approx. 1.3 billion people and is valued at around $1.3 trillion per year.
1eat – Global meat demand grew 2.9% er year between 1982 and 1994 and is xpected to increase 58% by 2025, ıcreasing people's protein intake.	**Carbon storage** – Agro-ecosystems contain 18-24% of the carbon stored in all terrestrial ecosystems, mostly in the soil rather than the plants.
'ibre – Fibre crops in North America omprised 0.1% of harvest area and about .03% of the total value of agricultural roduction.	**Biodiversity** – Although 90% of our caloric intake comes from just 30 crops, more than 7,000 crop species exist—a wealth of alternative food crops.

2.2.1 Agro-ecosystems versus Natural Ecosystems

Agro-ecosystems are distinct from unmanaged natural ecosystems as they are intentionally altered and often intensively managed for the purpose of providing food, fodder, fibre and other products. Hence they inherently have human community, economic and environmental dimensions (Fig. 2.2).

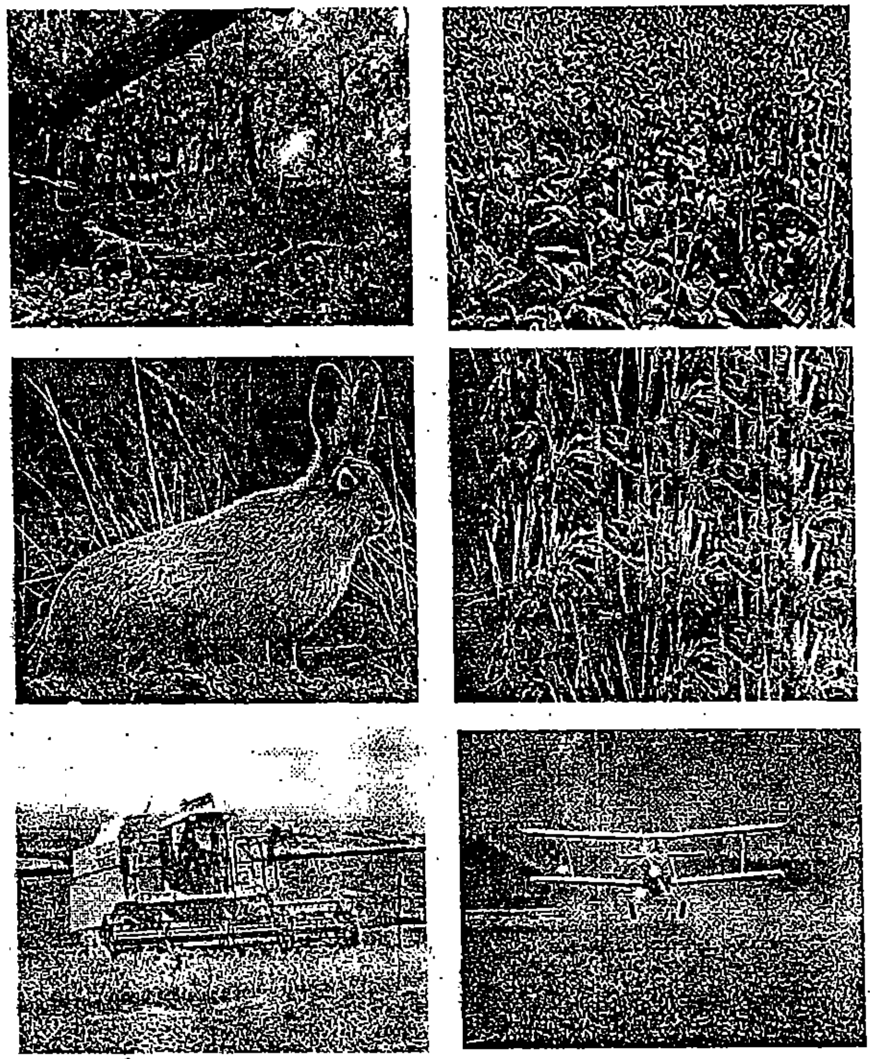


Fig.2.2: Agro-ecosystems differ from natural ecosystems

Agro-ecosystems can be distinguished from natural ecosystems on the following counts:

- In agro-ecosystems we try to stop ecological succession so that the ecological system is kept constant. Most crops are early successional species, which means that they grow best when sunlight, water, chemical inputs are abundant. Therefore, agro-ecosystems are intensively manipulated by humans through ploughing, tillage, mowing, irrigation, treatment with pesticides, fertilizers, etc.
- The auxiliary energy sources that enhance productivity are processed fuels along with human and animal labour rather than natural energy.
- In natural ecosystems, plants get nutrients from natural cycling of minerals. The leaves of plants and dead bodies of herbivores and carnivores get decomposed and release nutrients into the soil, which are then absorbed by the plants. In agro-

ecosystems farmers apply farmyard manure and inorganic fertilizers such as nitrogen, potassium and phosphorus, which augment the natural mineral cycles.

- In agro-ecosystems high yielding varieties are grown with application of fertilizers and extensive irrigation for getting higher production. Pesticides protect these. Crop varieties with inherent resistance to pests and diseases are bred through genetic selection. Thus genetic selection replaces natural selection.

- Diversity is greatly reduced by human management in order to maximize yield of specific food or other projects. Crops are planted in neat rows. In most natural ecosystems many species of plants grow mixed together in complex patterns. Therefore, pests and disease affect agro-ecosystems more easily.

- Food chains are generally simplified in agro-ecosystems. Pest control reduces the abundance and diversity of natural predator species and parasites of crop plants. This way species that could compete with crops for nutrition are eliminated. Thus agro-ecosystems have less species diversity than natural ecosystems making them more susceptible to undesirable changes.

- Control is external and goal oriented rather than internal control via subsystem feedback as in natural ecosystems.

- Ploughing and tilling disturb the natural formation of soil and expose it to erosion. Nothing in nature resembles the ploughing process, which turns over the soil to a specific depth.

- In natural ecosystems there is a natural dispersal of seeds from the plants. The new plants get established wherever they fall. In agro-ecosystems, natural seed dispersal is replaced by manual or mechanized sowing of seeds after ploughing the land.

2.2.2 Types of Agro-ecosystems

The broad divisions of agro-ecosystems are based on the types of crops cultivated or animals tamed. Some of the types of agro-ecosystems commonly found are:

- Seasonally Cropped Systems: The crops and plants that complete their life cycle in a single season are part of seasonally cropped agro-ecosystems. Most of the agro-eco systems in the world are cultivated with seasonal crops such as cereals, pulses, and oilseeds which fulfill the food requirements of the people. Soil is degraded more in seasonally cropped areas due to tillage operations. Soil fertility is lessened since in each season a new crop is to be sown, and the extent of nutrient depletion/erosion depends on the nature of the crop.

- **Permanently Cropped Systems:** Large tracts of land are under perennial cropping system such as orchards, plantation crops like cardamom, rubber, coconut, areca nut, cashew nut, oil palm etc. In this type of agro-ecosystems it is also possible to grow seasonal crops in the inter row spaces.

- Forestry Systems: All manmade forests are part of the agro-ecosystem. In some forests perennial grasses are grown for fodder purposes or for grazing of cattle. Man made forests are classified into (i) agro forestry which is forestry on farmed or cropped land; (ii) social forestry which means raising and management of forests outside the traditional forest area for meeting the basic requirements of the people, environment amelioration and rural development; (iii) government forest plantation.

- **Aquaculture Systems:** Manmade water bodies used for fish culture and cultivation of aquatic plants.

- **Integrated agro-ecosystems:** consisting of a suitable mixture of various farming components viz. cropping systems, livestock rearing, horticulture, aquaculture, poultry etc. (You will read more about integrated farming systems in Unit 12 of this course).

Box 2.1: Agricultural extent and land use changes in South Asia

- Total land area under agriculture – 73%
- Intensive agricultural use – 70%
- Crop based agro-ecosystems – 91%
- Share of global irrigated land area – 35%
- Annual harvested area as a proportion of total cropland or cropping intensity – 1.1% (average cropping intensity globally is 0.8%)

SAQ 1

Define an agro-ecosystem. Give two main differences between agro-ecosystems and natural systems.

2.3 COMPONENTS AND INTERACTIONS OF AN AGRO-ECOSYSTEM

Like any other natural ecosystem, agro-ecosystems may also be described as open systems that receive **inputs** from outside and lose energy and matter as **outputs.** The major outputs are primary and secondary production (plant and animal production) and nutrient elements. Internally, the system comprises a number of interrelated components through which energy and matter flow (Fig. 2.3).

Like natural ecosystems, agro-ecosystems can be thought of as including the processes of primary production, consumption, and decomposition interacting with abiotic environmental components and resulting in energy flow and nutrient cycling. Economic, social, and environmental factors must be added to this primary concept because of the human element that is so closely involved with agro-ecosystem creation and maintenance.

Inputs into the system occur in a number of ways– by weathering of rocks to provide nutrient elements and soil particles; by solar radiation to provide energy; by precipitation to provide water and nutrient elements; by transfer from nearby land surfaces that provide water, solids and nutrient elements (through erosion or runoff) and above all through the inputs provided by the farmers. These inputs by the farmers include seeds, fertilizers, manures, livestock, animal feeds, pesticides and fuel energy.

Through various inputs, human beings have been able to control the agro-ecosystems and maintain their capacity for high levels of outputs that characterize the modern agricultural systems. In the following subsections we will discuss the structural and functional attributes of the agro-ecosystem.

2.3.1 Structure of Agro-ecosystems

In order to understand the structure of agro-ecosystems we must understand the first principle of ecology that all things are interconnected and based on the relationships among the biotic (living) communities and the abiotic environment. Like natural ecosystems, the structure of agro-ecosystems is made up of biotic and abiotic components present at a particular place.

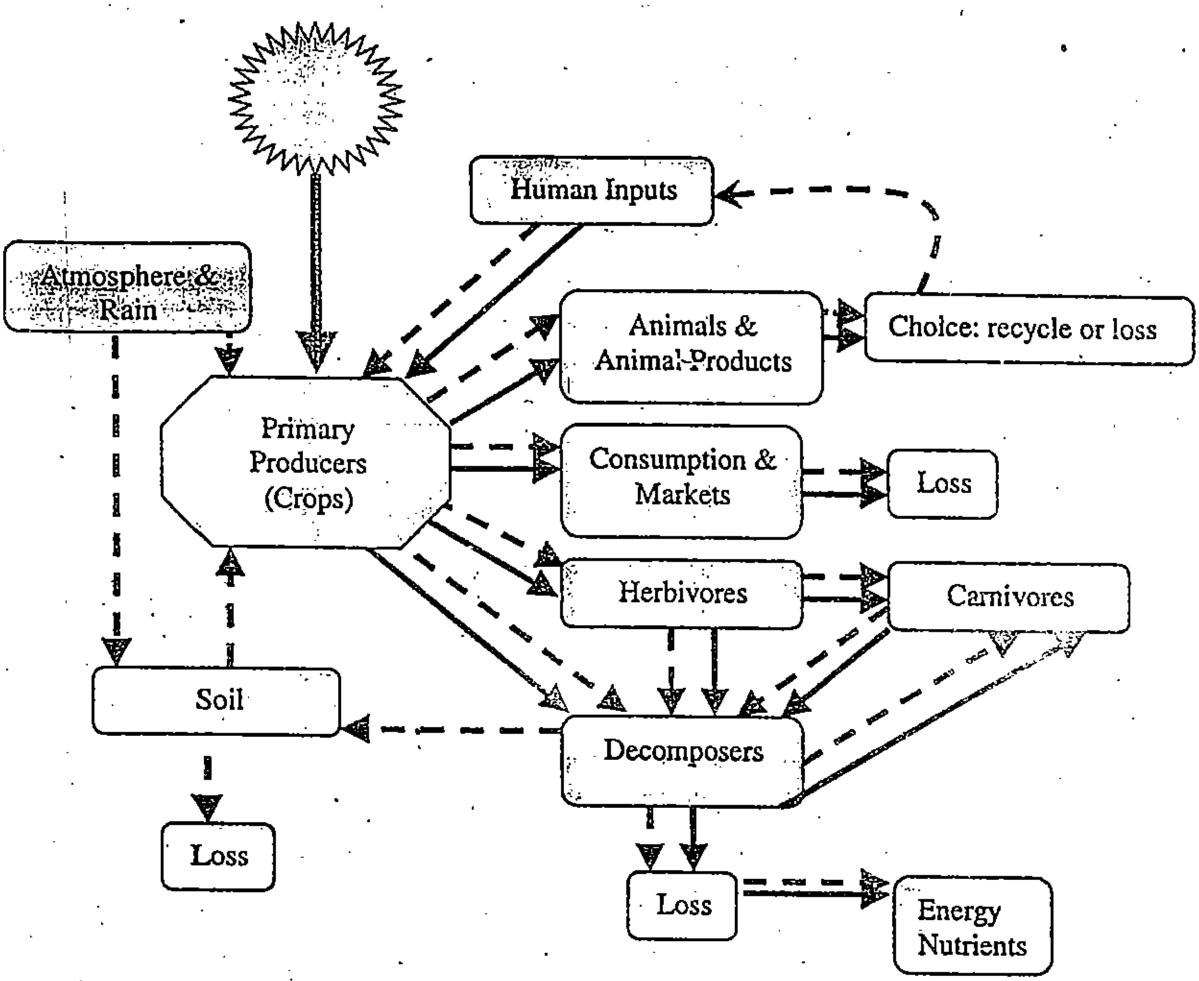


Fig.2.3: The general structure of an agro-ecosystem showing its components and relationship with external factors.

Biotic components

The biotic components of the system are the crop plants, animals and the microorganisms present in the soil. Crops and weeds are the primary producers while the secondary producers are the herbivores comprising insects, birds and small mammals. The decomposers are mostly species of fungi, microorganisms and nematodes etc.

Crop plants: Of the numerous species of plants, only about 7000 have been tried as agricultural crops and only150 species have been cultivated on a large scale. Some crops provide food; others provide fodder, and other commercial products including oil, drugs, pesticides and fibres. The world's food production is provided by only 14 crop species –wheat, rice, maize, potatoes, sweet potatoes, manioc, sugarcane, sugar beet, common beans, soybeans, barley, sorghum, coconut, and bananas. Of these, six species provide directly or indirectly 80% of the total calories consumed by human beings. Overall globally crops occupy 31% of agricultural areas and the remaining area is occupied by pasture and this varies region wise. In South Asia, 91% of the cropland is under annual crops such as wheat, rice and soybean, while perennial crops such as coffee, tea, fruits, sugarcane occupy the remainder. Though crops are maintained as pure populations, weeds grow along with the crops despite best efforts to control them, by adjusting their life cycle within the interim period of inter-cultural operations. Weeds enter into competition with crop plants for necessary growth requirements and reduce the growth and yield of the crops. The density, frequency and vigour of the crop system are useful in understanding the relationships between the crops-weed- insect- bird in the agro-ecosystem. Biomass is a good indicator of community structure and unlike natural communities the biomass of crops steadily increases from early vegetative stage till harvest. A study of the leaf area index, amount of chlorophyll distributed in the stem, leaves etc., biomass profile and energy storage patterns of the primary producers provide information about their activity zones.

The chlorophyll pigment in the green plants traps light energy, and synthesizes carbohydrates using carbon dioxide and water in the photosynthesis process. Chlorophyll content is correlated with dry matter production and used as an index of productive potential of the plant population. Chlorophyll content varies with different crop plants as well as between different varieties of the same crop. It increases with age and declines after flowering due to senescence and shedding of lower leaves. Their leaf area measures photosynthetic size of plants and the most appropriate measure of leaf area for field crops is the leaf area index, that is, the leaf area per unit area of land. In crop plant communities, the average value of leaf area index is 2-6, while in natural communities, the leaf area index may be as high as 6-13 for forests, and 3-15 for grasses. In annual crops, the leaf area index increases with age and starts to decline after flowering. Leaf area index is positively correlated with productivity and maximum net production is obtained when it is approximately 4.

Energy content of the crop plants is an indicator of the structure of the producer subsystem. Energy content varies with the age and chemical content of the plants. In certain paddy varieties, high energy content during early vegetative period has been reported. Of the total energy locked up in biomass, 85 to 90 percent is harvested by human beings as grain and fodder, while the remaining 10-15 percent is left as stump and roots and is available to heterotrophs in the soil.

Consumers: The homogenous plantation of crops in the fields permits very few animals to live and thrive in the agro-ecosystem. The crop plants provide shelter, site for nesting, protection from enemies and predators. Food chains in agro-ecosystems are simple with only 2 or 3 trophic levels. Activities like ploughing and tilling the soil disturb it to quite an extent, often changing the micro flora and fauna completely so that entirely new conditions are created. Also the crop communities provide scant shelter to mammals and only small mammals make temporary visits. For example, a study in Varanasi showed that in a maize crop ecosystem, insects and bugs were the main consumers. Some birds were found to come picking the insects of the farm and these were only temporary visitors so it was not possible to ascertain whether they were preyed upon by other consumers.

Decomposers: Decomposer activity is generally less in agro-ecosystems due to tillage in crop fields, application of chemical fertilizers, pesticides, herbicides and lack of organic matter in the soil. The soil is full of microorganisms such as bacteria, actinomycetes, fungi, algae, viruses and protozoa. Bacteria and actinomycetes are the most numerous of microbial groups present in the soil. Microbes impact the agro-ecosystem in a number of ways:

- Decomposition of organic matter with release of nutrients,
- Formation of beneficial soil humus by decomposing organic residue and through formation of new compounds,
- Release of plant nutrients from insoluble inorganic forms,
- By formation of mycorrhizal associations,
- Transformation of atmospheric nitrogen to plant available N,
- Improvement of soil aggregations, aeration and water infiltration, and
- Antagonistic action against insects, plant pathogens and weeds.

Abiotic Components

Abiotic components of the agro-ecosystem are soil, inorganic nutrients, climate, water, atmosphere and solar radiation.

Soil acts as a nutrient pool and forms the environment of the roots and microorganisms. Soil in agro-ecosystems is oversimplified because the upper layers are disturbed due to farming practices and extra inputs of energy and matter by the farmers in the form of manure fertilizers, fossil fuels and water. Often extra salts are leached due to water logging and irrigation patterns. The soils are generally poor in organic matter content as the crops are harvested and removed to be used as food and fodder

2.3.2 . Processes and Functions

Neither the agro-ecosystem nor its biotic components can exist without the constant supply of energy to maintain the biotic structures and their functions. The source in all cases is the sun, which drives the carbon and energy fixation in green plants. Trophic processes are the essence of ecosystem functioning for through them solar energy passes to the animals and other heterotrophs and allows them to exist. The ultimate limit on the growth of crops in the agro-ecosystem is determined by the energy flow through the system. To understand the actual and maximum possible production of organic matter in the agricultural system we must understand the basic concept of energy flow.

The total amount of organic matter in a particular ecosystem is called its biomass which includes all the living things and all the products of living things. Biomass is increased through biological production and this change over a period of time is known as net productivity.

Productivity is the quantity of product or output from the agro-ecosystem per unit of some specified input. Organic productivity that is from plants or livestock is driven by photosynthesis that uses the light energy. Crop plants during peak season can convert 6-8 % of total daily solar energy into organic matter in gross production.Net production averages about half the gross production. Therefore, only 50% of the energy retained in the plant body as net production is available to heterotrophs including humans and their cattle. The crop efficiency relationship between energy input (in terms of solar energy) and energy output (carbohydrate productivity) has been given in Table 2.2.

Table 2.2: Relationship between solar radiation and gross and net production (kcal/m^2/day)

Crop	Solar Radiation	Gross Production	Net Production
Sugar cane	4000	306	190
Maize	6000	405	190
Sugar beet	2650	202	144
Wheat	1567	55	43
Paddy	2904	–	60

In addition to the major inputs of solar energy, modern agriculture has substantial inputs in the form of fertilizers and pesticides. The energy input can be assessed in terms of energy necessary to produce them and in terms of energy necessary to apply it to the soil or crop. The energy cycles in most agro-ecosystems are inefficient in that only a small proportion of the total energy input is available to human beings through food. But the higher net production of the agro-ecosystem is attributed to the extra input of energy of fossil fuels, humans and their animals as well as materials such as fertilizers and water, genetic improvement of crop plants and pest control methods.

Energy flow is the movement of energy through the ecosystem– from the external environment through a series of organisms, back to the environment. In cropland, every effort is made to provide optimum conditions to producers to keep their efficiency at the maximum limit. In annual crops this happens for a short period of about 60-90 days, after which the producer subsystem reaches maturity and photosynthesis decreases due to aging. After harvesting of crops, 85-90% of energy accumulated by the above ground compartment of cereals enters into a simple grazing food chain consisting of humans and cattle.

Energy entering the detritus food chain of cropland agro-ecosystem amounts to about 5-15% of net production. The stubble, dead leaves, and litter fallen on the ground along with the roots inside the soil are sources of chemical energy input into the soil subsystem. This is not sufficient and therefore, a large amount of extra material is added to the soil with each crop. A flow chart showing the energy flow in an Indian agro-ecosystem is given in Fig. 2.4.

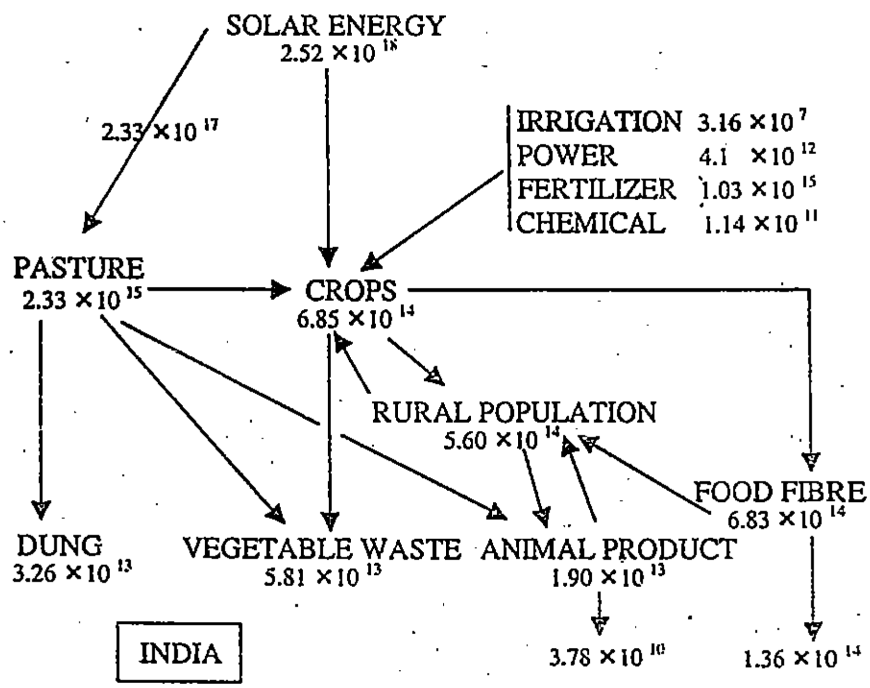
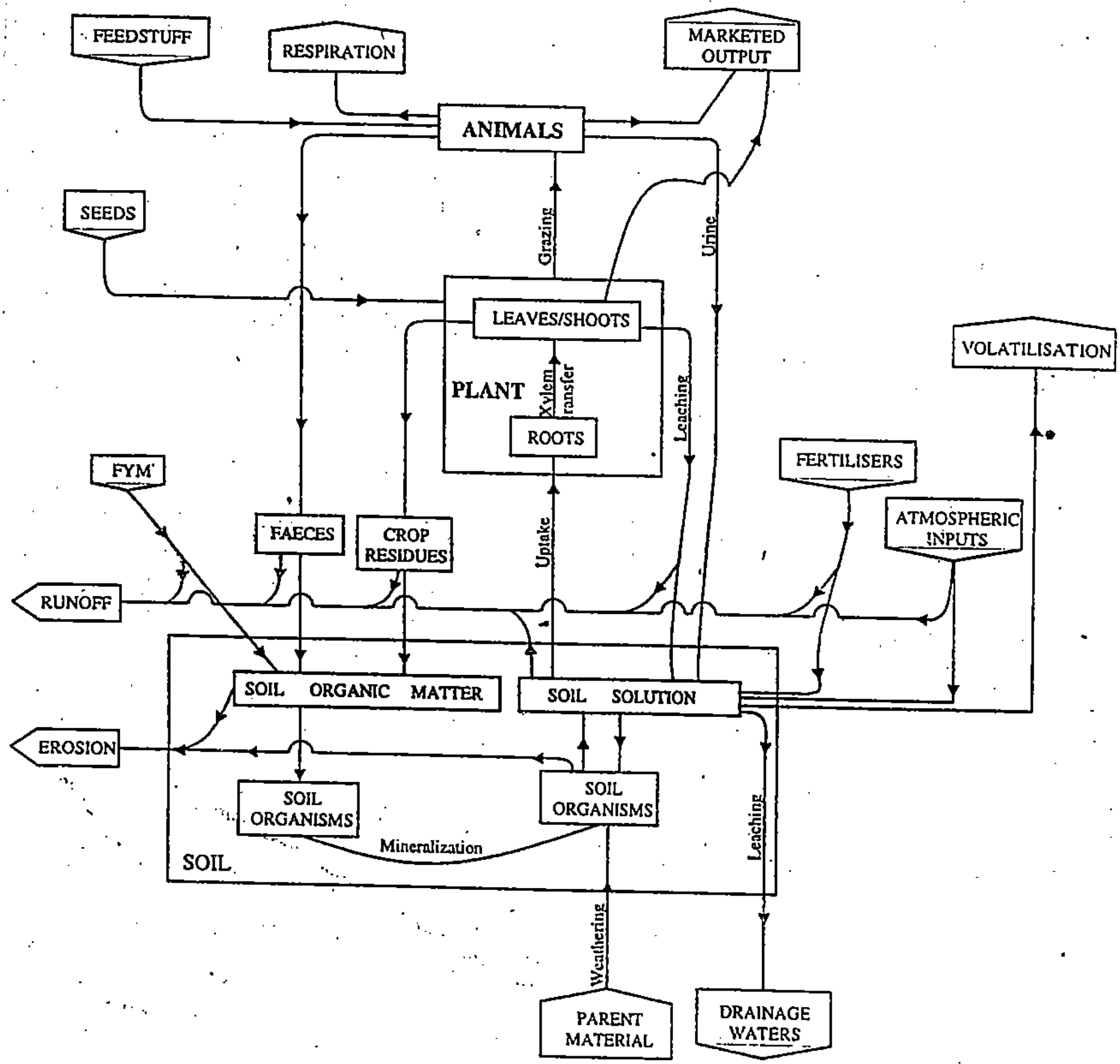


Fig.2.4: Energy flow in Indian agriculture, all values are in kcal per year.

The energy flows in Fig. 2.4 are based on a variety of sources and assumptions. Insolation was assumed to be 10^{10} kcal ha^{-1} yr^{-1}. Two other assumptions were made: (1) Pasture crop is one percent of incident energy and (2) 10 cal of food are required for one calorie of animal product. It is also assumed that half of the animal feed is from pasturage. The maximum estimate for the energy cropped from pasture would be the sum of kilocalories in dung, vegetable waste and animal products. The arrow from pasture to crop is the energy of bullocks used in cultivation.

Nutrient cycling: In terrestrial ecosystems the soil acts as a source of nutrient elements for the plant. In natural ecosystems the nutrient levels are maintained by biogeochemical cycling process. In agro-ecosystems natural processes do not replenish the nutrient loss. The huge inputs of fertilizers and other inputs into the stem make the nutrient cycles imperfect or acyclic. Fig. 2.5 shows the cycling of trients in an agro ecosystem.



.2.5: **Nutrient cycles in agro-ecosystem (FYM = Farmyard manure). The three main pools or reservoirs are crop plants, livestock and soil**

drological cycling: As we all know water plays a crucial role in all agro-systems. It is essential for maintaining turgor in plants and transporting nutrient ments to and through the plants. Water also has a vital role in leaching erosion and athering of rocks. The main input of water into the system is through rainfall and ere this input is insufficient, irrigation makes up for it. The main losses are due to po-transpiration, drainage to ground water and lateral flow to streams. Storage of ter occurs in soil, plant tissue and livestock. Fluctuations in water quantity have a siderable influence on the growth of crops.

Q 2

at are the basic components of agro-ecosystems?

2.3.3 Factors Affecting the Structure and Functions

Some of the factors affecting the structure and functioning of agro-ecosystem are inter and intra specific competition, agricultural practices such as ploughing, shifting agriculture, crop rotation, stubble burning, inorganic fertilizers, irrigation, pests and disease control, introduction of high yielding varieties. Besides these, climate and edaphic factors like drought, frost, day length, soil chemical properties affect the structure and functions of the agro-ecosystems.

Competition: Plant competition is density induced. In a crop land the primary producer is of the same life form and draws its life requirement from the same resource. Competition affects the community structure and changes the rate of transfer of nutrients by affecting the efficiency of the interacting individuals. Often plants show adaptations that enable them to use the environmental resources more efficiently. In the competition for light and carbon-dioxide, canopy structure and photosynthetic area are important. While for water and nutrient competition, root activity and uptake capacity are important. In cultivated fields, inter-specific competition occurs between plants and weeds. If the plants are not weeded in time then severe damage to the crop will be the result. Usually the competition occurs at an early vegetative stage; once the crop is established, the weed is suppressed.

Climate: The determinants of climate, solar radiation, temperature, humidity, rainfall and wind show cyclic changes during the year, thus forming a characteristic pattern of the climate. All activities of the plant from seed germination to seed formation are influenced by climatic conditions. Since crop plants have a narrow tolerance range of environmental factors they are affected by slightest changes in climate. For instance, it was seen from an experiment that when a high yielding paddy variety was sown in winter instead of the rainy season then in spite of all the external inputs like fertilizers, irrigation etc., it showed poor growth.

Ploughing: The field has to be prepared for each crop in the agro-ecosystem. Ploughing turns up the soil up to 30cm depth. This makes the top soil loose and vulnerable to erosion. The physical properties of soil are completely changed and the micro flora and fauna of the soil are affected, which has an impact on the structure and functioning of the system. Some times, the dormant weed seeds are exposed and cause severe problems.

Shifting Cultivation and Crop Rotation: Through shifting cultivation, large scale changes have been brought about in the vegetation patterns especially in the ecosystems along hills and in savannahs. Introduction of weeds and exotic species and biotic components of the abandoned agro-ecosystem results in completely changed community structure. The practice of crop rotation keeps the soil of agro-ecosystems healthy. In well drained soils, practices such as rotation of wheat, maize and legume and occasional green manuring of crop fields maintain the soil fertility and enhance its microbial population.

Fertilizers: Organic fertilizers (cow dung, compost and manure) have been used in traditional farming. These improve the physiochemical properties along with increase of microorganism population. The present day agro-ecosystems require chemical fertilizers to sustain the increased yields. Too much of these fertilizers cause salinization, the microbial density decreases and ultimately fertility gets reduced.

Irrigation: The use of chemical fertilizers and intensive cropping require increased irrigation. Only 17% of agro-ecosystems depend on irrigation. Irrigation without adequate drainage causes the raising of water table and water logging of soil; salts are lifted to the surface of soil, making the land infertile.

:roduction of high yielding varieties: New high yielding varieties of crops (HYV) .t have different environmental requirements have been introduced in the agro-)systems. They pose several ecological problems like water, nutrient and pesticides juirement and affect soil biodiversity.

sts and Weeds: Pests are small mammals, insects, fungi, bacteria, etc. that destroy : crop plants in modern agro-ecosystems. Almost 99% of the potential pests are :cked by natural enemies and not by human intervention, and by physical features :h as temperature, moisture, and availability of breeding site.

discussed earlier, weeds are competitors of crop plants for nutrient requirements. erefore, pest and weed control programmes attain top priority in managed :icultural systems. Pests and weeds are controlled manually or through application pesticides and herbicides. Large-scale use of these has been responsible for :ensive environmental damage. (You will read about this in the next unit.)

sts and weeds can also be regulated by biological control methods. When roduced under natural conditions, certain organisms affect certain harmful insects d plants without affecting the biological processes of the system. Bacteria, fungi, ;ects and other animals like fish and birds have been tried as possible agents of)logical control.

.Q 3

)w does the climate of a place affect the agro-ecosystem? Name two other factors it affect the agro-ecosystem structure the most.

4 AGRO-CLIMATIC ZONES

1ce agriculture is highly location-specific, grouping the available land area in a ;ion or country into different agro-ecological regions based on certain identifiable aracteristics becomes important. **An ecological region is an area of the earth's rface characterized by distinct ecological responses to macro-climate, as pressed by soils, vegetation, fauna, and aquatic systems (FAO, 1983).** This)uld help the region to engage in more rational planning and optimizing resource e for the present and in preserving them for the future. With the 329 million ctares of the geographical area, India presents a large number of complex agro- matic situations. Crop yield depends on many factors like weather, soil type and its trient status, management practices and other inputs. Of these, weather is a very iportant aspect, efficient crop planning, therefore, requires proper understanding of ro-climatic conditions in a region/country.

1 agro-climatic zone is a land unit in terms of major climates, suitable for a certain nge of crops and cultivars. Several attempts have been made to delineate major ro-ecological regions in respect to soils, climate, physiography (physical and ographical features) and natural vegetation. We present the some of the important ro-ecological and agro-climatic divisions of the Indian Subcontinent:

) Agro-ecological regions by the ICAR (Indian Council of Agricultural Research).

| Agro-climatic regions by the Planning Commission.

| Agro-climatic zones under NARP (National Agricultural Research Project).

) Agro-ecological regions by the NBSS & LUP (National Bureau of Soil Survey and Land Use Planning).

A) Agro-ecological regions by the ICAR

In 1973, ICAR identified eight major agro-ecological regions in India for more meaningful planning of agricultural research and development. These divisions are:

1. Humid Western Himalayan Region
2. Humid Bengal - Assam Basin
3. Humid Eastern Himalayan Region and Bay Islands
4. Sub-humid Sutlej-Ganga Alluvial Plains
5. Sub-humid to Humid Eastern and South-eastern Uplands
6. Arid Western Plains
7. Semi-arid Lava Plateau and Central Highlands
8. Humid to Semi-arid Western Ghats and Karnataka Plateau

These regions consist of large geographical area of land having major groups of geological formations, physiography, climate, soils, vegetation, land use and cropping patterns. Some of the essential features of these regions are described here.

1. **Humid Western Himalayan Region:** It consists of Jammu and Kashmir, Himachal Pradesh and hill division of Uttar Pradesh, namely, Kumaon and Uttaranchal. High mountains and narrow valleys characterize it. The climate varies from hot and sub-humid tropical in the South to temperate cold arid in the North, with the rainfall ranging from 8 cm in Ladakh to over 100 cm in Jammu area. It has sandy loam mountain meadow, loamy and acidic sub-montane and loamy brown hill soils. Nearly half of the area is under forest, and horticulture including sericulture supplements agriculture. Rich forest wealth and rangelands are the assets of this region. Degradation of forests is the major problem.

2. **Humid Bengal-Assam Basin:** It covers West Bengal and Assam representing the Ganga-Brahmaputra alluvial plain. It is characterized by semi-stabilized sand dunes on alluvial terraces, lateritic remnants in the West, and numerous creeks and swamps in the deltaic tract. It experiences hot humid monsoonal climate, and the rainfall ranges from 220 to 400 cm. The predominant soil groups are alluvial, red and brown hill. Rich forests in Assam and fertile deltas in West Bengal are the assets. Frequent floods in Assam and extensive occurrence of saline patches in the deltaic tracts are the major constraints.

3. **Humid Eastern Himalayan Region and Bay Islands:** It includes Arunachal Pradesh, Nagaland, Manipur, Mizoram, Tripura, Meghalaya, and Andaman & Nicobar Islands. It consists of the Eastern Himalayan and the Arakan Ranges with a wide range of elevation. The rainfall ranges from 200 to 400 cm. The major soil groups are brown hill, red and yellow, alluvial, and acidic laterites. It is endowed with rich evergreen forests. Animal husbandry and pisciculture have great potential. Major liability is shifting cultivation leading to deforestation and soil erosion.

4. **Sub-humid Sutlej-Ganga Alluvial Plains:** It comprises Punjab, plains of Uttar Pradesh, Delhi, and Bihar. The entire region is level, except for the Tarai-Bhabar tract. It experiences extremes of climate, with very hot summer and very cold winter. The rainfall ranges from 30 to 200 cm. The major soil groups are calcareous sierozem, reddish chestnut, alluvial, and patches of saline and alkali soils. The soils are highly disturbed in Bihar due to frequent floods. Major area is under cultivation. Generally, the region is double cropped. Flooding, salinity, alkalinity, and erosion are the major problems.

5. **Sub-humid to Humid Eastern and South-eastern Uplands:** It encompasses Orissa, Andhra Pradesh and the Raipur Division of Chhattisgarh. It is characterized by undulating topography, denuded hills, plateau, river valleys, and high lands. The climate is tropical monsoonal, and sub-humid to humid from West to East. The rainfall ranges from 100 to 180 cm. Major soil groups are mixed black, red and yellow, red sandy, laterite, black, and alluvial soils. Rich forest wealth is an asset, and shifting cultivation, soil salinity and acidity are the major constraints.

6. **Arid Western Plains:** It includes Haryana, Rajasthan, Gujarat, and Dadra & Nagar Haveli. It is characterized by extensive alluvial plain dotted with sand dunes, saline depressions and granite hills. The rainfall is scanty, ranging from 10 to 65 cm and erratic. Major soil groups are alluvial, black, desert, saline and alkaline. Nearly one-third of the area is under cultivation. Frequent dry spells, salinity and alkalinity are the major problems.

7. **Semi-arid Lava Plateau and Central Highlands:** It covers Maharashtra, Goa, Daman & Diu, and Western and Central Madhya Pradesh. It is predominantly a plateau region. The climate is semi-arid with extremes of temperature, and the rainfall ranges from 70 to 125 cm except in the Western Ghats where it varies from 330 to 750 cm. Major soil groups are alluvial, black, laterite, mixed red and black, and yellowish brown. More than half of the area is cultivated. Frequent drought is the major problem in the region.

8. **Humid to Semi-arid Western Ghats and Karnataka Plateau:** It consists of Karnataka, Tamil Nadu, Kerala, Pondicherry, and Lakshadweep Islands. The physiographic features are Western Ghats, plateau, river valleys, undulating rocky plains, and coastal plains. The western ghats is humid and the rest of the area is semi-arid. The rainfall ranges from 60 to 300 cm. Major soil groups are black, red, lateritic, and alluvial. Rich forest wealth and Western Ghats suitable for plantation crops are the main assets. Dry farming is prevalent and a considerable area is irrigated through wells, tanks and rivers. Salinity, alkalinity, erosion, and acidity are the major problems.

B) Agro-climatic regions by the Planning Commission

The Planning Commission, as a result of the mid-term appraisal of the planning targets of the Seventh Plan, has divided the country into fifteen broad agro-climatic zones based on physiography, soils, geological formation, climate, cropping patterns, and development of irrigation and mineral resources for broad agricultural planning and developing future strategies. These include:

1. Western Himalayan Region
2. Eastern Himalayan Region
3. Lower Gangetic Plains Region
4. Middle Gangetic Plains Region
5. Upper Gangetic Plains Region
6. Trans-Gangetic Plains Region
7. Eastern Plateau & Hills Region
8. Central Plateau & Hills Region
9. Western Plateau & Hills Region
10. Southern Plateau & Hills Region
11. East Coast Plains & Hills Region
12. West Coast Plains & Ghats Region
13. Gujarat Plains & Hills Region
14. Western Dry Region
15. The Islands Region

C) Agro-climatic zones under NARP

The country has been divided into 131 agro-climatic zones, under the World Bank supported National Agricultural Research Project (NARP) of the ICAR, essentially based on climate, soils, and existing cropping patterns of each State as a unit. The zones identified are:

Code No.	State & Agro-climatic Zone	Zonal Centre
	Andhra Pradesh	
001	Krishna Godavari Zone	-Lam (Guntur)
002	North Coastal Zone	-Anakapalle
003	Southern Zone	-Tirupati
004	Northern Telengana Zone	-Jagityal
005	Scarce Rainfall Zone of Rayalaseema	-Nadyal
006	Southern Telegana Zone	-Palem
007	High Altitude and Tribal Zone	-Rastakuntabai/ Chintapalli
	Assam	
008	North Bank Plain Zone	-North Lakhimpur
009	Upper Brahmaputra Valley Zone	-Tatabar
010	Central Brahmaputra Valley Zone	-Shillongani
011	Lower Brahmaputra Valley Zone	-Gossaingaon
012	Barak Valley Zone	-Karmganj
013	Hill Zone	-Diphu
	Bihar	
014	North West Alluvial	-Pusa/ Madhopur
015	North East Alluvial Plain Zone	-Purnea/Katihar/Agwanpur
016	South Alluvial Plain Zone	-Sabour
	Jharkhand	
017	Central and North Eastern Plateau Zone	-Dumka
018	Western Plateau Zone	-Chianki
019	South Eastern Plateau Zone	-Chatshila/Darisai
	Gujarat	
020	South Gujarat Heavy Rainfall Zone	-Navsari
021	South Gujarat Zone	-Baruch/ Surat
022	Middle Gujarat Zone	-Anand
023	North Gujarat Zone	-Dantiwada
024	North West Zone	-Bhachau
025	North Saurashtra Zone	-Targhadia
026	South Saurashtra Zone	-Junagadh
027	Bhal and Coastal Zone	-Arnej
	Haryana	
028	Eastern Zone	-Karnal
029	Western Zone	-Bawal/ Hissar
	Himachal Pradesh	
030	Sub-mountane and Low hills sub tropical Zone	-Dhaulakuan
031	Mild-Hills sub-humid zone	-Bajaura

032	High Hills Temperate Wet Zone	-Mashobra
033	High Hills Temperate Dry Zone	-Kukumseri
	Jammu & Kashmir	
034	Low attitude Sub-tropical Zone	-R.S. Pora
035	Mid to high altitude Intermediate Zone	-Rajori
036	Valley Temperate Zone	
037	Mid to high altitude Temperate Zone	-Kludwani
038	Cold-arid Zone	-Leh
	Karnataka	
039	North East Transition Zone	-Bidar
040	North East Dry Zone	-Raichur
041	Northern Dry Zone	-Bijapur
042	Central Dry Zone	-Sirsa/ Bidaramana gudi
043	Eastern Dry Zone	-Hebbal/ Chintamani
044	Southern Dry Zone	-Nagamangala
045	Southern Transition Zone	-Navile/ Shimoga
046	Northern Transition Zone	-Dharwar/ Hanumanmatti
047	Hill Zone	-Mudigere
048	Coastal Zone	-Brahmavar
	Kerala	
049	Northern Zone	-Pilicode
050	Southern Zone	-Vellayani
051	Central Zone	-Pattambi
052	High Altitude Zone	-Ambalavayal
053	Problem Areas Zone	-Kumerakom
	a) Onattukara zone	-Onattukara
	b) Kuttanadu Kole zone	-Kuttanadu
	c) Pokkali zone	-Kuttanadu
	d) Low rainfall zone	-Kumarakam
	Madhya Pradesh / Chhatisgarh	
054	Chhatisgarh Plane Zone including Balagharh Distt.	-Raipur
055	Bastar Plateau Zone	-Jagadalpur
056	North Hill Zone Chhatisgarh	-Ambikapur
057	Kymore Plateau and Satpura Hill Zone	-Jabalpur
058	Vindhya Plateau Zone	-Sehor
059	Central Narmada Valley Zone	-Powarkhera
060	Gird Zone	-Morena
061	Bundelkhand Zone	-Tikamgarh
062	Satpura Plateau Zone	-Chindwara
063	Malwa Plateau Zone	-Indore
064	Nimar Valley Zone	-Khargone
065	Jhabua Hills Zone	-Jhabua
	Maharashtra	
066	South Konkan Coastal Zone	-Vengurla
067	North Konkan Coastal Zone	-Karjat
068	Western Ghat Zone	-Igatpuri
069	Sub-mountane Zone	-Kolhapur
070	Western Maharashtra Plain Zone	-Pune

071	Scarcity Zone	-Sholpur
072	Central Maharashtra Plateau Zone	-Aurangabad
073	Central Vidharbha Zone	-Yavatmal
074	Eastern VIdharba Zone	-Sindhewahi
	Orissa	
075	North Western Plateau Zone	-Kerai
076	North Central Plateau Zone	-Keonjhar
077	North Eastern Coastal Plain Zone	-Ranital
078	East and South Eastern Coastal Zone	-Bhubaneshwar
079	North Eastern Ghat Zone	-G. Udayagiri
080	Eastern Ghat Highland Zone	-Semiligulda
081	South Eastern Ghat Zone	-Jeypore
082	South Western Undulating Zone	-Bhawanipatna
083	West Central Table Land Zone	-Chiplima
084	Mid-Central Table Land Zone	-Mahispat
	Punjab	
085	Sub-mountane Undulating Zone	-Kandi
086	Undulating Plain Zone	-Gurdaspur
087	Central Plain Zone	-Ludhiana
088	Western Plain Zone	-Faridkot
089	Western Zone	-Bhatinda
	Rajasthan	
090	Arid Western Plain Zone	-Jodhpur/ Mandore
091	Irrigated North Western Plain Zone	-Sriganganagar
092	Transitional Plain Zone of Inland Drainage Fatehpur	-Sikar
093	Transitional Plain Zone of Luni Basin	-Sumerpur/ Jalore
094	Semi Arid Eastern Main Zone	- Durgapura (Japur)
095	Flood Prone Eastern Plane Zone	-Navgaon (Alwar)
096	Sub-humid Southern Plain and Aravalli Hill Zone	-Udaipur
097	Southern Humid Plain Zone	-Banswara
098	South Eastern Humid Plain Zone	-Kota
	Tamil Nadu	
099	North Eastern Zone	-Vridhachalam
100	North Western Zone	-Paiyuar
101	Western Zone	-Coimbatore/ Bhawani Sagar
102	Cauvery Delta Zone	-Aduthurai
103	Southern Zone	-Aruppukottai
104	High Rainfall Zone	-Kanyakumari/ Peechaparaii
105	High Altitude and Hilly Zone	-Thadiankudisal
	Uttaranchal	
106	Hill Zone	-Ranichauri
107	Bhabar and Tarai Zone	-Pantanagar
	Uttar Pradesh	
108	Western Plain Zone	-Daurala
109	Mid-Western Plain Zone	-Nagina/ Sahajahanpur

110	South Western Semi-Arid Zone	-Madhuri Khund
111	Central Plain Zone	-Kanpur
112	Bundelkhand Zone	-Bharari
113	North Eastern Plain Zone	-Sardarnagar
114	Eastern Plain Zone	-Kumarganj
115	Vidhyan Zone	-Mirzapur
	West Bengal	
116	Hilly Zone	-Pedong/ Kalimpong
117	Tarai Zone	-Pundibari
118	Old Alluvial Zone	-Ranudia - Majhian
119	New Alluvial Zone	-Mohanpur
120	Laterite and Red Soil Zone	-Jhargram
121	Coastal Saline Zone	-Mathurapur/ Kakdweep
	North East Hilly Region	
122	Alpine Zone	-Hill of Arunachal Pradesh
123	Temperate Sub Alpine Zone	- Shergaon - Sangti (Arunachal Pradesh)
124	Sub Tropical Hill Zone	-Barapani-Shillong (Meghalaya)
125	Sub-Tropical Plain Zone	-Sanghaipet-Imphal
126	Mild Tropical Hill Zone	-Medziphema (Nagaland)
127	Mild Tropical Plain Zone	-Lembucherra – Agartala (Tripura)

D) Agro-ecological Regions by the NBSS & LUP

Since all the above mentioned approaches use State as a unit for subdivision, many zones having similar agro-climatic characteristics but occurring in different States have been created. Moreover, adequate attention was not paid in these approaches to soils which is the country's most important agricultural resource. In order to overcome these lacunae, the National Bureau of Soil Survey & Land Use Planning (NBSS & LUP) has recently brought out a 21-zone agro-ecological regional map of the country, essentially based on physiography, soils, bio-climatic types, and growing period which influences the supply of water for plant growth. This map is essentially based on 50 years data of over 350 meteorological stations and up-to-date soils database available in the country. The agro-ecological regions identified are:

I. Arid Ecosystem:

1. *Western Himalayas, Cold Arid Eco-region with Shallow Skeletal Soils:* The region covers 4.7% of the land area mainly in the Districts of Ladakh and Gilgit. It has mild summers and severe winters, with mean annual temperature and rainfall of less than 80 C and 150 mm, respectively. The annual growing period is less than 90 days. While the Northern part is covered under permanent snow, the valley areas show skeletal and calcareous soils. It has great potential for growing dry fruits like apricot and flowers like roses in valleys.

2. *Western Plain, Hot Arid Eco-region with Desert and Saline Soils:* It covers 9% of the land area in the Western Rajasthan, South-western Haryana and Punjab, Kutch Peninsula and Northern Kathiawar Peninsula. It has hot summers and cool winters, with an annual rainfall of less than 300 mm and growing period of less than 90 days. The soils are

sandy and saline. Rainfed agriculture is the traditional practice. Drought and salinity are the major constraints.

3. *Deccan Plateau, Hot Arid Eco-region with Mixed Red and Black Soils:* It includes the Districts of Raichur and Bellary of Karnataka, and Anantapur of Andhra Pradesh covering 1.4% of the land area. It is characterized by hot and dry summers and mild winters, with an annual rainfall ranging from 400 to 500 mm. The growing period is less than 90 days. The soils are shallow to medium red loamy and deep clayey black. Rainfed farming is most common. Prolonged dry spells and soil erosion are the major problems.

II. Semi-arid Ecosystem:

4. *Northern Plain and Central Highlands, Hot Semi-arid Eco-region with Alluvium - derived Soils:* It occupies 10% of the land area covering part of northern plain, central highlands and Gujarat plain. It has hot and dry summers and cool winters, with rainfall varying between 400 and 800 mm. The growing period ranges from 90 to 150 days. Soils are loamy and the terrain is interspersed by sand dunes. Rainfed farming is common, with intensive cultivation in areas irrigated through tube wells. Imperfect drainage leading to salinity and lowering of ground water due to over-exploitation are the major constraints.

5. *Central (Malwa) Highlands and Kathiawar Peninsula, Hot Semi-arid Eco-region with Medium and Deep Black Soils:* It covers 5.6% of the land area in the Western Madhya Pradesh, Eastern Rajasthan and Gujarat States. It has hot and dry summers and mild winters, with rainfall ranging from 600 to 900 mm. The growing period ranges from 90 to 150 days. Soils are loamy to clayey deep black. Dry farming is the common practice. Frequent dry spells, imperfect drainage, salinity and alkalinity are the major constraints.

6. *Deccan Plateau, Hot Semi-arid Eco-region with Shallow and Medium (Inclusion of Deep) Black Soils:* It includes most of Maharashtra and Northern part of Karnataka and Andhra Pradesh covering 10% of the land area. It has hot summers and mild winters, with rainfall ranging from 600 to 1000 mm. The growing period ranges from 90 to 150 days. It is characterized by medium to deep black soils. Rainfed agriculture is the traditional practice and prolonged dry spells adversely affect crop growth. The area has high productivity potential under judicious irrigation with watershed-based management.

7. *Deccan Plateau and Eastern Ghats, Hot Semi-arid Ecoregion with Red and Black Soils:* It covers part of the Deccan Plateau and Eastern Ghats in the State of Andhra Pradesh accounting for 6.3% of the land area. It has hot summers and mild winters, with 600 to 1000 mm rainfall and 90 to 150 days growing period. It has medium to heavy red and loamy black cotton soils. Rainfed agriculture is common and rice is cultivated under irrigation. Imperfect drainage, salinity and erosion are the major problems.

8. *Eastern Ghats (TN Uplands) and Deccan Plateau, Hot Semi-arid Eco-region with Red Loamy Soils:* It includes Tamil Nadu uplands and Western Karnataka covering 6.9% of land area. It has hot and dry summers and mild winters, with a rainfall of 600 to 1000 mm. The growing period varies from 120 to 150 days. Rainfed agriculture is

common and rice is grown under irrigation. Erosion and drought due to coarse soils are the major problems.

II. Sub-humid Ecosystem:

9. *Northern Plain, Hot Sub-humid Eco-region with Alluvium - derived Soils:* It covers part of Northern Indo-Gangetic plain occupying 3.7% of the land area. It is characterized by hot to warm summers and cool winters receiving 1000 to 1200 mm rainfall. The growing period ranges from 150 to 180 days. It has deep loamy alluvial soils. Both rainfed and irrigated agriculture are followed. Poor water management, water logging and salinity are the major problems.

10. *Central Highlands (Malwa & Bundelkhand), Hot Sub-humid Eco-region with Medium and Deep Black Soils:* It covers part of the central highlands mainly in the Districts of Arisen, Sager, Bhopal, Sehore, Shajapur and Hoshangabad in Madhya Pradesh. It occupies 2.5% of the land area. Hot summers and mild winters with 1000 to 1500 mm rainfall and 150 to 180 days growing period are the main features. It has moderately deep black soils. Rainfed and irrigated farming are practiced. Inundations along major streams and drought during Kharif season are the major problems.

11. *Deccan Plateau and Central-Highlands (Bundelkhand), Hot Sub-humid Eco-region with Red and Black Soils:* It comprises the Bundelkhand part of Madhya Pradesh and North-eastern part of Vidarbha region covering 4.2% of the land area. It is characterized by hot summers and mild winters, with 1000 to 1500 mm rainfall. The growing period varies from 150 to 180 days. It has medium red and heavy black soils. Both rain fed and irrigated farming are practiced. Cracking clay soils and soil erosion are the major problems.

12. *Eastern Plateau (Chhattisgarh Region), Hot Sub-humid Eco-region with Red and Yellow Soils:* It constitutes Chhattisgarh region of Madhya Pradesh and South-west highlands of Bihar covering 4% of the land area. It is characterized by hot summers and cool winters, with 1200 to 1600 mm rainfall. The growing period ranges between 150 and 180 days. The soils are medium to heavy and non-calcareous. Rainfed farming is common and rice and wheat are grown under irrigation. Severe erosion, partial water logging and seasonal drought are the common problems.

13. *Eastern (Chhota Nagpur) Plateau and Eastern Ghats, Hot Sub-humid Eco-region with Red Loamy Soils:* It includes Chhota Nagpur Plateau of Bihar, Western part of West Bengal, Orissa, and Bastar region of Madhya Pradesh covering 8.5% of the land area. It has hot summers and cool winters, with a rainfall of 1000 to 1600 mm and 150 to 180 days growing period. The soils are red loamy and non-calcareous. Rainfed farming is more common, seasonal drought and severe soil erosion are the major problems.

14. *Eastern Plain, Hot Sub-humid with Alluvium - derived Soils:* It covers North-eastern Uttar Pradesh and Northern Bihar occupying 2.8% of the land area. It has hot summers and cool winters, with 1400 to 1600 mm rainfall. The growing period varies from 180 to 210 days. The soils are mainly alluvium. Rainfed and irrigated farming are practised. Flooding, imperfect drainage and salinity are the major constraints.

15. *Western Himalayas, Warm Sub-humid (Inclusion Humid) Eco-region with Brown Forest and Podzolic Soils:* It includes Jammu and Kashmir,

Himachal Pradesh and North-western half of Uttar Pradesh covering 5.4% land area. It has warm sub-humid to cool humid climate, with mild summers and cold winters. The rainfall ranges from 1600 to 2200 mm and it has 150 to 210 days growing period. The soils are brown forest and podzolic. Agriculture is practised in valleys and terraces. Severe cold, deforestation, land slides, acidity, and imperfect drainage in valleys are the common problems.

IV. Humid-Per humid Ecosystem:

16. *Assam and Bengal Plains, Hot Humid (Inclusion Sub-humid) Eco-region with Alluvium - derived Soils:* It comprises the plains of the Brahmaputra and the Ganga rivers, covering parts of Assam and West Bengal and representing 3.6% of the land area. It has hot summers and mild to moderately cool winters, with the rainfall ranging from 1400 to 2000 mm. The growing period is more than 270 days. The soils are slightly acidic. Flooding, waterlogging and acidity are the major problems.

17. *Eastern Himalayas, Warm Perhumid Eco-region with Brown Hill Soils:* It encompasses Northern Bengal and Assam, and most parts of Arunachal Pradesh and Sikkim covering 2.4% of the land area. It has mild summers and moderate to severe winters, with a rainfall exceeding 2000 mm. The growing period is more than 270 days. The soils are loamy brown forest with high organic matter. Shifting cultivation is the traditional farming system followed. It has evergreen forests and faces the problems of deforestation and soil erosion.

18. *North-eastern Hills (Purvachal) Warm Perhumid Eco-region with Red and Lateritic Soils:* It constitutes North-eastern hilly States of Nagaland, Meghalaya, Manipur, Mizoram, and South Tripura covering 3.3% of the land area. It has warm summers and cold winters, with the rainfall ranging from 1600 to 2600 mm. The growing period exceeds 270 days. The soils are loamy red, yellow, and lateritic with slight acidity. Shifting cultivation is common leading to deforestation and severe erosion. It has tropical moist deciduous forests.

V. Coastal Ecosystem:

19. *Eastern Coastal Plain, Hot Sub-humid Eco-region with Alluvium - derived Soils:* It covers the Eastern coastal plain extending from Cauvery Delta to Gangetic Delta and occupies 2.5% of the land area. It has hot summers and mild winters, with an annual rainfall of 1200 to 1600 mm. The growing period ranges from 150 to 210 days. The soils are mainly clayey with slight acidity. Rainfed and irrigated rice farming are practised. Imperfect drainage and salinity are the major constraints.

20. *Western Ghats and Coastal Plains, Hot Humid - Perhumid Eco-region with Red, Lateritic and Alluvium - derived Soils:* It constitutes Western coastal plains of Maharashtra, Karnataka, and Kerala States covering 3% of the land area. It has hot summers, with rainfall exceeding 2000 mm. The growing period is more than 270 days. It has red, lateritic and alluvial soils. Water logging and severe erosion are the major problems. It has high potential for export-oriented plantation crops.

VI. Islands Ecosystem:

21. *Islands of Andaman-Nicobar and Lakshadweep, Hot Perhumid Eco-region with Red Loamy and Sandy Soils:* It comprises the Andaman and Nicobar Islands in the East and Lakshadweep in the West covering a meager 0.3% of the land area. The climate is typified by tropical conditions and the rainfall ranges from 1600 to 3000 mm. The growing period exceeds 270 days. The soils of the Andaman and Nicobar Islands are medium to very deep, red loamy and acidic, and that of the Lakshadweep Islands are highly calcareous and sandy. Most of the area is under forest and the land use is dominated by plantation crops. Forest degradation leading to severe erosion and inundation of coastal areas leading to saline marshes are the major constraints. It has greater potential for growing sustainable oil palm plantations.

2.5 SUMMARY

- Agro-ecosystems are those ecosystems that are modified for the purpose of agricultural production. They are found all over the world from wetland to lowlands, mountains and dry lands and comprise monocultures, polycultures, mixed systems, including crop-livestock, agro-forestry as well as aquaculture.
- An agro-ecosystem consists of both **biotic** (crops, trees, forage livestock, wildlife, insects, soil bacteria, non-crop vegetation) and **abiotic** components (air, climate, soil).
- Agro-ecosystems differ from natural ecosystems in a number of ways. Natural ecosystems have a continuous reinvestment of nutrients and energy; they are self-regulating while **agro-ecosystems don't have the capacity for self-regulation** (mediating nutrient cycling, mediating control of organisms).
- The **key processes** in an agro-ecosystem are **water balance, energy flow and nutrient cycling.**
- The factors affecting the **structure and function** of agro-ecosystem such as climate, competition between species of crops and weeds and agricultural practices such as ploughing, crop rotation, irrigation, pest and weed control, introduction of fertilizers and high yielding varieties have been discussed.
- The various agro-ecological and agro-climatic zones of the Indian subcontinent have been discussed.

2.6 TERMINAL QUESTIONS

1. How are agro-ecosystems similar to natural ecosystems? How are they different? Describe the differences that result from human management of agro-ecosystems for agricultural production.

2. a) What do the terms open and closed mean in relationship to nutrient cycles?
   b) Why are agro-ecosystems relatively open with respect to nutrient cycles?
   c) Describe the processes that lead to agro-ecosystems having open nutrient cycles.

3. Enlist the major ecological regions of India identified by National Bureau of Soil Survey and Land Use Planning.

REFERENCES

1. Conway, G.R. (1987) The properties of agro-ecosystems. Agricultural systems, 24: 95-117.

2. FAO Guidelines: Land Evaluation for Rain fed Agriculture. Soils Bull. No. 52, FAO, Rome, 237 p, 1983.

3. Indian Council of Agricultural Research and Education - Recent Progress, ICAR, New Delhi, 1977.

4. Planning Commission. Working Group Report on Agricultural Research and Education for the formulation of Eighth Five Year Plan, Government of India, 1989.

5. Sehgal, J.L. *et al* (1990) Agro Ecological Regions of India, Technical Bulletin, NBSS Publ. 24, 73 p.

6. Wood, S., Sebastian, K and Scherr, S. The Pilot Analysis of Global Ecosystem Agro-ecosystem – A joint study by International Food Policy Research Institute and World Resources Institute.

7. http://www.org/wr2000/page.html.

UNIT 3 IMPACT OF AGRICULTURE ON ENVIRONMENT

Structure

3.1 INTRODUCTION

No industry is more vital to our present and future well being than agriculture and few have shown the unsustainability of its existing practices. In Unit 1 of this course you have read about the evolution of agriculture, which humankind has been engaged in for thousands of years. However, earlier agriculture was closely knit at local level. All farm inputs were locally available. Livestock provided milk and farm power. The dung from livestock and agricultural residues were used as farmyard manure, which replenished soil nutrients depleted by the crops.

The high yielding modern intensive farming systems have shown the amazing ability of human beings to adapt and control the agro-ecosystems. They have been able to remove or diminish the limitations nature has put on productivity, and to provide a more favourable environment for crop growth, increasing dramatically their productive potential.

However, the problem started with the rise in population, and the consequent need for more food. For producing more food in the same land area, synthetic fertilizers came in. For protection against the damage caused by insects and pests, pesticides appeared on the scene. More food production also led to more withdrawal of water from the limited available sources leading to high water table in ground water, salinization etc.

The high input intensive agriculture has solved the food and nutrient problem for the growing population but agricultural land has continued to shrink and environmental threat to the region has become a reality. Thus agriculture has a major influence on the environment as it accounts for a large portion of the land use and water use patterns.

In 2010, the population of the developing countries of Asia is expected to become 3729 million. The demand for food is expected to be around 959 million tons and the production is estimated to be around 927 million tons leaving a gap of 32 million tons. It is estimated that though the region may be able to meet the demand without excessive imports by 2010, over 200 million people would still suffer from chronic under-nutrition, for crop yields per ha of land are declining every year alarmingly.

The slow down in agricultural output is due to several factors and one of the significant ones is that the land is becoming unable to support the burden of intensive agriculture as the environmental foundations of sustainable agriculture that is, land, water, biodiversity and forests are being damaged increasingly.

Agriculture has both primary and secondary environmental effects. A primary effect is also called **on-site** effect, i.e., an effect on the area where agriculture takes place. A secondary effect or **off-site** effect is an effect on an environment away from the agricultural site. The impact of agriculture on the environment can be **local**, which includes erosion, loss of soil, and increase in sedimentation in the local rivers; **regional** that results from the combined effects of agricultural practices in the same large area; or **global** which includes climatic changes as well as potentially extensive changes in the chemical cycles. In this unit we will discuss the impact of modern agricultural practices on natural resources and climate changes.

Objectives

After studying this unit, you should be able to:

- explain how agriculture is affecting the environment;
- identify the practices which are depleting the water resources and causing salinization and ground water pollution;
- explain the effects of pesticides and pesticide residues in fruits, vegetables, milk, fish, eggs etc., on the environment;
- explain how agriculture is affecting bio-diversity;
- identify practices which lead to soil degradation;
- explain whether agriculture is responsible for global warming–if so, to what extent;
- list the greenhouse gases emitted by agricultural practices and discuss how they are influencing the climate;
- suggest practices/ measures which can mitigate these greenhouse gases;
- suggest some measures on policy level to reduce the negative impact of agriculture on environment; and
- describe the positive and negative impact of agriculture on environment.

3.2 IMPACT ON NATURAL RESOURCES

Nations in all regions of the world, if they are to provide for long-term well-being of their citizens, must find the right means to protect the environment to ensure continued access to natural resources, generation to generation.

Deterioration of natural resources is being caused by various factors. Inappropriate agricultural development is one such factor. Conventional agricultural practices result in land degradation, deforestation, pollution of water bodies and loss of biodiversity. Some hot spots of severe environmental deterioration may be cited:

- the river basins of the Indus, Tigris and Euphrates in the middle east Asia (salinization),
- the foothills of Himalayas (water erosion),
- the forest margins of the lower Amazon (overgrazing and nutrient loss),
- the peri-urban areas of Mexico City (pollution from agricultural chemicals),
- the humid low land areas of Africa (nutrient depletion, acidification and erosion),
- the sub-humid, semi-arid border zone of West Africa (migration from dry land degradation), and
- the North-western plains of India (crisis due to ground water depletion).

In this section we will examine the negative impact of agriculture on environment.

3.2.1 Pollution

High production levels in modern agriculture are achieved by using nutrients such as nitrogen (N), phosphorus (P) and potassium (K) in the form of chemical fertilizers, manures, sludge, legumes and crop residues. When nutrients are applied in excess of plant needs they have the potential to pollute soils, and surface and ground water. A significant portion of nitrogenous fertilizers leaches through the ground and increases the nitrate concentration of ground water. When this high nitrate concentration water is used for drinking, it may cause diseases like methaemoglobinaemia (blue baby) in bottle fed babies and also cancer. WHO has prescribed the safe drinking water limit for nitrogen (N) as 45 ppm (part per million). But the study of nitrate content of ground water in several parts of India has revealed that in water table aquifers (dug wells), the nitrate concentration at many places is quite high, more than 100 ppm. (mg/l). Table3.1 shows the worst affected areas in India having nitrate concentration more than 300 ppm.

Table 3.1: Nitrate concentration in various Indian states exceeding 300 ppm

State	Site	District	Nitrate Concentration (ppm)
West Bengal	Jangipur	Murshidabad	480
Uttar Pradesh	Birdha	Hamirpur	434
Uttar Pradesh	Bansi	Jhansi	558
	Badshapur	Jaunpur	300
	Hastinapur	Meerut	694
	Mirapur	Saharanpur	300
	Bangarmaou	Unnao	390
Punjab		Sangrur	362
		Bhatinda	567
		Hoshiarpur	435
Haryana		Ambala	990
		Faridabad-1	560
		Faridabad-2	430
		Sirsa	325
		Hissar	419
		Hisar-2	363
		Hisar-3	610
		Gurgaon-1	310
		Gurgaon-2	450
		Gurgaon-3	722
		Mahendragarh-1	1310
		Mahendragarh-2	300
		Mahendragarh-3	393
		Mahendragarh-4	385
		Mahendragarh-5	830
Jammu & Kashmir		NIL	
Himachal		NIL	
Orissa	Bisam	Koraput	310
Bihar		NIL	

Though the nitrate in water is harmful for drinking purposes, it is beneficial for crops. Most of the plants/crops take nitrogen in the form of nitrate or ammonium. When this water having high nitrate concentration is used for agriculture, the requirement of nitrogen fertilizer is reduced accordingly. For example, 10 cm irrigation with ground water containing 100 ppm nitrate (mg/l) will contribute 44.5 kg of NO_3-N. If a farmer is using the recommended dose of 120 kg N, then three irrigation of such water will meet the entire nitrogen requirement of the crop thus making any additional nitrogen unnecessary.

In crop production the main emphasis is on the use of synthetic N fertilizers. As an example, in Haryana N, P (P_2O_5), K (K_2O) is used in the ratio of 48:11:1 showing the heavy dose of nitrogen application as compared to P and K. If the NO_3 concentration in ground water is not taken into consideration and additional nitrogen is applied, it will further accentuate the nutrient imbalance and ground water pollution may go on accumulating further. Excessive nitrogen is also not good for plants because it affects the maturity of crop adversely. It may cause lodging and even reduce the sugar content in beetroot and sugarcane crops.

Besides giving the required elements to the crop, the chemical fertilizers used in agriculture also supply heavy metals to the soils. Though some of them like copper (Cu), zinc (Zn), manganese (Mn), and iron (Fe) in low concentrations are beneficial to the crops as micronutrients, some of the other heavy metals like cadmium, lead, arsenic are toxic and may pollute the soils resulting in uptake of these toxic heavy metal by plants and enter the food chain for humans and animals. It is therefore, necessary to know about such fertilizers, which contribute more heavy metals thereby, exceeding the safe limits.

Table 3.2: Heavy metal contents (ppm) of some of the fertilizers

Fertilizer	Cu	Zn	Mn	Mo	Pb	Cd
Single super phosphate	26	60-165	65-270	3.5	609	187
Urea	0.36	0.5	0.5	0.2	4	1
Calcium Am. Nitrate	0.2	6	11	-	200	6
Muriate of Potash	3	3	8	0.2	88	14

Rock Phosphate is also responsible for heavy metal pollution.

Impact on air pollution

Though agriculture is not polluting the atmosphere directly, there are incidences when air pollution occurs and becomes responsible for human health hazards. It is mainly during the accidents and gas leaks in factories where pesticides are manufactured. You would recall that a major accident that occurred in December 1984 when a poisonous gas called Methyl Isocyanide leaked from the Union Carbide factory in Bhopal, India, causing hundreds of deaths and injuring and disabling many others. Many cases of illness have been reported from Karnataka and Kerala during pesticide spraying in the cashew nut plantations (Down to Earth, 2001).

Gaseous emissions from fertilizer manufacturing units are also responsible for air pollution. (Emission of greenhouse gases from agriculture is discussed later in this unit).

SAQ 1

a) How does agriculture lead to nitrate pollution of ground water?

b) What should be done to prevent further nitrate pollution?

3.2.2 Land Degradation

In terms of direct impact on the environment, farming activities are major contributors to soil erosion, land salinization and loss of nutrients. For example, it has been estimated that about 25 percent of soil degradation in Asia and Pacific region has occurred directly from agricultural activities.

One of the most serious impact of intensive agriculture is the clearing of forest land and burning of vegetation. In fact agriculture is the most important cause of forest loss in Southeast Asia. Subsequent burning of the remaining vegetation after land clearing had been responsible for the haze that covered much of South-east Asia in 1997 and 1998. The burning of vegetation in Kalimantan and Sumatra, after land clearing for oil palm plantations, got out of hand and spread to forest areas that were not supposed to be burnt. The problem became more serious when the peat just below the soil surface also started burning. Once the peat land catches fire it is very difficult to extinguish it. The smoke produced mainly contributed to the haze experienced in South-east Asia during last two years.

Decline in Soil Nutrients and Soil Biological Activity

Soil fertility and soil health are two major attributes of soil. Intensive agriculture without proper care is responsible for depletion of soil nutrients. A fertile soil has all major and micro and secondary nutrients, which are needed by crops. Once you grow a crop with excessive fertilizers (say nitrogenous) the crop also draws many other nutrients, which are not supplied, by these fertilizers. A crop may draw zinc, sulphur or any other element and the soil may become depleted in that.

Soil biological activity is another important attribute of the soil. By indiscriminate use of fertilizers and pesticides, soil microbial activity is affected. Even earthworms and other soil organisms are affected by intensive agricultural practices.

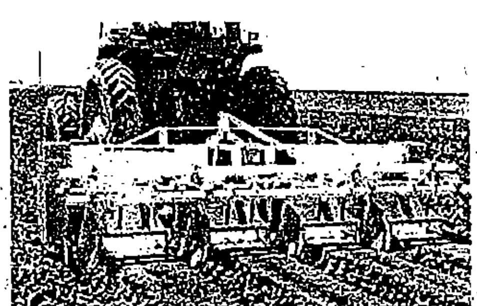
Decline in Soil Structure

Take the example of bricks. If the bricks are just kept haphazardly one over the other, it will form an unstable heap. But if the same bricks are arranged properly and mutually bounded, they can form a house or factory. In the same manner soil can be a loose and unstable assemblage of random particles or it can be a properly structured pattern of inter-bonded particles associated into bigger aggregates having regular sizes and shapes. The manner in which the soil particles are packed and held together in a continuous spatial network is commonly called soil matrix or fabric. The arrangement and organization of the particles in the soil is called soil structure.

Soil structure is strongly affected by changes in climate, biological activity and soil management practices. It is vulnerable to destructive forces of mechanical and physico-chemical nature. Soil structure also affects the retention and transmission of fluids in soil, including infiltration and aeration.

Agricultural practices responsible for decline in soil structure are

- Excessive cultivation/ tillage;
- Overgrazing and loss of soil cover;
- Excessive Animal / machine movement on wet soils (Fig. 3.1).



(a)

(b)

Fig.3.1: Some of the agricultural practices responsible for declining soil structure: a) Excessive movement of heavy machines; and b) Overgrazing

Whenever soil is disturbed it becomes loose and may move with water or wind. There is natural erosion of soils, especially in hilly areas. But there too human activity/agricultural activity enhances soil erosion. Levelling of the land and the drainage system also cause environmental problems.

Soil erosion in humid tropics is a very serious problem especially on slopes. Poor cultivation techniques, overgrazing, lack of vegetative cover are agricultural practices that lead to soil erosion.

Much of the eroded soil ends up in waterways. Downstream sedimentation is a serious impact of modern agricultural practices. Sedimentation fills in productive water reservoirs, destroys fisheries, coral reefs in tropical waters and as we had said earlier sediments carry ammonia, nitrates, and other chemicals in downstream waters causing eutrophication.

Soil Salinization

The soil or water containing excessive salts is classified as saline. The degree of salinity is measured by the concentration of salts. The easiest way to quantify the concentration of salts in a soil is to measure its electrical conductivity (EC). Its unit is Siemens/m. Soil with less salt will have low electrical conductivity. As the amount of salts increases its EC also increases. A soil is classified as saline if its EC becomes more than 4 dS/m. A number of factors are responsible for salinity build-up. Some of them are nature and content of soluble salts in irrigation water, soil type, water table, nature of crops grown, and the water management practices.

The agricultural practices responsible for saline soil problems are:

- Excessive drawing of ground water
- Water logging
- Use of improper fertilizers/pesticides
- Too frequent irrigation
- Use of brackish water for irrigation.

Canal Water Irrigation

Expansion of irrigation has been one of the key strategies in achieving self-sufficiency in food production in the region. For example, India has increased net irrigated area from 20 M ha in 1950 to about 45 M ha in 1995. A major expansion in the irrigated area has been achieved through transported canal irrigation. In almost all such cases the ground water table, which was several meters deep prior to introduction of irrigation canals, has risen. When ground water table reaches within 2 m of the surface, the ground water table contributes significantly to evaporation from soil surface and causes soil salinization. In most canal-irrigated areas, soil deterioration due to accumulation of salts has assumed a serious dimension. According to one estimate about 50% of the canal-irrigated areas are affected by salinity.

Ground Water Irrigation

Salt problems have also increased where saline ground waters have been used for irrigation in the absence of good quality irrigation water. Ground waters are being exploited to supplement the water requirement for producing more food, fodder and fibre. In India about 40% of the net irrigated area receives irrigation through ground waters drawn through wells. A large number of ground water aquifers especially in the states of Rajasthan, Haryana and Uttar Pradesh are unfit for irrigation as their use leads to salinity.

In coastal areas, excessive exploitation of ground water for agriculture has caused intrusion of sea water, resulting in worsening of salinity related problems.

Soil acidification

When pH of a soil becomes less than 6.5 it becomes acidic. Normally soils having pH between 6.5 and 7.5 are classified as neutral soils. If the soil pH becomes lower than 6.5 it becomes acidic and if it becomes higher than 7.5 it is classified as alkaline.

Agricultural practices that may cause soil acidification are:

- Excessive use of acidifying fertilizers.
- Use of shallow rooting pastures.

SAQ 2

What is soil structure and what agricultural practices disturb it?

3.2.3 Water Resources

The growth of agriculture and urbanization has imposed growing pressure on the South Asian region's already strained water resources in terms of both quality as well as quantity. This is evident in the gradual decline in per capita availability of water throughout the region. In India, for instance, the per capita availability fell from 6000 cubic meters in 1947 to 2300 cubic meters in 1998. Estimates for the year 2030 predict acute shortage of water in India (TERI 2000). Use of groundwater for irrigation has led to the depletion of underground aquifers in several parts of the region.

In some parts of the Indian states of Haryana, Rajasthan, Punjab and Gujarat the extent of over exploitation ranges from 100%-260% as compared to the critical levels of 85%. In Bangladesh excessive withdrawal of water has led to water logging and salinity and to land subsistence in cities like Dhaka (TERI 2000).
Water quality is affected through intensive agriculture in the following ways:

- Soil salinity due to water logging in irrigated areas;
- Soil salinity due to water logging in dry land;
- Contamination of ground water by nitrogen through nitrate;
- Eutrification of rivers, marshes and lakes; and
- Contamination of water by agrochemicals.

Lowering of Water Table

Due to excessive withdrawal of water for irrigation, the ground water table is lowered. In some cases it has gone down at the rate of 2-3 meters per year.

The methods of irrigation presently used are not very scientific. With a lot of gadgets now available for measuring the status of water/ moisture in the soil or when the crop requires water, we can make judicious use of water and save a significant quantity of water. Standing water throughout the rice crop is not essential. There are better methods of irrigation like drip irrigation and sprinkler irrigation to save water (Fig.3.2). These methods have several advantages over conventional methods of irrigation.

It is worth mentioning how a water scarce country like Israel has solved this problem by modern methods of irrigation, timely application of water, recycling of water etc.

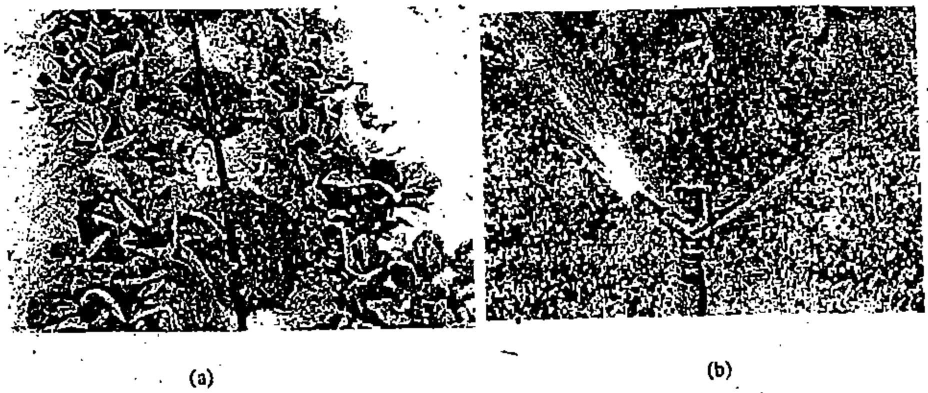


Fig.3.2: a) Drip irrigation; and b) sprinkler irrigation is more useful for saving water

"India has on the whole good rainfall and reasonable water resources. We can manage with water available provided we follow Gandhi's advice-Nature provides for every body's need but not for everybody's greed." *(Quoted from DR. M.S. Swaminathan's article on Greening a Nation published in Times Agricultural Journal Nov-Dec, 2001)*

SAQ 3

How can we save water and still fulfil the requirements of the crops?

3.2.4 Biodiversity Erosion

Within the Asia-Pacific region, overall habitat losses have been the most acute in the Indian Subcontinent. The underlying causes are international trade in timber; introduction of non-native species, improper use of agro-chemicals, excessive hunting and poaching (TERI 2000).

Intensive agriculture has resulted in loss of biodiversity in the following ways:

- Pressure on habitat of wild organisms;
- Loss of species when the habitats are degraded;
- Abandoning of traditional varieties in favour of high yielding varieties; and
- Practice of monoculture for more production of a particular variety (Pusa basmati in rice). This is normally done either because of high yields or some varieties which are more in demand. You will learn more about biodiversity erosion in Unit 8 of the next block of this course.

3.2.5 Pesticide Residues

Pests are undesirable competitors, parasites, or predators.

All types of agriculture suffer from pest infestation. Even today with modern technology the total losses from all pests are huge. The major agricultural pests are insects, diseases and nematodes, and weeds and vertebrates (mainly rodents and birds) that feed on grain and fruits.

Before the Industrial Revolution, farmers could do little to prevent pests except remove them when they appeared or use farming methods that tended to decrease their density.

With the advances in modern agricultural sciences, chemical pesticides were developed. The use of pesticides has grown, reaching $31.25 billion worldwide in 1996. About 80% of the pesticides in use are applied in developing countries.

Pesticides are a group of chemicals meant for preventing/ destroying any pest detrimental to man or his interest during production, processing, storage, ansportation and distribution of food items like cereals, fruits, vegetables and other rops. These include insecticides, herbicides, rodenticides, nematicides, hemosterilents, mollusides, fungicides, plant growth regulators, defoliants, desiccants ttractants, and repellents.

Box 3.1: Chemical pesticides

Chemical pesticides like DDT, aldrin and carbendazim etc. have created a revolution in agriculture. However, in addition to the negative environmental effects of individual chemicals such as DDT, their use has other major drawbacks. One such problem is known as *secondary pest outbreaks*, which occur after extended use (and possibly because of extended use) of a pesticide. Secondary pest outbreaks can come about in two ways: (1) reduction in one target species reduces competition with a second, which then increases and becomes a pest or (2) the pest develops resistance to the pesticides through evolution and natural selection, which favour those in the population with a greater immunity to the chemical. Developed resistance has occurred with many pesticides.

has been estimated that the crop losses in India because of pests and diseases vary om 10% to 30 % depending upon the crop, climate and region. In financial terms iese losses amount to Rs. 290 billions per year (Table 3.3).

Table 3.3: Estimated crop losses due to pests and diseases in India

Crop	Loss in %	Financial loss in million Rs.
Rice	18.6	55, 120
Wheat	11.4	14,150
Jowar	10.0	1,732
Pulses	7,0	4,840
Oilseeds	25.0	41,800
Cotton	22.0	20,000
Sugarcane	15.0	13,360

Ionitoring of Pesticide Residues

ll India Coordinated project on Pesticide Residues conducted analysis of 4100 fruits id vegetable samples collected from different states of India. Out of these 265(55%) samples were found contaminated with pesticides. However, only 9% of em exceeded the MRL (Maximum Residue Limit) as you can see from Table 3.4.

Table 3.4: Region wise contamination of fruits and vegetables by pesticides

State/Centre	No of samples analysed	% samples contaminated	% samples above MRL
Haryana	1236	56.2	4.5
H.P.	436	19.5	1.4
Tamil Nadu	85	91.8	15.3
Gujarat	104	80.8	13.5
A.P.	275	29.8	-
U.P.	244	100	45.9
W.B	75	56	-
Kerala	72	100	52.8
Punjab	148	58.1	4.7
Orissa	105	51.4	12.4
Delhi	68	77.9	-
Assam	32	46.9	-
Rajasthan	388	63.4	12.1
Karnataka	370	19.7	7.3
M.P.	195	96.5	1.5
Maharashtra	278	73.4	13.7
Total Average	**4111**	55.3	9.5

The analysis has shown that pesticide residues affect most of the crops. A comparative analysis is given in Table 3.5.

Table 3.5: Contamination of fruits and vegetables crops by pesticides (crop wise)

Crop	No of samples	% of samples contaminated	% samples above MRL
Tomato	598	45.3	5.4
Cucumber	186	52.5	6.5
Apple	142	18.3	--
Okra	468	60.0	15.8
Cabbage	302	62.6	7.0
Smooth Gourd	81	64.2	--
Pointed Gourd	15	46.7	--
Brinjal	843	58.5	9.8
Capsicum	124	31.5	12.1
Indian Bean	22	72.7	9.1
Bitter Gourd	125	65.6	6.4
Ridge Gourd	46	47.8	--
Pea grains	161	47.8	7.5
Potato	219	62.6	9.6
Cauliflower	376	66.2	16.8
Pea	20	65.0	--
Beans	8	62.5	--
Spinach	40	85.0	7.5
Mustard	12	41.7	--
Cowpea	55	81.8	32.7
Cluster bean	24	50.0	4,2
French bean	51	17.6	15.7
Bottle Gourd	33	45.6	3.0
Snake Gourd	36	80.5	19.4
Carrot	14	57.1	--
Fenugreek	12	41.7	8.3
Pigeon pea	12	100	58.3
Total Average	4111	55.1	9.5

Pesticides residues were also found in milk samples collected from the following. locations showing that the cows and buffalo were eating such fodder or feed material which contained pesticide residues and then these residues entered in the food chain of milch cattle and in the milk (Table 3.6).

Table 3.6: Residues of HCH and DDT in whole milk in India

(a) HCH (Hexachloro cyclohexane)

Location	No. Analyzed	No. contaminated	No. above MRL
New-Delhi	12	12	7
Ludhiana	30	30	30
Hissar	25	25	25
Kanpur	24	24	24
Hyderabad	38	38	38
Coimbatore	90	90	60
Pusa Bihar	24	8	8
Bangalore	30	25	25
Bhubaneshwar	45	45	45
Jorhat	12	12	12
Jaipur	20	20	17
Anand	60	60	59
Vellyani	25	25	12

MRL in dairy milk HCH = 0.01 mg/kg

(b) DDT (Dichloro diphenyle trichloro ethane)

Location	No. Analyzed	No. contaminated	No. above MRL
New Delhi	12	12	12
Ludhiana	30	30	25
Hissar	25	25	02
Kanpur	24	19	09
Hyderabad	21	21	3
Coimbatore	80	80	22
Pusa Bihar	24	11	9
Bangalore	30	26	02
Bhubaneshwar	45	36	11
Jorhat	31	31	22
Jaipur	16	16	10
Anand	60	60	52
Vellyani	18	18	10

MRL for dairy milk DDT = 0.05 mg/kg

'esticide Residues in Fish

'he data on pesticide residue in fish suggests that fish in India are relatively less ontaminated. Out of 82 samples analyzed, only 40% were found contaminated with esidues of insecticides and none of the samples was above MRL. These samples were ollected from Kerala, Assam and Andhra Pradesh and residue analysis was onducted for HCH, DDT, Endosulphan, monocrotophos and quinaphos.

'esticide Residues in Poultry and Poultry Feed

'hicken and eggs are the preferred food in a non-vegetarian diet. In India samples of ggs and chicken were analyzed for the residues of HCH, DDT, aldrin and arbendazim (a fungicide). The analysis of chicken flesh have shown that residues of)DT, HCH and aldrin, were either non-detectable or below MRL. But surprisingly esidues of carbendazim fungicide used to control fungal diseases were much higher ian its MRL value. The presence of high amounts of carbendazim in poultry feed learly shows that these are coming from feed particularly maize as maize grains are eated to control fungal diseases.

'he area under pesticide cover has increased from 6 Mha in 1960 to 125 Mha in 1990. .t present there are about 145 pesticides in use and annual consumption is about 5000 t. The consumption of pesticides in India is the maximum among the South sian countries. During the last five decades this has increased by about 500 times, e., from 154 t in 1953 to 85,000 t in 1998.India is also the largest producer of esticides in South Asia, with more than 500 industries producing it.

lotwithstanding this fact, the consumption of pesticides in India is quite low (about .5 kg /ha) as compared to countries like Korea and Japan where its consumption rate 6.6 and 12.0 kg/ha, respectively. There is widespread contamination of food ommodities with pesticide residues. In a recent survey by ICMR (Indian Council of ledical Research) it was revealed that 51% of our food items were contaminated with esticides out of which 20 % had pesticides residues above MRL (Maximum Residue imit). In spite of the warnings and bans the use of pesticides in India is increasing at ie rate of 2-5 % per year and is likely to grow in future as well unless strict measures re taken. On a regional level, agricultural run-off has also contributed to ocean ollution. An estimated 1800 t of pesticides enter the Bay of Bengal annually and icreased use of pesticides in some areas has resulted in contamination of molluscs nd fish species.

Shrimp breeding in coastal swamps has accelerated the depletion of mangroves in estuaries, lagoons and bays and threatens such important natural processes as soil binding, nutrients recycling and prevention of soil erosion and silt accumulation.

SAQ 4

Why are pesticides used in agriculture? Find out the MRL of pesticide residue in your area.

3.3 IMPACT ON CLIMATE CHANGE

So far we have discussed the local and regional effects of agriculture on the environment. Global effects are not so obvious, though they are equally serious. In this section, we will examine and assess the global impact of modern agriculture on climate change. Intensification of agriculture has resulted in heavy reliance on irrigation, increased fertilizer and pesticides use and crop residue burning. All of them have a direct impact on global climate change via emission of greenhouse gases.

3.3.1 Greenhouse Gas Emissions

Green house effect is the warming of the lower atmosphere and surface of a planet by a complex process involving sunlight, gases and particles in the atmosphere.
All hot objects emit electromagnetic radiation at a range of wavelengths depending on the temperature of the object. The higher the temperature is, the shorter the wavelength of the radiation, and vice versa. The sun, with a surface temperature of over 6000°C, emits radiation with wavelengths 200nm to 4µm.

The earth is enveloped by gaseous atmosphere and gases in the atmosphere absorb radiation selectively. When the short-wave radiation from the sun passes through these gases, they allow it to fall on the earth. As a result, the earth absorbs some of the radiation and it gets heated to a mean temperature of about 15°C. In turn, the earth radiates long wave infrared radiation some of which is absorbed by the atmospheric gases and particles. As a result the gases and particles are heated. Sending out infrared rays of their own then cools them. Some of these rays go into space. The remainder radiate back towards the earth's surface adding to the warming of the surface layer of air (Fig. 3.3). The heat trapping gases of the atmosphere are known as greenhouse gases.

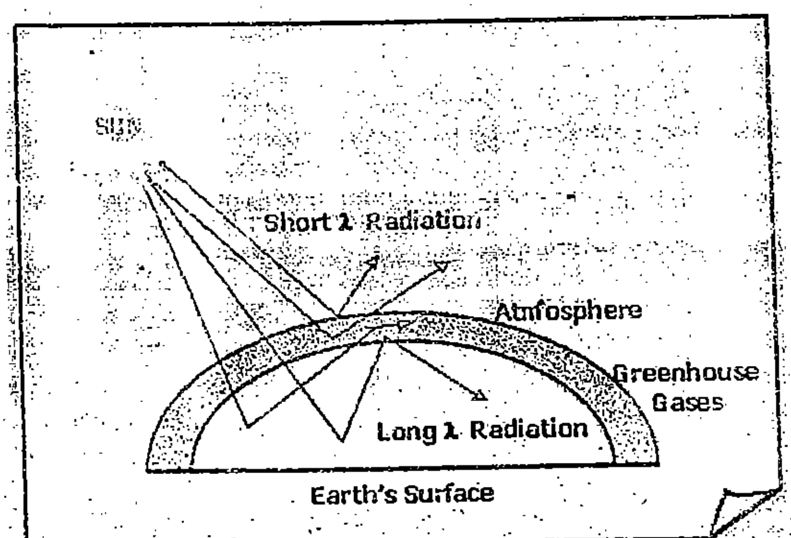


Fig.3.3: Greenhouse effect; λ refers to the wavelength of the radiation. Short λ implies greater energy and long λ radiation has less energy

The greenhouse gases are: carbon dioxide, methane, water vapour, nitrous oxide and ozone. The natural greenhouse gases keep the earth roughly 33°C warmer than what it would be if there was no atmosphere. However, on an average for the earth as a whole, the incoming solar energy is balanced by outgoing terrestrial radiation. It is important to understand that the green house effect is a natural phenomenon that has been occurring for millions of years on earth as well as other planets of our solar system. The majority of natural greenhouse warming is due to water in the atmosphere but the gases we are concerned with are those that result in part from anthropogenic processes, that is, those that occur due to human activities.

Increases in the concentration of greenhouse gases will reduce the efficiency with which earth cools. More of the outgoing terrestrial radiation from the surface is absorbed by the atmosphere and emitted at higher altitudes and colder temperatures. This results in an **enhanced greenhouse effect** which tends to warm the lower atmosphere and surface. This effect has operated in the earth's atmosphere for billions of years due to the naturally occurring greenhouse gases: water vapour, carbon dioxide, ozone, methane and nitrous oxide.

Anthropogenic aerosols (small particles) in the troposphere, derived mainly from the emission of sulphur dioxide from fossil fuel or biomass burning can absorb and reflect solar radiation. They create a negative effect and cool the climate. But these aerosols have a much shorter lifetime (days to weeks) as compared to most greenhouse gases (decades to centuries) so their presence responds much more quickly but for short duration.

Any change in the radiative balance of the earth whether due to greenhouse gases or aerosols will tend to alter atmospheric and oceanic temperatures and the associated weather patterns (hydrological cycles, cloud distribution and rainfall patterns).
As explained above, the presence of these green house gases has raised the earth's surface temperature from –19° C to 15° C.

It is quite clear that not only the presence of these gases but their contribution in raising the temperature is also equally important. Some gases contribute more and some less depending upon their concentration and warming potential (Table 3.7).

Table 3.7: Greenhouse gases influences by anthropogenic activities

Gas	CO_2	CH_4	N_2O	CFC-12
Pre-industrial atmospheric concentration	280 ppmv	0.70 ppmv	280 PPBV	0
Current concentration	370 ppmv	1.72 ppmv	310 ppbv	5.03 pptv
Current annual increase (%)	0.5% (1.5 to1.8 ppmv)	0.8% (0.013 ppmv)	0.25% (0.75 ppbv)	4% (18-20 pptv)
Atmospheric life time (Yrs)	50-200	12-17	150	102
Global warming potential relative toCO_2	1	24.5	320	4000

The table shows that from many thousand years to about 200 years ago the concentration of these green house gases in the atmosphere was almost the same/ unchanged. The changing trend started only 200 years ago mainly because of increased anthropogenic activities. Not only this, some of the gases (CFCs) which were not present in the atmosphere earlier entered into atmosphere from the year 1930 onwards. Though their concentration is very low, their overall contribution to global warming is very high.

The rise in the concentrations of greenhouse gases in the atmosphere is caused primarily because of human and industrial activities. The increasing levels of CO_2, the most important greenhouse gas, are mostly because of fossil fuel combustion. Similarly, CFC emissions are only caused due to industrial processes and products. On the other hand the increased agricultural activities and organic waste management are contributing to the build-up of methane and nitrous oxide (Fig. 3.4).

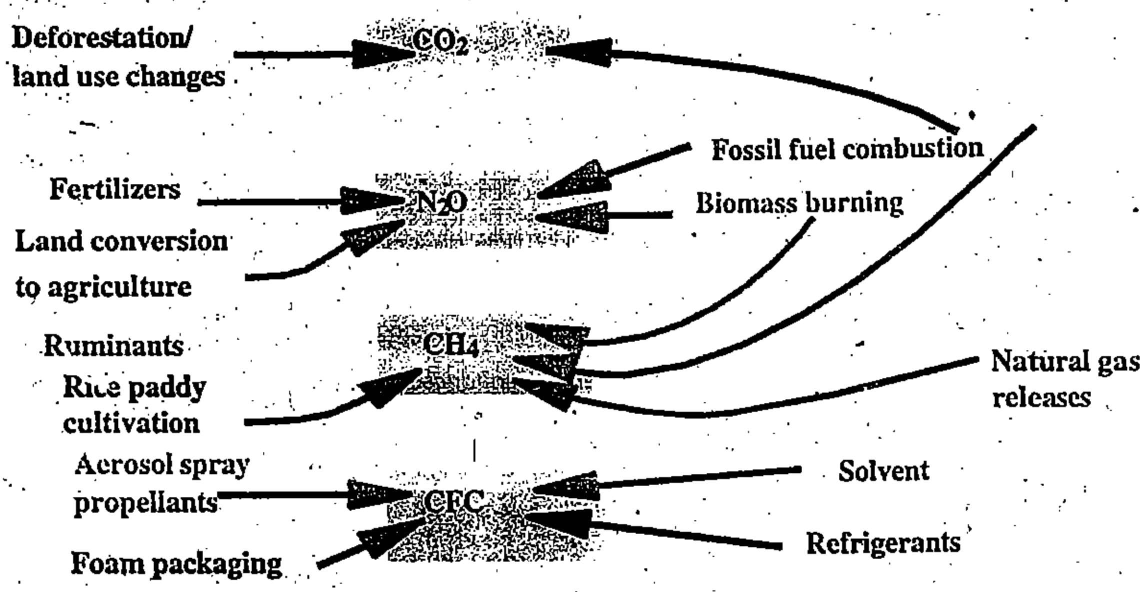


Fig. 3.4: Greenhouse Gases and their anthropogenic sources

The composition of greenhouse gases is shown in Fig. 3.5. Note that carbon dioxide. methane and nitrous oxide are directly related with agriculture.

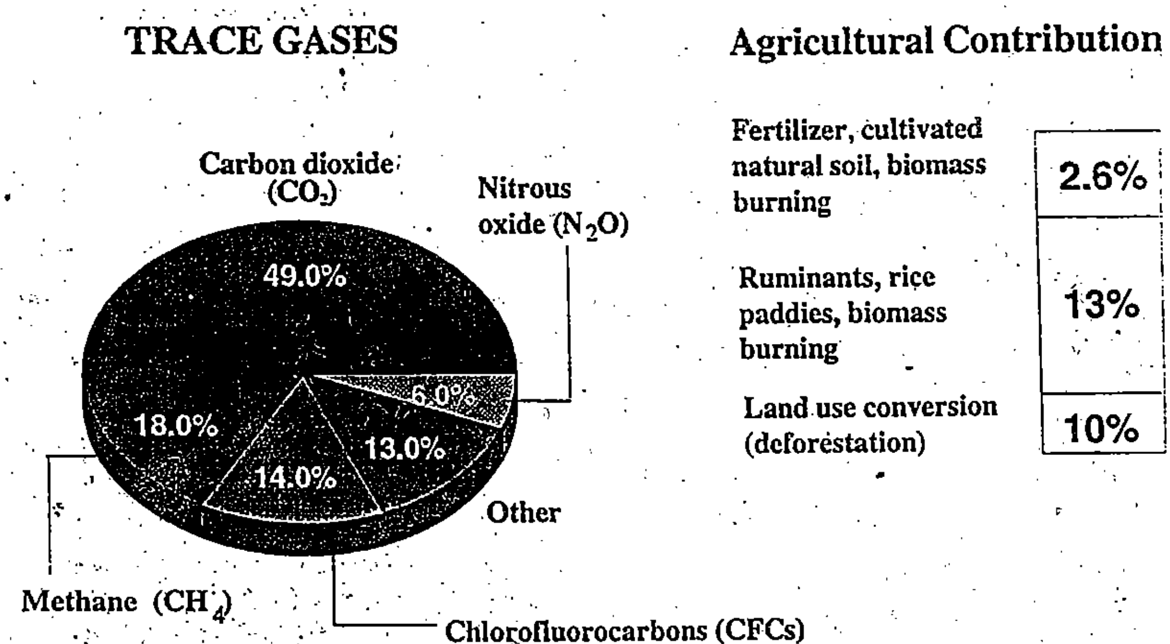


Fig.3.5: Composition and source of greenhouse gases in the atmosphere

While it is certain that agriculture is a source of carbon dioxide, methane and nitrous oxide, it can also be considered as a sink of carbon dioxide and to some extent methane. We will discuss each gas separately in the following subsection.

SAQ 5

a) Why does the sun radiate in the short wave range (mainly UV and visible) while the earth radiates long wave radiation?

b) Why is global warming known as greenhouse effect?

3.3.2 Carbon Dioxide

Agriculture is not a major source of carbon dioxide. It mainly comes from the burning of fossil fuels for energy (electrical power, vehicles etc). However, agriculture and forestry play an important role in land use conversion, (land clearing and forest burning for cultivation or grazing) which is the second largest cause of increased carbon dioxide emission. The net effect is carbon loss from both biomass and soils. Main source of carbon dioxide to the atmosphere by agriculture is through tillage. The tillage operation increases the biological decomposition of soil organic matter resulting in release of CO_2. The second pathway is use of machinery where fuel (diesel) releases CO_2. The third important source of CO_2 is burning of crop residue.

Inter Government Panel on Climatic Change (IPCC)

It may be noted the agriculture is also a sink for CO_2. During plant growth, the process of photosynthesis absorbs atmospheric CO_2. Due to this very reason the global Climate Change Community does not consider agriculture as a source of CO_2. (In official GHG (Greenhouse Gases) accounting procedures as supported by IPCC).

Carbon dioxide from Tillage Operations

During a tillage operation, soil aggregates are broken, increasing oxygen supply and surface exposure to soil organic matter and thereby promote its decomposition.

International Maize and Wheat Improvement Centre (CIMMYT)

In one long- term trial at CIMMYT, Mexico, the impact of 3-4 cultivations per year was compared with a no tillage experiment. After 8 years it was revealed that soil organic carbon in the top 20 cm declined from 1.37% to 1.12 %. The net loss of soil organic carbon in 8 years was 3.6 t C/ha (equivalent to 450 kg C/ha/yr.).

Where has this carbon gone? It has gone to the atmosphere through CO_2 emission.

Fuel Consumption in Agriculture

Heavy diesel fuel used by tractors is also responsible for CO_2 emission. It is estimated that for every litre of diesel consumed, 2.6 kg of CO_2 is released to the atmosphere. Assuming that 150 litres of diesel is used per hectare for tractor and irrigation pumping in conventional systems, this would amount to 400 kg CO_2 being emitted per year. An off site source which is often neglected, is the production of CO_2 during the manufacture of fertilizers. It is estimated that production of I kg of N fertilizer would release 1.8 kg of CO_2.

3.3.3 Methane

Methane is the lightest hydrocarbon having one carbon and four hydrogen atoms. Its molecular weight is 16. It is also a fuel gas commonly called marsh gas because it is produced from marshy lands. Biogas or Gobar gas also contains 60-70% of methane.

Even if the concentration of methane is quite low as compared to that of CO_2, its global warming potential (GWP) is 20 times that of CO_2. Rice and ruminant animal production are the two largest sources of anthropogenic methane. These two sources together contribute about 40% to global methane budget (Table 3.8).

1 Tg = 1 million tons

Table 3.8: Estimated sources and sinks of methane in Tg/ yr (IPCC 1995)

Sources	Individual estimate	Total
Natural		
Wetlands	115(55-150)	
Termites	20(10-50)	
Oceans	10(5-50)	
Others	15(10-40)	
Total of Natural Sources		**160(110-210)**
Anthropogenic Sources		
Fossil fuel based		
Natural gas	40(25-50	
Coal mines	30(15-45)	
Petroleum Refining	15(5-30)	
Coal combustion	? (1-30)	
Total of fossil related		**100(70-120)**
Biogenic		
Enteric Fermentation	85(65-100)	
Rice paddies	60(20-100)	
Biomass Burning	40(20-80)	
Landfills	40(20-70)	
Animal wastes	25(20-30)	
Domestic sewage/waste	25(15-80)	
Total of Bionic Sources		275(200-350)
Total (All Identified Sources)		535(410-660)
Sinks		
Atmospheric removal		
Troposphere OH	445(360-530)	
Stratosphere	40(32-48)	
Soils	30(15-45)	
Total Sinks		515(430-600)
Implied Total Sources		**552(465-640)**
Implied Increase		**37(35-40)**

If domestic waste decomposition through sewage and landfills and burning of agricultural waste is also included under this category of anthropogenic sources of methane, its contribution may rise to about 70% (Fig. 3.6).

The methane we release today could still trap heat more than a decade from now. It stays in the atmosphere that long.
Each molecule of methane traps heat 20 times more effectively than a carbon dioxide molecule.

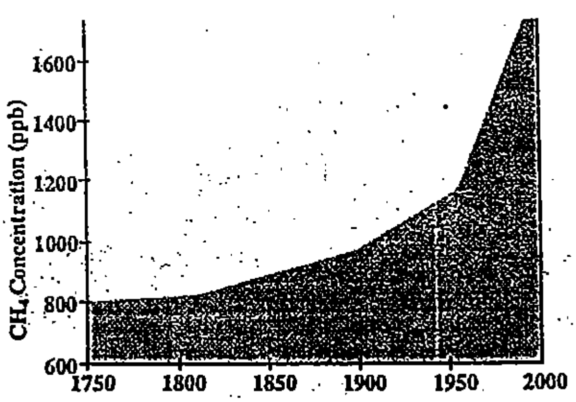


Fig.3.6: Methane on the rise. Since 1750 methane in the air has more than doubled due to human activity. It could double again by 2050.

ethane emission from rice fields

ethane is produced in soil during microbial decomposition of organic matter and duction of CO_2 under strictly anaerobic conditions. The methane emissions are ntrolled by two microbial processes, i.e., CH_4 production through methanogenic cteria and CH_4 oxidation through methanotrophs. While former requires strict aerobic environment, the latter requires oxygen for metabolism. The dry terrestrial ils may also act as sink of atmospheric methane.

ie continuously flooded rice fields are the source of methane, because anoxic nditions favour methanogenesis and production of methane and rice plants serve as nduit for its release to atmosphere. However, if the fields could be drained or ermittently irrigated, then the methane production as well as emission could be nificantly reduced.

lobal Methane Emission from Rice Fields

ie global estimate of methane emission from rice fields started from 200 Tg/yr, iich have come down to 60 (20-100) Tg/yr in 1996.There is a possibility of further cline in the estimated values of methane budget from rice fields. It is estimated that ethane emission from rice fields is in the range of 25-54 Tg/yr.

ethane from Indian rice fields

ethane from Indian rice fields covering a harvested area of 42.3 Mha was estimated 4-6 Tg/yr. There is no doubt that the continuously flooded fields emit considerable iount of methane, but the question would be the source of carbon substrate, which is eded for the methane production. This substrate comes from either the native ganic carbon in the soil, or the applied organic carbon added to the soil in the form organic manures, rice straw etc.

ie rice plants also provide this carbon substrate in the form of organic leachates and ot exudates. The recent measurements using both automatic and manual measuring stem have clearly shown that methane emission is significantly reduced using the actice of intermittent irrigation as compared to continuous flooding.

ie experiments in all parts of the world have shown that addition of organic manures ke green manure, farm yard manure (FYM), biogas slurry, rice straw etc., enhances e methane emission from rice fields. The experiments [illegible] at IARI have also own that methane emission from rice fields amended with biogas spent slurry is nificantly lower than other organic amendments like green manuring, FYM etc.

periments have also shown that there is no significant increase in methane emission neem coated urea is used in place of urea, while grain yields are significantly creased.

e total annual injection of methane into the atmosphere is estimated to be 552 (465-0) Tg and its oxidation being less, there is a net accumulation of about 37 Tg/yr. As result, the abundance of methane in the atmosphere (which is currently 1.74 ppm) is creasing at a rate of about 0.7 % per year. Although the increase in annual load of ethane in the atmosphere is only 1/100 that of CO_2. its high [illegible] absorption nounts to higher contribution (15-20%) in the global warming.

ole of organic wastes under continuously flooded rice fields

rganic wastes are the potential source of methane emission. Normally the wastes ntain lot of water and the dry matter content of a large number of organic wastes is ry low (10-20%). When these wastes are dumped, they remain in partially anaerobic nditions and produce both carbon dioxide as well as methane .The ratio of CO_2/CH_4

depends upon the toxic conditions of the dumps. When these wastes become a part of stagnant water, the amount of methane increases considerably. Among the various types of wastes, the most important is the animal excreta. But the crop wastes and other wastes which are also sometimes used in rice fields also emit methane. The more the organic matter in the stagnant water, the more methane is expected to come out. The process also depends upon the temperature and pH. Temperature between 30-35°C is most favourable for methane production.

The production of methane is reduced as the temperature goes down and below 15°C, the methane production becomes very low. As regards the pH, its range between 6.4-8.0 is most favourable, on either side of this range, methane production is reduced.

Box 3.2: Methane emission in South Asian Region

Under UNDP-IRRI Inter regional programme, methane emission from rice fields was measured at eight locations in five rice producing countries (India, China, Thailand, Philippines and Indonesia) covering main rice ecosystems, i.e., irrigated, rain fed and deepwater. The results revealed that irrigated rice fields had the highest emission rates of all rice ecosystems. Seasonal emission varied from 1g/m^2 to 50 g/m^2.

Continuously flooded fields emitted more methane. Depending upon local precipitation, emission from rain fed rice fields may be less than half of the emission from irrigated fields and was generally less than 5 g/m^2. In a reference treatment at all these locations using common cultivar IR72 and continuously flooded conditions, the seasonal methane emission varied from 1.7 g/m^2 to 24.4 g/m^2, which may be attributed to soil conditions and climate.

Experiments at IARI during 1994-97 have shown that intermittent irrigation, which is the usual practice, reduces methane emission unto about 28%. At Pant Nagar the reduction in methane emission due to intermittent irrigation was found to be 30% as compared to continuous flooded conditions. IPCC in 1996, on the basis of results obtained by various rice growing countries, have suggested that emission factors under single and multiple aeration as 0.5 and 0.2 of that against continuously flooded fields. Using IPCC methodology and country's default value of 10 g/m2, the methane emission from rice cultivation in India should not exceed 2.5Tg/yr.

The main reason of low methane emission from rice fields in India is that the soils of major portion of rice growing areas have very low organic carbon. Incubation studies on some soils of rice growing areas of India have shown large differences in the methane production potential because of their organic carbon content. The use of organic manuring is also not very common in India and Indian soils have very low organic carbon. This is one of the reasons of low methane emission from Indian rice fields.

Methane Emission from Burning of Crop Residues

The burning of crop residues also contributes to global methane budget. For each ton of residues that is burnt 2.3 kg of methane is released which is equivalent to 48.3 kg of carbon dioxide.

In order to clear the field for the next crop, farmers quite often burn the crop residue, because that appears to them as the easiest way.

As an example take the case of rice-wheat system in Indo-Gangetic plains. Assuming about 10 t/ha of residue production and if half of the 12 million ha area under rice-wheat is burnt, a total of 0.14 million tons of methane is emitted. This is equivalent to 20% of the total methane emitted from rice fields in this area. Hence burning of crop residues is also an important source of methane besides carbon dioxide.

Mitigation of methane emission from rice fields

Experiments have shown that methane emission can be reduced significantly (Table 3.9) by adopting the following mitigation practices:

- Water management: through intermittent irrigation or drainage;
- Use of digested manure instead of fresh manure; and
- Selection of suitable cultivars which emit less methane.

But studies have also shown that mitigation of methane emission through intermittent flooding may lead to N_2O emission. However, more experiments are needed to quantify the combined effect of emissions of methane and nitrous oxide from rice fields. This has become necessary because the global warming potential of N_2O is 15 times more than that of CH_4.

Table 3.9: Estimated effect of management practices on CH_4 emission from flooded rice

Mitigation Practice	Estimated decrease Mt (CH_4)/yr
Irrigation management	5 (3.3-9.9)
Nutrient management	10 (2.5-15)
New cultivars and other practices	5 (2.5-10)
Total	20(8-35)

Methane Emission from Enteric Fermentation

Ruminants are the largest source since they are able to digest cellulose, a type of carbohydrate, in the presence of specific micro organisms in their digestive tracts. An adult cow emits about 200 litres of methane every day. The methane production from the digestive process of domesticated animals is a function of several variables including quantity and quality of feed intake, the growth rate of the animals, its productivity (reproduction and/ or lactation) and its mobility.

Feed Intake

Feed intake in terms of dry matter (DM) is most crucial for the estimation of methane emission from livestock and is generally expressed in terms of energy, i.e., MJ (Mega Joules) per kg dry matter. The total dry matter intake of an animal is converted to MJ as gross energy intake using the factor 18.45 MJ/kg.

The gross energy intake value (GE) for each animal category is arrived at, taking into account the Indian feeding conditions/ situations based on feed intake requirements of various categories of cattle. The requirement varies according to age, feeding situation, (stall or housed, pasture, grazing large areas) production level and performance (maintenance, lactation, work, breeding, growth etc).

Depending upon the population and the methane production potential of different livestock in India it is seen from Fig. 3.7 that cattle (cows) contribute maximum followed by the buffalo.

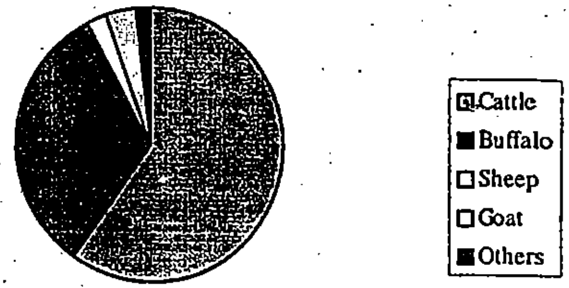


Fig.3.7: Methane Emission from Animal Sector in India.

Among the green house gases emitted from animal (enteric fermentation and manure management), methane was the highest (99.985%) with N_2O accounting for only very small fraction (0.015%), which is negligible. Methane emission from domestic animal source (anthropogenic activities) was 10.0 Tg for the year 1994 of which 8.9 Tg (90%) was from enteric fermentation and the balance 1.1 Tg (10%) came from manure management. The proportional contribution of emission is almost in the ratio of 9:1 (enteric fermentation and manure management).

The best way to mitigate the methane emission from enteric fermentation of ruminant animals is to improve their feed. Several efforts have been made to improve the feed in such a way that they produce less methane.

SAQ 6

a) Why is methane an important greenhouse gas even if its concentration in atmosphere is 1.8 ppmv as compared to a high concentration of about 360 ppmv of CO_2?

b) Can other aquatic plants and stagnant water emit methane?

3.3.4 Nitrous Oxide

Nitrous oxide is one of the oxides of nitrogen. Some other oxides of nitrogen like NO and NO_2 (together called NOx) are pollutants and are emitted by vehicles and other stationary engines. N_2O is another greenhouse gas responsible for climate change.

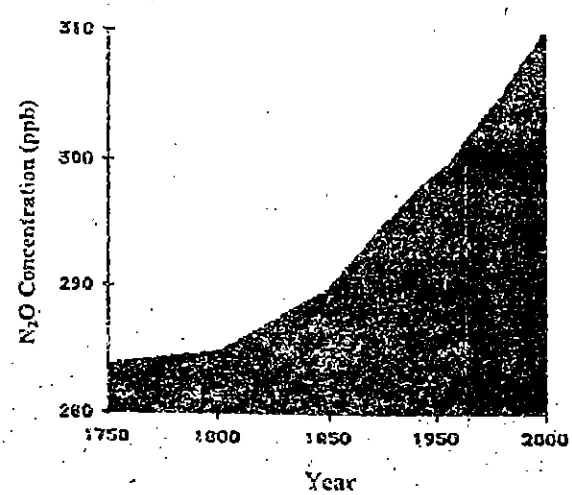


Fig.3.8: Nitrous oxide on the rise

ince 1750, nitrous oxide in the atmosphere has risen by more than 15 percent (see ig. 3.8). Each year we add 7 to 13 million tons of nitrous oxide to the atmosphere ıainly by using nitrogen-based fertilizers and disposing of human and animal wastes.

he nitrous oxide we release today could still trap heat more than a century from now. stays in the atmosphere about that long. A nitrous oxide molecule traps heat about 00 times more effectively than a carbon dioxide molecule.

he Table 3.10 of the sources and sinks of nitrous oxide clearly indicates that there is high degree of uncertainty in the emission figures of nitrous oxide. One of the easons may be its low concentration in the atmosphere (300 ppbv) and determination f N_2O concentration at such low levels. But the latest measuring techniques have ıade it possible to measure these fluxes at reasonable costs. Hence it has become ecessary to have more and more experimental measurements to come out with more nd more reliable estimations.

oth fertilized and unfertilized soils emit N_2O. While the fertilizer is a source in case f fertilized soils, the inbuilt nitrogen of the soil contributes otherwise to the release of ıis gas. Measurement of N_2O fluxes from soils as a result of use of N in inorganic or rganic forms is of great importance to the atmospheric scientists because of the effect f N_2O on ozone destruction and its radioactive forcing. But the soil scientists and gronomists are also concerned about the nitrogen losses from the applied fertilizers nd manures.

Table 3.10: Sources/sinks of nitrous oxide

Sources	Production (Tg N/ yr)
Nitrification	?
Denitrification	?
Cultivated soils	1.8-5.3
Fertilized soils	<3
Unfertilized soils	4-5
Tropical soils	2.7-5.7
Temperate soils	0.6-4.0
Oceans	1-5
Fossil fuel	0.7-1.8
Biomass burning	0.2-1.0
Total	**17-20**
Total emission from soil	**5-15**
Sink	
Stratospheric reaction with ozone	6-11
Photolysis	11

Experiments have shown that both the processes of nitrification and denitrification contribute to the release of nitrous oxide from the soils.

Experiments in rice fields conducted at IARI have shown that as the redox potential becomes positive methane emission is decreased, but N_2O emission increases. In another experiment it has been shown that use of nitrification inhibitor DCD along with urea and ammonium sulphate reduces both the methane and nitrous oxide emission as compared to their lone use. Though there is lot of uncertainty about the amount of N_2O released, it is suspected that 1-2 % of applied N is lost as N_2O.

Nitrous oxide Emission from Histosols

The high organic soils undergo microbial process (both nitrification and denitrification) resulting in the release of nitrous oxide. It has been reported that these soils emit 2-15 kg /ha N_2O N /yr.

Indirect N_2O Emissions from Nitrogen used in Agriculture

The following pathways also contribute to nitrous oxide emissions because of inorganic and organic fertilizers applied in the fields.

1. Volatilization and subsequent deposition of NH_3 and NOx;
2. Nitrogen leaching and runoff;
3. Human and animal consumption of crops followed by further excreta/sewage;
4. Formation of N_2O in the atmosphere from NH_3; and
5. Food processing wastes.

N_2O Emissions from Animal Waste Management Systems

Nitrous oxide emission depends on the N_2 excreted by animals, its quantity, quality and its management. Animals themselves may be very small sources of N_2O but the proportion of total nitrogen intake that is excreted and partitioned between urine and faeces is dependent on the type of animal, the intake of dry matter, and the nitrogen concentration of the diet. Hence there are three potential sources of N_2O emissions related to animal production. These are (a) animals themselves, (b) animal wastes during storage and treatment, (c) dung and urine deposited by free-range grazing animals. N_2O emission emitted directly from animals is not reported here.

Production of N_2O during storage and treatment of animal wastes can occur via combined nitrification-denitrification of ammoniacal nitrogen contained in the wastes. The amount released depends on the system and duration of waste management. As fresh dung and slurry is highly anoxic and well buffered with near neutral pH, one would expect N_2O production to increase with increasing aeration. Aeration initiates the nitrification-denitrification reactions, and hence makes release of N_2O possible.

SAQ 7

What is the relative global warming potential of nitrous oxide?

3.4 SUMMARY

- Food, fibre and fodder are the three important produce of agriculture on which whole mankind is dependent. Even though the impact of agriculture practices on environment is quite significant, it is certain that only remedial measures can be adopted to reduce or prevent the negative impacts of agricultural practices on environment.
- Negative impacts of intensive and exploitive agriculture include water pollution, land degradation and associated problems of soils like soil salinization, soil acidity, soil acidity, depleting ground water reserves.
- Examples of pesticide residue in fruits, vegetables, milk, poultry products creating human and animal health problems are given.

- The emission of greenhouse gases from agriculture is a serious problem which is responsible for global warming and climate change. One of the important green house gases emitted by agriculture is methane from rice fields, ruminant animals, burning of crop residue and animal manure management. The mitigation options are to be adopted to reduce these emissions from rice fields and ruminant animals.

  The second important gas is nitrous oxide, though its actual emission is low, but in view of its warming potential, it is also contributing significantly to climate change. Its main sources are Nitrogen fertilizers (both chemical and biological) and animal waste. The main greenhouse gas carbon dioxide is also being emitted but since agriculture is also a sink for carbon dioxide its net contribution is not well known. However, efforts are to be made to reduce these emissions also by reducing tillage operations.

3.5 TERMINAL QUESTIONS

1. Identify two impacts of agriculture on environment that you think are the most negative impacts of agriculture.
2. What types of agricultural practices are responsible for soil degradation?
3. How secure is India with respect to water resources? Suggest ways in which we can improve water security.
4. What are pesticides and why are they used in agriculture?
5. How can methane emission from rice fields be reduced?
6. Why is global warming known as greenhouse effect? And why is climate change being linked with emission of green house gases?
7. Is agriculture responsible for global warming? If so, to what extent?
8. Which greenhouse gases are emitted by agricultural practices?
9. What is the warming potential of methane / nitrous oxide as compared to that of carbon dioxide? What agriculture practices emit carbon dioxide?
10. How is methane produced from rice fields? What agricultural practices can reduce methane emission from rice fields?
11. What is nitrous oxide and why is it classified as a greenhouse gas?

REFERENCES

1. Abrol, I.P. and Sehgal, J: Degraded lands and their rehabilitation in India. In Soil Management for Sustainable Agriculture in Dry Land Areas; Indian Soc. Soil Sc. pp. 107-118.
2. Agnihotri, N.P. (1999) Pesticide – Safety Evaluation and Monitoring, All India Coordinated Projecton Pesticide Residues, IARI, New Delhi.
3. Greenhouse gas emissions in India for the base year 1990: Scientific Report No.11, May 1998, Eds.: Bhattacharya, S. and Mitra, A.P.
4. "Improving the productivity and sustainability of rice-wheat systems: Issues & Impacts" American Society of Agronomy Special Publication (ASA 65) 2003 Eds.: Gupta, R.K. and Ladha, J.K.
5. "The green revolution turns sour" Devender Sharma, New Scientist July (2000), pp. 44-45.

6. Dr. M.S. Swaminathan's article on 'Greening a Nation' published in Times Agricultural Journal Nov.-Dec., 2001, pp.12-13.

7. Methane emissions from major rice ecosystems in Asia (2000); Eds. Wassmann, R., Lantin, R.D. and Neue, H.U., published by Kluwer Academic Publishers, Dordrecht / Boston / London.

8. Climate Change (1995) Eds Watson, R.T., Zinyowera, M.C., Moss, R.H. and Dokken, D.J. Published for IPCC by Cambridge Universe Press, pages 877.

9. Environmental Impact Assessment for Farms (2000) Published by Secretary General Asian Productivity Organization, Tokyo.

10. htpp://www.ghg.online.org

UNIT 4 IMPACT OF ENVIRONMENT ON AGRICULTURE

Structure

4.1 INTRODUCTION

It is not only the contribution of agriculture in the climate change process, but also the mpact of climate change on agriculture that is of concern to farmers and policy nakers. In Unit 3, you have studied about the impact of agricultural practices and operations on the environment, and have learnt that during the last century, farm nechanization, introduction of synthetic fertilizers and pesticides and improved ultivars have increased productivity and made many developing countries self ufficient in food grain production. However, these changes created new kinds of roblems for the environment.

n this unit, we shall provide some details of the ways through which changes in the nvironment influence agriculture (production and productivity of crops) as a whole. Environmental problems to agriculture are caused by natural stresses such as drought, alinity etc. Some of these relate to human activities, which in turn affect the global limate. The climatic changes, such as rising temperature, increased CO_2 emissions, zone layer depletion, and sea level rise etc., influence agriculture in many ways. This orms the subject of discussion in this unit.

bjectives

fter studying this unit, you should be able to:

- define environmental stress, salinity stress and moisture stress and their impact on agriculture;
- describe how changes in temperature and rise in CO_2 level in the atmosphere influence agricultural productivity; and
- explain the effect of ozone layer depletion on agriculture and other living organisms.

2 ENVIRONMENTAL STRESSES

an environmental stress constitutes a major limitation to agricultural production and e farmer's livelihood. Crop production is rarely ever free of environmental stress. e major plant environmental stresses of economic importance worldwide are ought, cold (chilling and freezing), heat, salinity, soil mineral deficiency and soil neral toxicity. Stress has potential to cause injury, brought about by the aberrant anges in physiological processes in plants. It may manifest itself as reduction in owth and yield, and sometimes lead to the death of the plant and plant parts.

Plant stress can be very obvious visually; but often it is so slight as to go unnoticed by the casual observer until the yield results are in. Adverse soil moisture and temperature conditions in combination with nutrient deficiencies, diseases, insects, and weeds interact to create complex crop stress (Table 4.1). And proper diagnosis of such stress under field conditions becomes difficult.

Table 4.1: Sources of environmental stress for plants

Physical	Chemical	Biotic
Drought	Air pollution	Human Activities
Temperature	Allelochemicals	Insect
Radiation	Nutrients	Pests
Flood	Pesticides	Diseases
Wind	Salinity	

Moisture stress

Water is one of the major elements for agriculture and its shortage will certainly decrease crop production and productivity. In most of the arid and semi-arid regions, precipitation is too low to produce crops.

While heat availability determines the probability that a crop will reach maturity in a region, moisture availability establishes yield potential.

The occurrence of moisture stress during flowering, pollination, and grain filling, is harmful to most crops and particularly so to corn, soybean and wheat. Increased evaporation from the soil and accelerated transpiration in the plants causes moisture stress; as a result there is a need to develop crop varieties with greater drought tolerance. Peak irrigation demands also rise due to more severe heat waves. Additional investment for dams, reservoirs, canals, wells, pumps, and piping are needed to develop irrigation networks in new locations. Finally, intensified evaporation increases the hazard of salt accumulation in the soil.

Frequent droughts not only reduce water supplies but also increase the amount of water needed for plant transpiration. Higher air temperatures can also be felt in the soil, where warmer conditions are likely to speed up the natural decomposition of organic matter and increase the rates of other soil processes that affect fertility.

Salinity Stress

Salinity and drought stress are the major causes of historic and modern agricultural productivity losses throughout the world. Both drought and salinity may lead to inhibition of plant growth. Soil salinity affects plant physiology through changes of water and ionic status in the cells. Ionic imbalance occurs in the cells due to excessive accumulation of Na^+ and Cl^- (sodium and chlorine ions) and reduces uptake of other mineral nutrients, such as K^+, Ca^{2+}, and Mn^{2+} (potassium, calcium and manganese ions).

The agricultural use of saline soils can benefit many developing countries. Salt tolerant plants can utilize land and water unsuitable for salt-sensitive crops (**glycophytes**) for the economic production of food, fodder, fuel and other products. **Halophytes** (plants that grow in soils or waters containing significant amounts of inorganic salts) can harness saline resources that are generally neglected and are usually considered impediments rather than opportunities for development.

ere are three possible domains for the use of salt tolerant plants in developing untries. Theses are:

- Farm lands salinised by poor irrigation practices,
- Coastal deserts, and
- Arid areas that overlie reservoirs of brackish water

u may like to attempt an SAQ to fix these ideas.

Q 1

at do you understand by moisture stress and salinity stress? What effect do these esses have on plants, in general?

3 CLIMATE CHANGE AND AGRICULTURE

mate is one of the primary determinants of agricultural productivity. Agriculture s been a major concern in the discussions on climate change. You have learnt in it 3 that the increased atmospheric concentration of greenhouse gases (GHGs) is tributing to the process of climate change and global warming (Fig.4.1). In fact, United Nations Framework Convention on Climate Change (UNFCCC) cites intenance of our societal ability for food production in the face of climate change one of the key motivations.

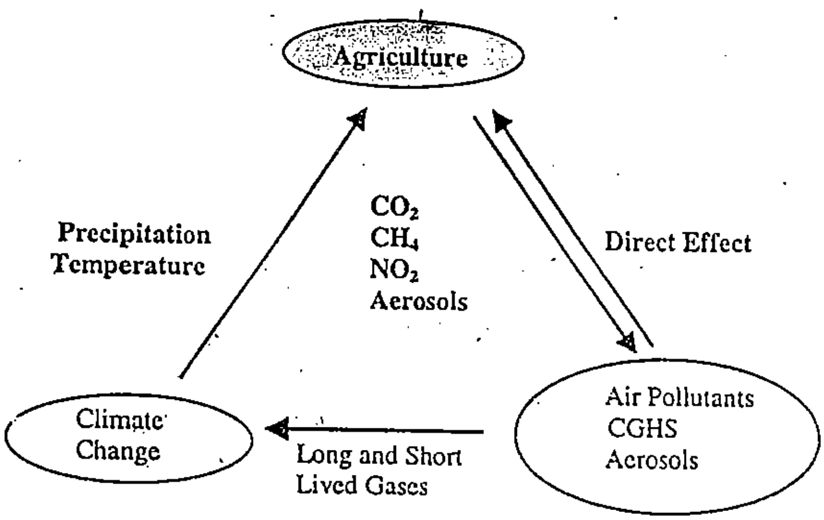


Fig.4.1: Changing atmosphere and agriculture

r Changing Atmosphere

ergy from the sun controls the earth's climate and weather, and heats the surface of earth; in turn, the earth radiates energy back into space. Atmospheric greenhouse es (water vapour, carbon dioxide, and other gases) trap some of the outgoing rgy, retaining heat somewhat like the glass panels of a greenhouse. Without this ural "greenhouse effect," temperatures would be much lower than they are now. l life as known today would not be possible. Instead, thanks to greenhouse gases, earth's average temperature is a more hospitable 60°F. However, problems may se when the atmospheric concentration of greenhouse gases increases.

ice the beginning of the Industrial Revolution, atmospheric concentrations of bon dioxide have increased by nearly 30%, methane concentrations have more than ibled, and nitrous oxide concentrations have risen by about 15%. These increases e enhanced the heat-trapping capability of the earth's atmosphere.

You may like to know: Why are greenhouse gas concentrations increasing?

Generally scientists believe that the combustion of fossil fuels and other human activities are the main reasons for the increased concentration of CO_2. Plant respiration and the decomposition of organic matter release more than 10 times the CO_2 released by human activities; but these releases have generally been in balance during the centuries leading up to the Industrial Revolution with carbon dioxide having been absorbed by terrestrial vegetation and the oceans.

An estimate of future emissions is difficult, because it depends on infrastructural; demographic, economic, technological, policy, and institutional developments. By 2100, in the absence of emissions control policies, carbon dioxide concentrations are projected to be 30-150% higher than today's levels.

Green House Gases and their Effects

The greenhouse effect plays a crucial role in regulating the heat balance of the earth. It allows the incoming short-wave solar radiation to pass through the atmosphere relatively unimpeded; but the long-wave terrestrial radiation emitted by the earth's surface is partially absorbed and then re-emitted by a number of trace gases in the atmosphere (Fig.4.2.). These gases known as **GHGs** (greenhouse gases) are: **water vapour, carbon dioxide, methane, nitrous oxide and ozone** in the troposphere and in the stratosphere. This natural greenhouse effect warms the lower atmosphere.

If the atmosphere were transparent to the outgoing long wave radiation emanating from the earth's surface, the equilibrium mean temperature of the earth's surface would be considerably lower and probably below the freezing point of water. Mere incidence of GHGs in the atmosphere, by itself, is no concern. What is more important is that their concentration should stay within reasonable limits so that the global ecosystem is not unduly affected.

However, by increasing the concentrations of natural GHGs and by adding new GHGs like chlorofluoro carbons, the global average and the annual mean surface-air temperature (referred to as the global temperature) can be raised, although the rate at which it will occur is uncertain. This is the **enhanced greenhouse effect**, which is over and above that occurring due to natural greenhouse concentration. Such a rise in the atmospheric concentration of GHGs has led to an upward trend in global temperature.

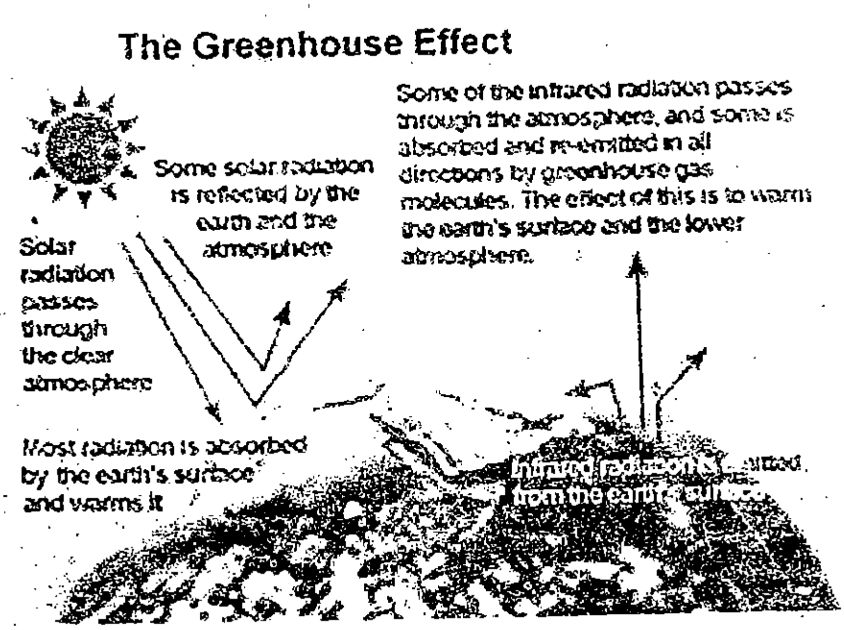


Fig.4.2: The Green House effect

Some sources of GHGs are:

- Energy production,
- Industries,
- Changes in land use patterns, and
- Agriculture and livestock.

However, sinks of GHGs like the following, help in removing them from the atmosphere:

a) Ocean is an important reservoir of CO_2.
b) Vegetation and soil sequester CO_2.
c) Major sink for methane (CH_4) is its reaction with OH in the troposphere.
d) There is no mechanism for the removal of halogenated halocarbons viz. (CFCs and HCFCs/ hydrochlorofluorocarbon); they are only removed by the photo dissociation in the stratosphere.

While it is required to follow the general commitments under the Framework Convention on Climate Change, many countries are not required to adopt any GHG reduction targets. Irrespective of international commitments, it seems prudent to be ready with

- Inventory of sinks and sources of GHG emission;
- Predictions of the cumulative impact of national and international GHG emissions to plan for temperature and sea level rise;
- Land use plans for the coastal areas likely to be affected;
- Water and land management strategies especially in the agricultural sector.

The atmospheric concentration of CO_2 has grown from about 280 to almost 370 ppmv, Methane (CH_4) from 0.70 to 1.72 ppmv (in 1994), Nitrous oxide (N_2O) from 280 to about 310 ppbv and CFC -12 from zero to 5.03 pptv since the industrial period (Table 4.2). This enhanced the naturally occurring green house effect.

Table 4.2: Green house gases influenced by anthropogenic activities

Gas	CO_2	CH_4	N_2O	CFC-12
Pre-industrial atmospheric concentration	280 ppmv	0.70 ppmv	280 ppbv	0
Current concentration	370 ppmv	1.72 ppmv	310 ppbv	5.03 pptv
Current annual increase (%)	0.5% (1.5 to 1.8 ppmv)	0.80% (0.013 ppmv)	0.25% (0.75 ppbv)	4% (18-20 pptv)
Atmospheric Life Time (Yrs.)	50-200	12-17	150	102
Global warming potential relative to CO_2	1	24.5	320	4000

Agronomic and economic impacts from climate change depend primarily on two factors:

1. The rate and magnitude of change in climatic factors and the agricultural effects of these changes; and

2. The ability of agricultural production to adapt to changing environmental conditions.

The snow cover in the Northern Hemisphere and floating ice in the Arctic Ocean have decreased. Globally, sea level has risen 4-8 inches over the past century. Worldwide precipitation over land has increased by about one percent. Increasing concentrations of greenhouse gases are likely to accelerate the rate of climate change. Scientists expect that the average global surface temperature could rise by 0.6-2.5°C in the next fifty years and by 1.4-5.8 ° C in the next century, with significant regional variation.

Evaporation will also increase, which will increase average global precipitation. Soil moisture is likely to decline in many regions, and intense rainstorms are likely to become more frequent (Fig.4.3).

Climate change can impact agricultural sustainability in two interrelated ways:

- First, by diminishing the long-term ability of agro ecosystems to provide food and fibre supply for the world's population; and

- Second, by inducing shifts in agricultural regions that may encroach upon natural habitats, at the expense of floral and faunal diversity.

Global warming may encourage the expansion of agricultural activities into regions now occupied by natural ecosystems such as forests, particularly at mid- and high-latitudes. Forced encroachments of this sort may thwart the processes of natural selection of climatically-adapted native crops and other species.

While the overall, global impact of climate change on agricultural production may be small, regional vulnerabilities to food deficits may increase, due to problems of distributing and marketing food to specific regions and groups of people. For subsistence farmers and more so for people who now face a shortage of food, lower yields may result not only in measurable economic losses, but also in malnutrition and even famine.

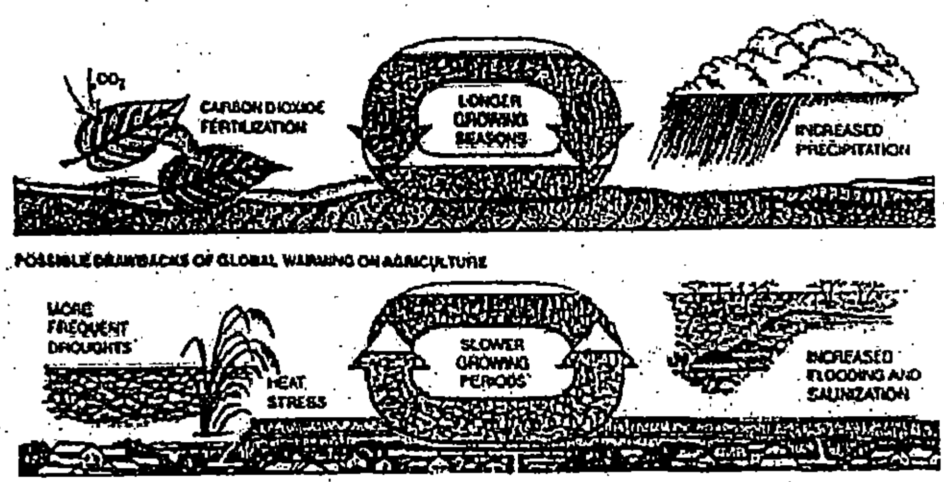


Fig.4.3: Advantages and disadvantages of global warming

It has also been observed that the warming has not been globally uniform, Northern hemisphere is experiencing more warming than Southern hemisphere (Fig.4.5). The most obvious feature of the global average temperature record is that of considerable variability, not just year to year but from decade to decade. However, there is still a lot of uncertainty on temperature changes.

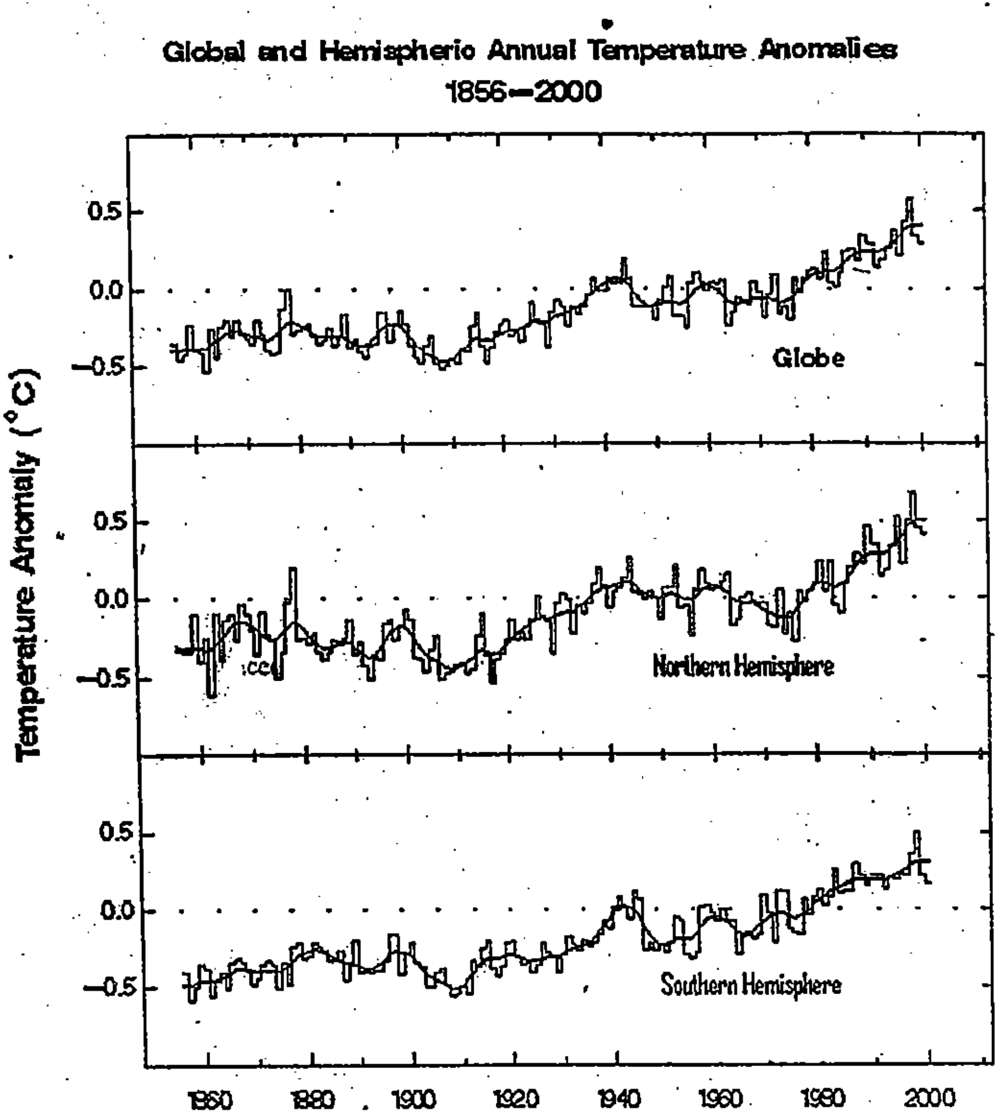


Fig.4.5: Temperature changes over the years

Climate and agricultural zones would tend to shift towards the poles. Because average temperatures are expected to increase more near the poles than near the equator, the shift in climate zones will be more pronounced in the higher latitudes. In the mid-latitude regions (45 to 60° latitude), the shift is expected to be about 200-300 km for every degree Celsius of warming. Since today each one of the latitudinal climate belts is optimal for particular crops, such shifts could have a powerful impact on agricultural and livestock production. Crops for which temperature is the limiting factor may experience longer growing seasons. For example, in the Canadian prairies the growing season might lengthen by 10 days for every 1°C increase in average annual temperature.

While some species would benefit from higher temperatures, others might not. A warmer climate might, for example, interfere with germination or with other key stages in their life cycle. It might also reduce soil moisture; evaporation rates increase in mid-latitudes by about 5% for each 1°C rise in average annual temperature. Another potentially limiting factor is that soil types in a new climate zone may be unable to support intensive agriculture as practiced today in the main producer countries. For example, even if sub-Arctic Canada experiences climatic conditions similar to those now existing in the country as southern grain-producing regions, its poor soil may be unable to sustain crop growth.

Longer growing seasons and warm winter will enable insect pests to complete a greater number of reproductive cycles and also allow larvae to winter-over in new areas and cause greater infestation during the following crop season. Altered wind patterns may change the spread of both wind-borne pests and of the bacteria and fungi that are the agents of crop diseases.

Climate models suggest that potential evapo-transpiration tends to rise most where the temperature is already high (i.e., low to mid latitudes), while precipitation tends to increase most where the air is cooler and more readily saturated by the additional moisture (i.e., in higher latitudes and near seacoasts). Thus, drier conditions may occur in many of the world's most important agriculture regions, a consequence that could have great practical importance. Both demand for and the supply of water for irrigation will be affected by changing hydrological regimes. Water quality tends to deteriorate under conditions of low flows and higher water temperatures, predicted for arid areas. In such areas, the effect of climate change on water quality may be especially significant.

Mid-latitude yields may be reduced by 10-30% due to increased summer dryness. Climate models suggest that today's leading grain-producing areas – in particular the Great Plains of the US– may experience more frequent droughts and heat waves by the year 2030. Extended periods of extreme weather conditions would destroy certain crops, negating completely the potential for greater productivity through "CO_2 fertilization". During the extended drought of 1988 in the US Corn Belt region, for example, corn yields dropped by 40% and, for the first time since 1930, US grain consumption exceeded production. The pole ward edges of the mid-latitude agricultural zones– northern Canada, Scandinavia, Russia, and Japan in the northern hemisphere, and southern Chile and Argentina in the southern one – may benefit from the combined effects of higher temperatures and CO_2 fertilization. But the problems of rugged terrain and poor soil suggest that this would not be enough to compensate for reduced yields in the more productive areas. In a $2 \times CO_2$ climate, an overall decline in production of wheat may be expected as a consequence of increase in temperature in the mid-latitudes.

The impact on yields of low-latitude crops is more difficult to predict. While scientists are relatively confident that climate change will lead to higher temperatures, they are less sure of how it will affect precipitation – the key constraint on low-latitude and tropical agriculture. Climate models do suggest, however, that the intertropical convergence zones may migrate pole ward, bringing the monsoon rains with them. The greatest risks for low-latitude countries, then, are that reduced rainfall and soil moisture will damage crops in semi-arid regions, and that additional heat stress will damage crops and especially livestock in humid tropical regions.

Warm temperatures may expand crop producing lands but crops that have become adapted to the growing-season day lengths of the middle and lower latitudes and may not respond well to the much longer days of the high latitude summers. Less than optimal conditions for net growth are more likely in warmer lower latitude regions.

Agriculture in low-lying coastal areas, where impeded drainage of surface water and of groundwater, as well as intrusion of seawater into estuaries and aquifers, might take place, would be threatened by sea-level rise. Adaptations may come in the form of switching crop varieties, introduction of high-efficiency irrigation which may involve major investments. Another way would be to breed heat and drought-resistant crop varieties by utilizing genetic resources that may be better adapted to new climatic and atmospheric conditions. Genetic manipulation may also help to exploit the beneficial effects of CO_2 enhancement on crop growth and water use. Adaptation may not be easy since major shifts in crops need to be made. Grain farmers may find themselves more exposed to marketing problems and credit crisis brought on by higher capital and operating costs of fruit and vegetable production.

In several areas where temperature is the limiting factor in crop production, growing seasons will lengthen by several days. This shift could also have disastrous effects on the economy of some smaller countries whose climate belts are optimal for a particular crop. The global warming trend would also increase evaporation from soil and plants. Also, it is true that warmer air holds more water vapour than cooler air, so global warming will bring about more precipitation on a global scale. This increased precipitation, however, does not necessarily mean more precipitation in certain regions. There would tend to be more frequent droughts in some areas and more frequent flooding in others.

In Africa, right on the edge of the world's largest, driest desert, the Sahara, there is a large freshwater lake, Lake Chad. This is a great example of effects on an area due to agricultural use. Lake Chad was once the sixth-largest lake in the world, but constant drought since the 1960's has shrunk it to 1/10 its size. The Chari River, at the southeast, which provides 90% of Lake Chad's water, now averages only about half of its original 40 billion cubic meters per year in the 1930-60s. The recent low levels are a concern, and have been monitored through satellite and other means by the Lake Chad Basin Commission and others.

Crops respond to increased temperature in complex ways– above a minimum level, response to a rise in temperature tends to be positive up to a characteristic optimum range. Similarly, experiments in India reported by Sinha (1994) found that higher temperatures and reduced radiation associated with increased cloudiness caused spikelet sterility and reduced yields to such an extent that any increase in dry-matter production as a result of CO_2 fertilization proved to be no advantage in grain productivity. Similar studies conducted recently in Indonesia and the Philippines confirmed these results.

But when temperature exceeded, crops tended to respond negatively, resulting in a steepening drop in net growth and yield (Fig.4.6).

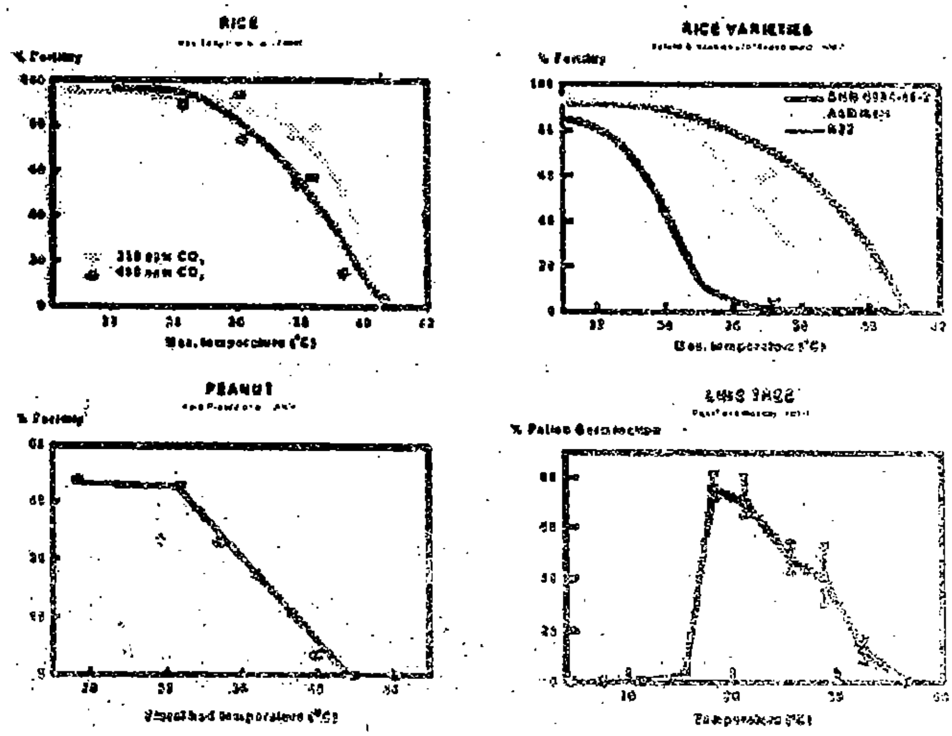


Fig.4.6: Temperature response of panicle fertility (rice and peanut) and pollen germination (lime tree)

The accelerated growth due to warmer temperatures results in quicker maturation and can actually reduce the yield of annual crops. Since many weeds are associated with major C_4 crops (maize, sorghum, sugarcane, and millet), the weed/crop competition for such crops may favour the weeds. Feeding requirement for insects may increase:

- Higher CO_2 may increase the carbon-nitrogen (C:N) ratio in crop leaves, stimulating the feeding of some insects.
- Some insects may need to eat more C-enriched leaves to gain adequate nutrition.

Impacts depend on how the hydrological regime changes the total seasonal precipitation, its within-season pattern, and its between-season variability. In Fig.4.7 we summarise the impact of global environmental factors on food production.

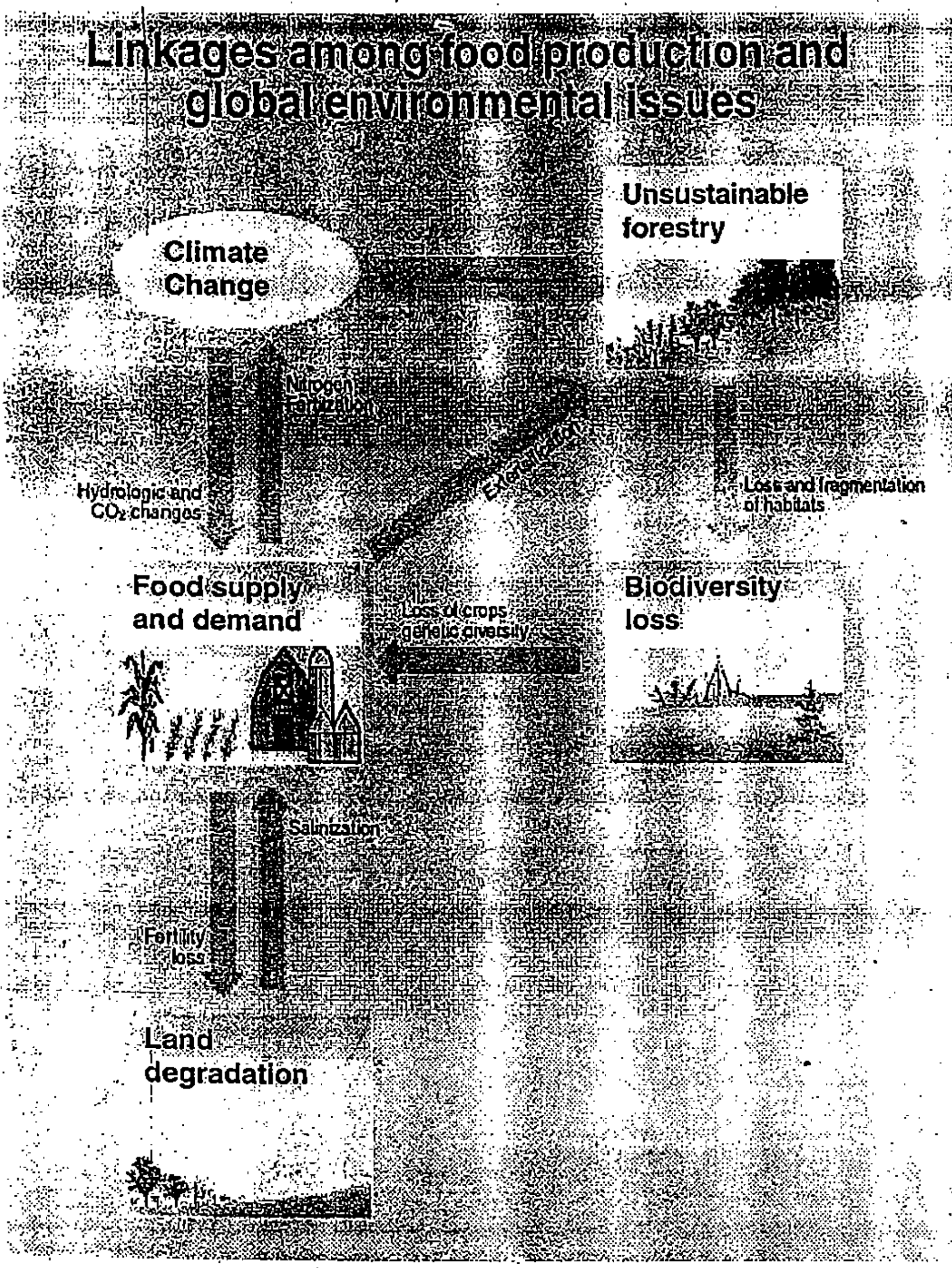


Fig.4.7: Linkages among food production and global environmental issues

SAQ 2

List the factors affecting global climate change. How does the increase in temperature affect agriculture?

4.3.2 Rising Atmospheric Carbon Dioxide (CO_2)

Increasing atmospheric CO_2 levels are expected to influence crop production in many different ways. The response to an initial increase in temperature by itself in isolation should generally be positive for crop yields. (The magnitude of the response varies from crop to crop and can change from positive to negative if the temperature change is too high.)

In terms of plant growth and development, higher rates of photosynthesis are found in entire canopies placed in a CO_2-enriched atmosphere due to the CO_2 "fertilization" effect.

Effect of increased concentrations of CO_2 on crop productivity

In principle, higher levels of CO_2 should stimulate photosynthesis in certain plants; a doubling of CO_2 may increase photosynthesis rates by as much as 30-100%. Laboratory experiments confirm that when plants absorb more carbon they grow bigger and more quickly. This is particularly true for C_3 plants (so called because the product of their first biochemical reactions during photosynthesis has three carbon atoms). Increased carbon dioxide tends to suppress photo-respiration in these plants, making them more water-efficient. C_3 plants include such major mid-latitude food staples as wheat, rice, and soybean. The response of C_4 plants, on the other hand, would not be as dramatic (although at current CO_2 levels these plants photosynthesize more efficiently than do C_3 plants). C_4 plants include such low-latitude crops as maize, sorghum, sugar-cane, and millet, plus many pastures and forage grasses.

Increased concentrations of CO_2 boost crop productivity. Yields of crops grown under drought conditions also respond to higher CO_2 concentrations. The greater the drought stress the greater is the relative response to CO_2 even in C_4 species. Thus crops grown in semi-arid environments would be expected to have as great or greater percent yield increase under high CO_2 – as do well watered crops. Crops with nutrient deficiencies can also respond positively to higher CO_2 concentration, though the extent of response and its mechanism need further investigation. The C: N ratio of the vegetation is greater for higher-CO_2 grown plants. Moreover, there have been indications that increased CO_2 concentration reduces the severity of yield reduction by soil salinity stress.

Most of the studies on climate change and agricultural production have been confined to temperate crops and hence such studies on tropical and sub-tropical crops need to be undertaken. A systematic effort to develop cost effective CO_2 enrichment technology in relation to crop production, may be made.

Effects on Weeds, Insects, and Diseases

Rising atmospheric CO_2 and climate change will also affect the associated agricultural pests. Distribution and proliferation of weeds, fungi, and insects are determined to a large extent by climate. Much more research has been done on the potential changes in weed growth than on changes in the spread of insects and diseases.

Weeds will be directly affected by changes in climate and in CO_2 levels. Insects and diseases are not likely to be directly affected by CO_2 changes, but may be affected indirectly because of altered host plant metabolism, development and morphology. New, previously unobserved combinations of climate, atmospheric constituents, and soil conditions may result and lead to new infestations of various pests. The overall importance of such developments is unclear at this point, but crop losses due to weeds, insects, and disease are likely to increase.

In general, populations of herbivorous insects are held in check by their ability to acquire enough nitrogen compounds from healthy unstressed plants. In longer term, vegetation grown in higher concentrations would be unable to support large insect population (as flea beetle, pink ball worm, leaf hopper on CO_2- enriched crop with low available nitrogen).

Overall impact of climate change

Temperature, precipitation, atmospheric carbon dioxide content, the incidence of extreme events and sea level rise are the main climate change related drivers which impact agricultural production.

Briefly the main categories of implications for agricultural productivity are **crops and forage productivity and production cost** where temperature, precipitation, atmospheric carbon dioxide content and extreme events are likely to alter plant growth and harvestable or grazable yield. Changes in wheat yield as affected by climate change with time are projected in Fig.4.8. Extreme events also play a role. For example, where droughts and floods become more severe or frequent, agricultural losses would increase.

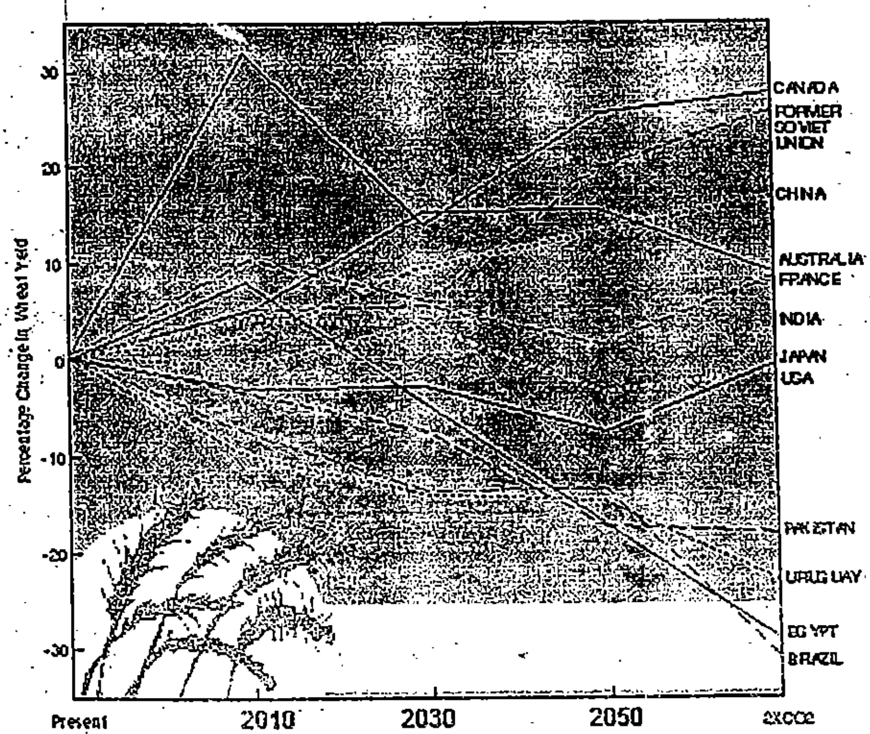


Fig.4.8: Calculated change in wheat yield resulting from a "business as usual" increase in atmospheric CO_2 and modelled climate change scenario, as applied to present conditions in the 12 countries shown.

Irrigation water supply will be influenced by changes in the volume of water supplied by precipitation as well as by temperature alterations effects on evaporation. Also changes in temperature regimes can alter the timing of snow melt based runoff and thus both the seasonality of available water supply and the needed size of impoundments holding water for summer supplies. Groundwater recharge rates and aquifer exploitation may also be altered. Non-agricultural water demand by municipalities and possibly some industries is also likely to be increased by increases in temperature. Extreme events also play a role where, for example, some studies indicate that the hydrologic cycle will be intensified such that droughts and floods will become more severe in low to mid-latitude regions again altering water availability seasonally and the need for impoundments.

Other Effects: In addition to the direct effects of climate change on agriculture, there are important indirect effects that can affect production. For example, sea level rise can inundate or require mitigation efforts along low-lying coastal regions. Indirect effects may also arise from alterations in the growth rates and distribution of weeds, pests and pathogens, rates of soil erosion and degradation, and alterations in ozone levels or UV-B radiation.

Effects on soil resources

Soil is a complex and dynamic system, consisting of a solid phase (both mineral and organic, particulate and amorphous), a liquid phase (water and solutes), and a gaseous phase (air with associated water vapour, often enriched with carbon dioxide and sometimes with methane as well). Soil responds to both short-term events such as the episodic infiltration of rainfall and long-term processes, such as physical and chemical weathering.

Only rough, qualitative estimations of the predicted climate change effects on soil are practical now, due to the uncertainties in the forecasts but also to the complex, interactive influences of hydrological regime, vegetation, and land use. Factors that need to be considered include:

- Temperature effects on soil nutrients;
- Hydrological effects on soil nutrients;
- CO_2 effects on soils; and
- Soil carbon accretion/depletion.

Soil suitability for agricultural production is affected in terms of available soil moisture for plant growth, moisture storage capacity and fertility. In particular, soil moisture loss is determined by temperature and maintenance of a constant water supply. Of course, any temperature increase needs to be offset by precipitation increases and/or expansions in applied irrigation water. Furthermore, microbial decomposition is stimulated by warmer temperatures. Therefore, the availability of soil nutrients and organic matter which helps hold the soil moisture may be negatively affected by warmer temperatures.

Livestock productivity and production cost are affected both directly and indirectly. Direct effects involve consequences for the balance between heat dissipation and heat production. In turn, a change in this balance can alter: a) animal mortality, b) feed conversion rates, c) rates of gain, d) milk production, and e) conception rates. Appetite may also be affected. Finally, carrying capacity in a region is altered by changes in the availability of feed and fodder.

SAQ 3

Explain the impact of rising atmospheric CO_2 on agricultural production.

4.4 OZONE HOLE AND ULTRAVIOLET RADIATIONS

Ozone is an unstable molecule formed by lightning and when free oxygen atoms are released in an oxygen-rich atmosphere. In atmosphere, most ozone is created when normal oxygen molecules are split apart by the action of ultraviolet light in normal sunshine. Ozone remains at the top of the atmosphere where it absorbs ultraviolet light, forming a "protective layer." Ozone decays naturally. It is broken apart faster in the presence of CFCs (refrigerants and propellants), oxides of nitrogen (auto emissions, power plants, forest fires, and volcanoes), and methane (agriculture and volcanoes). Thus, ozone that drifts into the lower atmosphere is destroyed. The "hole" refers to a thinning of this layer because of chemical reactions in the upper atmosphere, especially at the Earth's poles. The Antarctic ozone hole is defined as thinning of the ozone layer over the continent to levels significantly below pre-1979 levels. Ozone blocks harmful ultraviolet "B" rays. Loss of stratospheric ozone has been linked to skin cancer in humans and other adverse biological effects on plants and animals.

> The size of the ozone hole reached 10.9 million square miles on September 11, 2003. It was slightly larger than the North American continent, but smaller than the largest hole ever recorded, on September 10, 2000, when it covered 11.5 million square miles.

Life at the Earth's surface is protected from the harmful ultraviolet (UV) radiation from the Sun by the stratospheric ozone layer. Over the last several decades, synthetic chemical compounds, such as chlorofluorocarbons (CFCs) and halons, were developed to provide a new generation of refrigerants, insulating foams, fire retardants, and other products. Unfortunately, after extensive use of these compounds, it was discovered that they remain inert in the atmosphere until they reach the stratosphere, where they break down into an active form that destroys ozone (Fig.4.9). One chlorine atom originating from a CFC molecule can destroy thousands of protective ozone molecules.

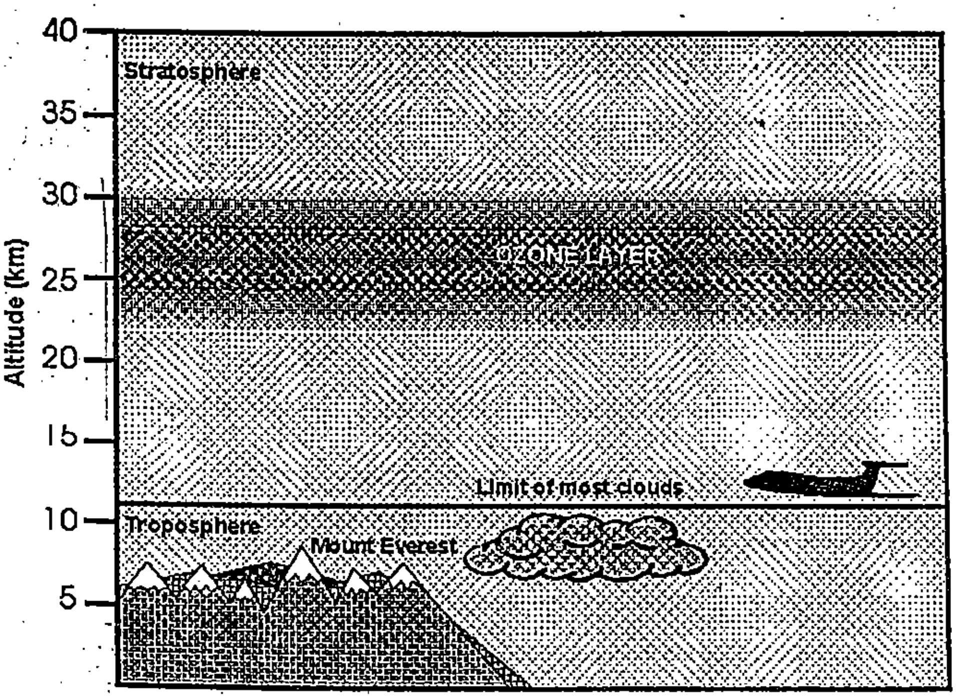


Fig.4.9: The location of the ozone layer

Satellite and ground-based observations confirm that losses of ozone are occurring seasonally, particularly in the springtime polar vortex of the Antarctic stratosphere, leading to what is known as the ozone "hole." Also of concern is the more moderate ozone depletion observed in mid-latitudes, where a large portion of the Earth's population resides.

A one percent reduction in ozone concentration in the upper atmosphere results in roughly a two percent increase in the amount of harmful UV-B radiation that reaches the earth's surface. This will have substantial negative impact on growth and yield of terrestrial plants as well as the health of many organisms that inhabit our planet including humans and animals.

- For every 1% decrease in stratospheric ozone, non melanoma skin cancers are predicted to increase by about 3%, and the mortality rate due to malignant melanomas among light skinned populations is expected to increase by roughly 1%.

- Increased UV-B radiation reduces the ability of the body's immune system to fight foreign substances that enter the body through the skin. It is also associated with various diseases of the eye, such as cataracts and deterioration of the cornea and retina in both humans and animals.

- Increased UV-B radiation negatively affects the growth of terrestrial plants, including many agricultural crops. It also penetrates the ocean surface and can damage fish larvae and juveniles. Studies performed in Antarctica during the appearance of the springtime ozone hole have shown that these short duration increases in UV-B radiation are already having an effect on natural populations of tiny microscopic plants called phytoplankton, which form the base of the ocean's food web. Reduction in the productivity of marine phytoplankton can have broad ranging implications for the entire marine ecosystem.

> UV-B can damage plant and animal life on earth. More UV-B reaches the earth as ozone levels decline because stratospheric ozone is the primary absorber of UV-B. This thin blanket shields us from the sun's harmful rays.
>
> High levels of UV-B radiation (280 to 320 nm wavelength) are responsible for many biologically harmful effects in both plants and animals.

Increasing UV-B irradiance and irradiation time decrease photosynthetic activity (thus production) in seedlings of common crops like radish (*Raphanus sativus*), soybean (*Glycine max*), bean (*Phaseolus vulgaris*), and loblolly pine (*Pinus taeda*). Also UV-B causes these plants to increase their flavonoid leaf content (apparently protective pigments). Furthermore, as the UV-B/photo synthetically active radiation (PAR) ratio increases with decreasing total irradiance (for instance, with increasing cloud cover), low radiation levels are potentially dangerous to some plants even though the UV-B levels may seem negligible. In the beginning of this decade, the US Environmental Protection Agency and International Rice Research Institute have initiated a co-operative programme to investigate the effects of UV-B and global climate change on rice. Rice is the world's most important food crop which responds to both UV-B and climate change.

We now summarise the contents of this unit.

4.5 SUMMARY

- Environmental factors that affect agriculture directly and indirectly include drought, salinity and global climate changes. Moisture and salinity stresses significantly affect agricultural productivity.

- Climate change affects agricultural production and productivity. In particular, accumulation of greenhouse gases (GHGs) leads to rise in temperature and influences agriculture. Rising atmospheric CO_2 on agricultural productivity is a subject of detailed investigation.

- When increased variability is included, significant increases in the variability of food supplies are foreseen. This leads to many concerns that need to be addressed by the International community:
  - Perception of increased risk may discourage adoption of new technologies and slow the growth of agriculture,
  - Diversification of crop production system,
  - Higher instability of food supplies on regional basis,
  - Frequent droughts and floods over larger areas,
  - Increased destabilizing effects of agricultural prices on food production and consumption.
- The **depletion of ozone (O_3) layer** allows the penetration of harmful UV-radiations through the atmosphere. This affects crop production and human health.

4.6 TERMINAL QUESTIONS

1. What is environmental stress? Name various sources of stress for plants. Describe two major environmental stresses in plants.
2. Describe sources and sinks of greenhouse gases (GHGs).
3. Explain the impact of ozone layer depletion on agriculture.

REFERENCES

1. Brinkman, R. (1995). 'Impact of climatic change on coastal agriculture'. In: "Climate Change Impact on coastal habitation", Edited by Doeke Eisma, Lewis Publ., 235-245.
2. CZMS, (1990). "Strategies for adaptation to sea-level rise". Published for IPCC, Geneva, by Ministry of Transport, Public works and Water management, The Hague, Netherlands. 122 pp.
3. Coastal Zone Management System (CZMS), 1992. "Global Climate change and the rising challenge of the sea". Published for IPCC, Geneva, by Ministry of Transport, Public works and Water management, The Hague, Netherlands. 35 pp and 5 appendices.
4. Downing, T.E., (1991). "Assessing socio-economic vulnerability to famine: frameworks, concepts and applications". FEWS Working Paper 2.1. USAID, Washington. 102 pp.
5. Downing, T.E., (1992). "Climate change and vulnerable places: global food security and country studies in Zimbabwe, Kenya, Senegal and Chile". Res. Rep. N. 1, Envir. Change Unit, Oxford, x + 54 pp.
6. Factbook, (1997). "The World Factbook 1996

   http://www.odci.gov/cia/publications/nsolo/wfb-all.htm
7. FAO, 1997. "Seawater intrusion in coastal aquifers. Guidelines for study, monitoring and control". FAO Water Reports N. 11, Rome. 152 pp.
8. Fedra, K., L. Winkelbauer and V.R. Pantalu, (1991). "Expert systems for environmental screening. An application in the lower Mekong basin". IIASA report RR-91-19, Laxenburg, Austria. 169 pp.

9. Gommes, R., (1992). 'Current climate and populations constraints on agriculture', chapter 4 (pages 67-86) in: Kaiser, H.M., and T.E. Drennen, "Agricultural Dimensions of Global Climatic Change". St. Lucie Press, Delray Beach, Florida, 311 pages.

10. Gommes, R., (1998). 'Some aspects of climate variability and food security in sub-Saharan Africa'. To be published in "Proceedings of the International Conference Tropical Climatology, Meteorology and Hydrology", Brussels 22-24 May 1996. G. Demaree, J. Alexandre and M. de Dapper, eds. 19pp.

11. IPCC, (1996a). "Climate change 1995", 'The science of climate change'. Contribution of Working Group I to the Second Assessment Report of the Intergovernmental Panel on Climate Change. Edited by J.T. Houghton, L.G. Meira Filho, B.A. Callander, N. Harris, A. Kattenberg and K. Maskell. xii + 572 pp.

12. Sinha, S.K., Rao, N.H. and Swaminathan (1989). Food security in the changing global climate. In: Climate and food security (Proceeding of International Symp. on climatic variability and food security in developing countries, IRRI, Philippines. pp. 579-598.

UNIT 5 SUSTAINABILITY: THE NEW PARADIGM

Structure

5.1 INTRODUCTION

The introduction of high yielding varieties in the developing countries required intensive use of fertilizers and the past few decades witnessed remarkable increase in agricultural productivity. The agro-technological innovations also brought about an element of resilience in agriculture to ward off the threats of famines. The impact of Green Revolution in India on mitigating hunger and on bringing an overall rural prosperity was so dramatic that India emerged as a role model for many developing countries.

But success always has its costs, and Green Revolution has been no exception. Recent evidences, though not always verifiable, support the adverse impact of excessive use of agro-chemicals including fertilizers and water on the crop productivity, environment and health of living beings. The productivity growth rates of major food crops like rice and wheat have started stagnating, or even declining, in some intensively cultivated areas, thus posing a threat to national food security.

Today agriculture in developing countries faces major problems such as depletion of soil nutrients and water reserves, increased incidences of soil salinity and water-logging, decline in factor productivity, resurgence of pests and diseases and increased environmental pollution. Continuous diversion of prime agricultural lands to non-agricultural purposes and fragmentation of farm holdings have further aggravated the problems. It is in fact due to these pressing problems that sustainability of agricultural production systems and environment has emerged as a serious concern.

The amount of food needed would keep increasing as we progress in time. Multiple crops would need to be grown from the same land which implies increased mining of soil for plant nutrients. We know that large amounts of plant nutrients are lost due to soil erosion. The question is: Will the soils in South Asian Countries be able to sustain such heavy nutrient mining? Deficiencies of several micronutrients are already showing up in large areas in these countries. This is just one indicator of decreasing sustainability of our agricultural production system. The sustainability of environment and other natural resources like water is also being questioned by politicians, policy makers, researchers and the farmers themselves. Therefore, in this unit we sensitise you to the issue of sustainability in agriculture.

Objectives

After studying this unit, you should be able to:

- explain the concept of sustainable agriculture;
- describe the parameters of sustainable agriculture; and
- discuss various approaches for practicing sustainable agriculture.

5.2 CONCEPT OF SUSTAINABILITY

Sustainable agriculture is a loosely defined term that encompasses a range of strategies to address the **problems of agriculture**. These problems include

- loss of productivity from soil erosion,
- non-judicious use of agro-chemicals particularly pesticides and fertilizers,
- pollution of surface and ground water due to agricultural practices and inputs,
- diminishing supply of non-renewable energy sources, and
- decreased farm income owing to low commodity prices and high production costs.

Thus the **concept of sustainability** has several dimensions: **socio-economic, cultural and environmental**.

Depending upon the stage of development of scientific agriculture, extent and quality of natural resources, resource base of the farming community, intensity of biotic pressure etc., sustainability has different meanings for different socio-economic strata in the developed and developing countries. It is a complex concept which is generally seen as human-centred, long-term and involving interaction with natural systems.

Giampietro et al. (1992) noted that agricultural production systems optimized through economic indicators ignore the fact that human managed systems may be degrading human resources by consuming non-renewable sources and reducing the capacity of some parts of the natural systems to renew or recycle. Adams et al. (1992) also highlighted the need for linkages between economic and ecological indicators of changes in land use. In view of this, FAO, (1989) observed that

> **The goal of sustainable agriculture is to maintain production at levels necessary to meet the increasing aspirations of an expanding world population without degrading the environments.**

Before

After

Fig.5.1: Sustainable agriculture should help in meeting food needs without degrading the environment

Janvry and Garcia (1988) emphasized the need for gender equity in sustainable agricultural production systems. Thus from the viewpoint of developing countries, sustainable agricultural production must:

- meet the changing food, feed, fibre and fuel requirement of the nation,
- assure adequate profit to the farmers,
- conserve and, if possible, improve the natural resource base,
- prevent the degradation of the environment,
- discourage regional imbalances, and
- encourage gender equity.

All these measures of sustainability are subjective rather than quantifiable concepts. Two indices are commonly used to identify the practices which give maximum sustainable yield or maximum sustainable income. These are 'Sustainable Yield Index (SYI)' and 'Sustainable Value Index (SVI)'.

Sustainable Yield Index (SYI)

SYI is defined as

$$SYI = \frac{Y - \sigma}{Y_{max}}$$

where Y is the estimated average yield of a practice over years, σ is its estimated standard deviation and Y_{max} is the observed maximum yield in the experiment. In calculating SYI, the negative values of $(Y - \sigma)$ should be takes as zero since yield is always a positive quantity. With this premise, the index takes values between zero and unity. In this index, σ quantifies the risk associated with the average performance Y of a treatment. When $\sigma = 0$ and $Y = Y_{max}$, SYI = 1.

Sustainable Value Index (SVI)

In the case of cropping systems, since more than one crop is involved, the economic assessment of these systems becomes important. In these situations, obtaining maximum sustained level of income is more desirable. To asses these situations on the basis of sustainable income, the index called Sustainable Value Index (SVI) is used. For arriving at SVI, the monetary values of economic produce are used instead of yield values. On one end of the spectrum are the developed countries with almost a zero growth rate of agricultural production, and threatened with a problem of over-production of agriculture and environmental degradation through industrialization and excessive use of agro-chemicals. On the other end are developing countries like those of the South Asian Region with population growth outstripping agricultural productivity growth. They need to produce more and more food, fibre and fuel from less and less of land. At the same time they are facing the ill effects of modern agricultural practices on the environment.

In South Asian countries, it is envisaged that if the current practice of exploitative management of natural resources and low productivity of agriculture continues, a child born today has less chance of getting adequate food to eat, enough space to live, clean water to drink and pure air to breathe in the years to come. Hence, sustaining the past achievements without deterioration in environment, particularly soil and water resources will continue to be the greatest challenge before agriculture in developing countries like ours.

SAQ 1

Why has the issue of sustainability become so important? Explain in the specific context of your region/country.

5.3 PARAMETERS OF SUSTAINABLE AGRICULTURE

You have just studied that sustainable agriculture involves successful management of resources to satisfy changing human needs while maintaining or enhancing the quality of environment and conserving natural resources. In predominantly agriculture-driven economies, sustainable agriculture could more aptly be defined as the one that over the long-term:

- enhances environmental quality and the resource base on which agriculture depends,
- provides for basic human food and fibre needs,
- is economically viable, and
- enhances the quality of life for farmers and society as a whole.

From these definitions as well as other relevant documents on the subject, the following aspects of sustainable agriculture emerge:

i) Meeting the changing needs of today and tomorrow,

ii) Economic viability and enhanced productivity,

iii) Successful management of external and internal, and renewable and non-renewable resources,

iv) Maintenance, and preferably enhancement of the quality of environment,

v) Conservation of natural resources, particularly, soil, water and biodiversity, which form the base of agriculture.

Fig.5.2: Sustainable agriculture should help us conserve our natural resources

A system should be considered sustainable if it uses inputs, both those produced on the farm and those purchased externally, in the most efficient manner to maximize productivity and profitability while minimizing their adverse effect on environment. In other words, technology or practice, which over a period causes adverse effect on soil, water, biodiversity or climate would be considered contributing to unsustainable agriculture.

There are several parameters that characterize sustainable agriculture and we discuss some of these here.

5.3.1 Sustainability Indicators

Certain parameters related to crop yields, productivity, nutrient status, diseases as well as soil health and soil properties are referred to as **sustainability indicators.** We briefly discuss some of these.

Crop sustainability indicators (SI)

Yield: Crop yields determine agricultural production and therefore, this is an important SI. Several studies on rice-wheat cropping system done at experimental centres in India have reported a yield decline in rice (Nambiar, 1994). Of the 7 long-term rice-wheat experiments examined by Ladha et al. (2000), none had a significant decline in wheat yield, but rice yields at Pantnagar declined at a rate of 2.3% per year, while the decline at Ludhiana was 2.7% per year. Such results question the sustainability of the rice-wheat cropping system and call for ameliorative measures if this cropping system is to continue.

Factor productivity: Factor productivity is the ratio of output and input in a production system. When only one input such as fertilizer nitrogen is taken into consideration, it is termed as **partial factor productivity** (PFP) and the input indicated by a subscript. For example, PFPn is referred to as PFP for nitrogen. Yadav (1998) studied PFPn from the field experimental data for 16 years from 4 research centres in India (Pantnagar, Faizabad, Sabour and Rewa) and observed that there was a decline in PFPn in rice but not in wheat.

Kumar et al. (1998) on the other hand studied **total factor productivity** (TFP) in 3 states of India (Punjab, Haryana and Uttar Pradesh) and found that TFP during 1985-92 was lower than that in 1976-85; as a matter of fact, it was negative in Uttar Pradesh. Farmers in these 3 states have increased their fertilizer application rates over the years to obtain the same yield and this indicates a general feeling of reduced PFP due to fertilizers.

Nutrient deficiencies in crop plants: Nutrient deficiencies are good sustainability indicators, which if detected in time can save a crop and future prophylactic measures can sustain production from that crop.

Disease and pest hazards: Disease and pest hazards can sometimes make an agricultural production completely unsustainable unless ameliorative measures are immediately taken up.

Soil sustainability indicators

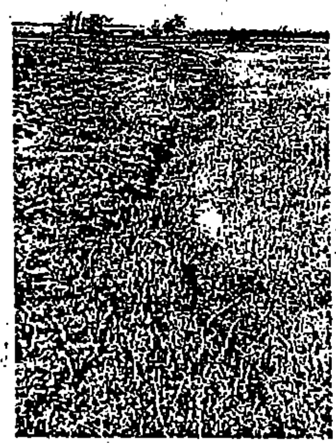
The quality and health of soils determine agricultural sustainability and environmental quality and as a consequence, plant, animal and human health.

Soil fertility: Soil fertility is an important SI and can be easily monitored.

Soil physical properties: Soil physical properties such as soil structure, bulk density, hydraulic conductivity and infiltration rate affect agricultural production.

Soil ecology: Soil ecology can influence organic matter dynamics, nutrient cycling, soil structure and aeration, and is an important SI.

Soil salinity and alkalinity: With increasing area under irrigation without adequate drainage, salinity/alkalinity problem is on the increase and it is becoming a serious problem in many areas of our country for sustained agricultural production.



(a)

(b)

Fig.5.3: Soil and water conservation measures transform a field from (a) to (b).

5.3.2 Water

Agriculture is the biggest consumer of water worldwide. In Asia, it accounts for 86% of total annual water withdrawal. Of all the crops, irrigated rice in particular is a heavy consumer of water; it takes some 5,000 litres of water to produce 1 kg of rice. The general figures for rice and wheat are 7,650 and 4,000 m^3/ha. Projections suggest that most Asian countries will have severe water problems by the year 2025 (IRRI, 1995).

Water availability is an important index of sustainability of agriculture. In the rice-wheat belt of northern India, there are reports of serious decline in ground water and its level is receding fast. This is attributed to over-withdrawal of ground water. Such an agricultural production system is definitely not sustainable and calls for immediate measures to change it. In Unit 7, we discuss the issues related to water in detail.

5.3.3 Socio-economic Factors

Regional imbalance: Progress in agriculture has not been uniform in developing countries. An example may be taken from India of irrigation as a natural resource and input. Data on growth in irrigated area by 1966-67 and 1996-97 in different states of India shows that by 1996-97, the state of Punjab had 92.9% of its area under irrigation, followed by Haryana (76.2%) and Uttar Pradesh (68.7%). On the other hand, Maharashtra had only 14.4% area under irrigation by 1996-97 and the value for Karnataka was only 21.9%.

Although regional imbalances are unavoidable due to availability of water resources in a region, they do create a problem for a uniform sustainable agricultural production in a given country. The only option left is to develop different agricultural production systems for different states/regions, depending upon their water and soil resources so that the differences between money earned per hectare are minimized. The effort should be towards maximizing per capita agricultural income so that near uniform living standards are attained, which is a Herculean task for all developing nations and governments.

Gender equity: In several regions of these countries, hard manual labour in agriculture is left for women, while they have little role in decision-making. However, with the progress in women's education and opening of more and more job opportunities for them, this trend is on the decline. This is a welcome change. Such changes in the social system will have a definite bearing on agricultural production systems in rural areas of these countries, hopefully towards betterment.

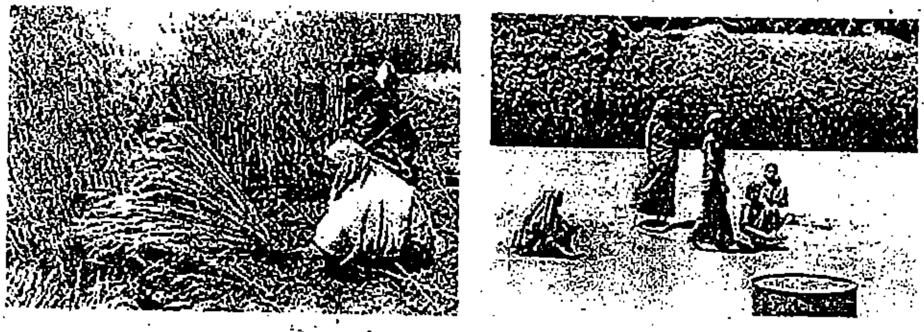


Fig.5.4: Gender equity is a major issue in sustainable agriculture

As the perception of the term sustainability is not the same under all situations, the parameters to define and measure sustainability of an agricultural system may also vary according to local and national needs, food security scenario, socio-economic conditions of the farmers and the quality of resources. A sustainable system is one with a non-negative trend in a measured output. In other words, **a system can be considered sustainable over a defined period if the outputs do not decrease when inputs are not increased.**

Some research efforts have been made to identify and evaluate efficient sustainability parameters. Important indices that have emanated out of sporadic studies are given as under:

i) Partial factor productivity and total factor productivity;

ii) Agronomic or incremental efficiency of external inputs;

iii) Physiological or internal efficiency of external inputs;

iv) Soil quality index;

v) Sustainable yield index;

vi) Benefit-cost ratio;

vii) Soil organic matter levels; and

viii) Apparent nutrient balance sheets.

In fact, a single sustainability index that addresses productivity, resource utilization, environmental aspects and economic viability is lacking, though the same may be of immense practical significance. Unfortunately, 'sustainability' has been used merely as a fancy word by researchers, planners and policy makers. Sincere and continued efforts to understand and evaluate sustainability of an agricultural system, management practices or processes are scarce and sporadic.

SAQ 2

a) List the sustainability indicators. Which parameters of sustainability are relevant to your country's agriculture?

b) What do you understand by the term 'factor productivity'?

5.4 APPROACHES FOR SUSTAINABLE AGRICULTURE

The term 'sustainable agriculture' and 'alternative agriculture' are often used as synonyms to refer to a spectrum of farming practices which provide farmers with economically viable and environmentally sound alternatives to developing their farming systems. The sustainable or alternative agriculture should necessarily pursue the following goals:

- More thorough incorporation of natural processes such as nutrient cycles, nitrogen fixation and pest-predator relationships into the agricultural production systems,
- Reduction in the use of off-farm inputs (you will learn about these in Unit 10) having greatest potential to harm the environment or the health of farmers and consumers,
- Greater productive use of the biological and genetic potential of plant and animal species,
- Matching cropping patterns and their production potential with physical limitations of agricultural lands (this would ensure long-term sustainability of current production levels), and
- Profitable and efficient production with emphasis on improved farm management and conservation of soil, water, energy and biological resources.

Sustainable agriculture can be achieved through the following measures:

Crop Diversification: Crop diversification methods like rotation, mixed cropping, inter-cropping, double cropping have been found successful in many situations. The major advantages of these types of diversification include

- reduced erosion,
- improved soil fertility,
- minimization of risk, and
- increased yield.

Crop diversification can be done by adopting the principle of crop rotation, inclusion of crops with biological nitrogen fixation and following the practices of mixed cropping and efficient cropping systems.

(a)

(b)

Fig.5.5: a) Inter-cropping; b) Mixed cropping

Choice of crops and animal components of farming system: The sustainable agricultural revolution may be triggered by shifting our mindset from a commodity-centred approach to an entire cropping or farming system. The triple goals of "more food, more income and more livelihoods" per hectare of land can be achieved provided suitable combinations of farming system components (crops, animal husbandry, forestry, fisheries, poultry agro-industries) are chosen and supported by resource based eco-technologies and farmers' participatory approach.

Genetic Diversity: Green revolution has led to genetic homogeneity with a greater genetic vulnerability to biotic stresses. Therefore, there is a need of growing crop varieties with different genetic constitutions in different agro-climatic zones. This will minimize the risk of crop failure during the insect-pest and disease attack as well as during the adverse climatic situations.

Integrated Nutrient Management (INM): INM is a principle and concept of using the different sources of nutrients like organic manures, chemical fertilizers, biological nitrogen fixation and other methods of nutrient saving in an optimum manner. Thus the productive potential of the soil can be maintained over a long period of time without adverse effects on the environment. INM also includes use of a suitable variety, optimum cultural management and soil and water use for efficient and sustainable crop production.

The important components of INM are – **fertilizers, farmyard manure, compost, crop residues, green manure, green leaf manure, rhizobium, blue green algae, phosphate solubilizing bacteria** and **azolla.**

The important steps for the adoption of INM are as follows:

i) a system approach for the management of nutrients should be followed so that input use efficiency can be increased,

ii) the recommendation of fertilizers should be based on soil test values,

iii) agronomic practices like split application of fertilizers, use of coated and granulated fertilizers, optimum combination of organic and inorganic sources of nutrients and right method of fertilizer placement should be adopted,

iv) conjunctive use of farm waste should be made,

v) nutrient responsive varieties should be selected, and

vi) appropriate water management strategies considering the right moisture nutrient interaction, should be used.

The basic concept underlying the principles of INM is the maintenance of and/or improvement of soil-fertility for sustaining crop productivity on long-term basis. This may be achieved through combined use of all possible sources of nutrition and their scientific management for optimum growth, yield and quality of different crops in their cropping systems in an integrated manner and in specific agro-ecological situations (recall Unit 2).

Organic materials were practically the only external source of nutrients to crops before the introduction of inorganic fertilizers. As a result of the advent of quick acting chemical fertilizers, a stage has reached that the supplementary and complimentary role of organic materials is being understood once again for sustainable agriculture and keeping the soil health in order. With an ever increasing cost of chemical fertilizers and their contribution to the degradation of the agricultural lands, it has been realized that organic materials such as organic manures, crop-residues, green manures, bio fertilizers and legumes in rotation, will have to be utilized judiciously to maintain and improve the soil fertility and productivity.

The manuring and recycling of various forms of residues has the advantage of converting the animal and farm wastes into useful product for meeting nutrient requirement of crops, besides maintaining the soil conditions and improving the overall ecological balance. As most parts of the plant nutrients are required by animals and human beings, if not regulated properly, enormous losses take place and substantial amount of nutrients are wasted.

Resource conservation and their regulated recycling for production is the option for sustained living.

But two basic questions remain unanswered while recommending integrated nutrient management.

i) **To what extent can INM replace commercial fertilizers on field scale?**

In developing countries like India, most farmers are poor and marginal and may not afford to go for a green manure crop at the cost of some economic crop in sequence. Animal manure in huge quantities may not be available to effectively contribute to the nutrient needs of the intensive cropping systems and that also when most of the cow dung is utilized as cakes to meet the domestic needs of fuel.

ii) **To what extent can the use of commercial fertilizers be reduced through INM without any reduction in the targeted growth rate of food grain production to accommodate the growing needs of the increasing population of the country?**

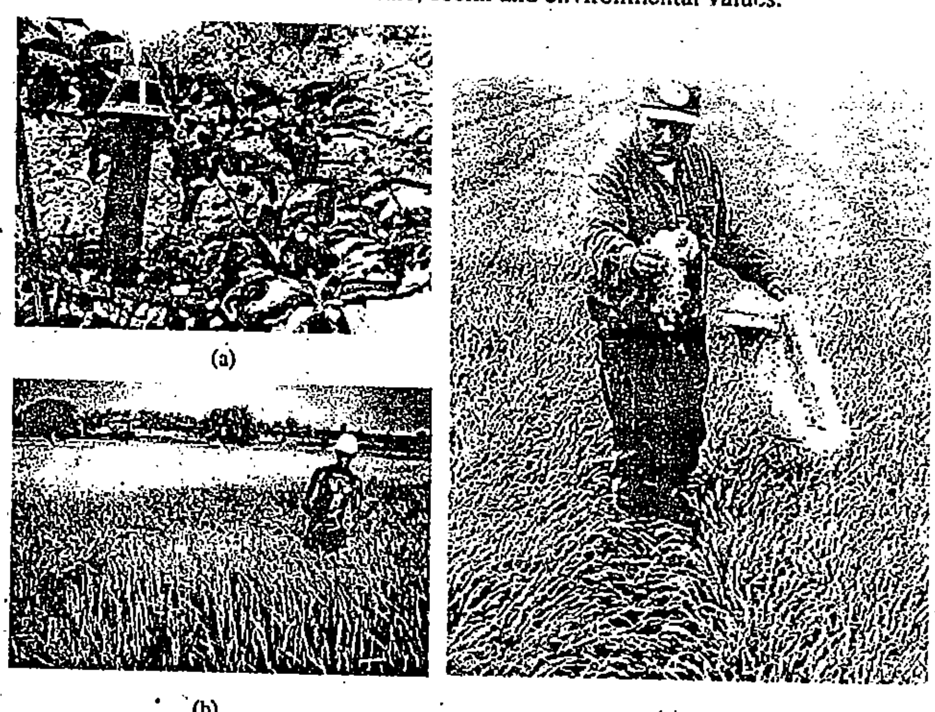
It is widely felt that in the event of a heavy cut on fertilizer use, it will be difficult to meet the growing food needs and no alternative will be left except bringing additional land under cultivation and thereby again damaging or destroying the natural ecosystem.

SAQ 3

a) What do you understand by integrated nutrient management?

b) How does integrated nutrient management affect the sustainability of agriculture?

Integrated Pest Management (IPM): IPM is a philosophy of controlling the pest in the crop field (in the context of the associated environment) by utilizing all suitable techniques and methods in as compatible a manner as possible and maintaining the pest population at levels below those causing economic injury. It deals with the optimization of different pest control practices and not the maximization of pest control in terms of overall economic, social and environmental values.



(a) (b) (c)

Fig.5.6: Practices in IPM; a) Bug trap; b) Spraying insecticide and c) Releasing ladybugs for aphid control

The important components of IPM are

- use of pest resistant or tolerant varieties,
- cultural practices like early or late planting, summer ploughing, use of pheromone traps, use of parasites, predators, and pathogens of crop pests, quarantine measures, hand collection etc.,
- judicious use of pesticides and other chemicals used for pest control.

IPM is a knowledge intensive approach and is still more of an aspiration than a reality for the average farmer in developing countries.

Sustainable Water Management: Water is an important natural resource required for crop production, human and animal need and for a number of atmospheric phenomena which are necessary for life. The necessary steps for achieving the sustainable use of water resources are as follows:

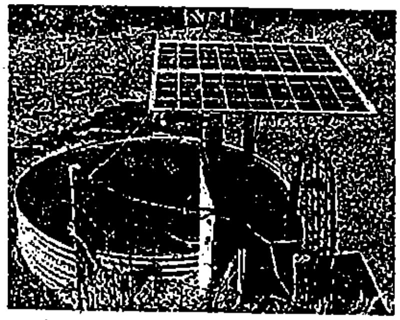
- effective water saving,
- equity in water sharing,
- efficiency in water delivery and use, maintenance and recharge of both ground and surface water resources.
- there should be an integrated policy for the conjunctive and appropriate use of rain, river, ground, sea and sewage water.

Fig.5.7: Water conservation through drip and sprinkler irrigation

Post harvest Management: Income enhancement through better management of plant produce by ensuring good transport, grading, processing is becoming popular now-a-days. Farmers will not only adopt the best available threshing, storage and processing measures but will also try to produce value added products from every part of the plant or animal.

Investment in sanitary and phytosanitary measures is important for providing quality food both for domestic consumers and for export. To assist the spread of post harvest technology awareness, governments in developing countries should make a major investment in storage, roads, transportation and on sanitary and phytosanitary measures.

Energy Management: Energy management is an important and essential input. Besides the energy efficient systems of land, water and pest management described earlier every effort will have to be made to harness biogas, biomass, solar and wind energies to the maximum extent possible. Solar and wind energy can be used in hybrid combinations with biogas for farm activities like pumping water and drying grains and other agricultural produce as you will learn in Unit 9.



(a)

(b)

Fig.5.8: Alternative energies in farming; a) solar water pump; b) wind energy.

Extension of Technologies and Managing Information Input: New communication and computing technologies will have profound implications in everyday research activities. Remote sensing and other space satellite outputs are providing detailed geographic information useful for land and other natural resource management.

Programmes for extension education and communication for farmers will certainly help popularize the sustainable agricultural practices. A very important option in extension techniques towards sustainable agriculture is "Social Engineering" which means influencing the farmers' attitude to make them aware about ecological production and economic consequences of a technology and policy being adopted. This can make all the above components successful at a farmer's field level.

Decision Support System (DSS): The decision support systems (DSS) involving simulation modelling comprises of studying simultaneously the soil-plant-environment continuum. Once an appropriate model is developed and validated under a defined farming situation, sustainability of a management practice or practices can be evaluated even without long term experiments (LTEs) under similar situations. The data of existing LTEs can also be used for deriving useful predictions and trends on sustainability of production systems. The weather data, genetic coefficients of the crops and soil parameters as per requirements of the DSS models usually suffice.

The major problem with this approach is that modelling of biological systems is still in its infancy. Whichever models are developed, their success and reliability of simulation depend on the quality and the amount of minimum data set generated to validate and run the models. Nevertheless, there is a great scope to develop and improve the simulation models for their use in sustainability analysis. Majority of the existing models are meant for simulation of crop growth and nutrient dynamics in soil-plant system under given set of environmental conditions. There should be an effort to include, if possible, an economics sub-routine in existing models, or develop new models with capability to simulate economic viability besides crop growth and other parameters.

We now summarise what you have studied in this unit.

5.5 SUMMARY

- Sustainability of agriculture in developing countries is believed to be at stake for three major reasons that emerged as a consequence of intensive farming:
  - excessive use of irrigation water,
  - replacement of rich diversity of traditional varieties with fewer high yielding varieties, and
  - indiscriminate use of fertilizers and pesticides.
- As the per capita availability of agricultural land in these countries is further shrinking, sustainable agricultural productivity has to be thought about in terms of raising yield levels until population stabilizes and malnutrition is alleviated. Here

sustainable productivity implies a reasonable level of production without harming the ecosystem.

- In order to realize sustainable agriculture, it is important to **maintain soil health and quality, practice scientific principles of crop rotation, maximize benefits from natural nutrient cycles of flows, minimise soil loss and protect ground waters from contamination.**

- Though considerable improvement in productivity has so far come from greater use of energy, chemicals, water and machinery, the alternative route for achieving the goal without harming the long-term productive potential of soil exist in adoption of sustainable agricultural strategies. Research on restoration ecology and intensification of agriculture in inter-connectivity with animal husbandry, forestry, plantation, horticulture, fisheries and other agricultural enterprises requires much more support.

5.6 TERMINAL QUESTIONS

1. What do you understand by sustainability?
2. Describe the reasons for unsustainability in agricultural practices in your area.
3. What are the parameters and goals of sustainable agriculture?
4. Discuss the approaches of sustainable agriculture.

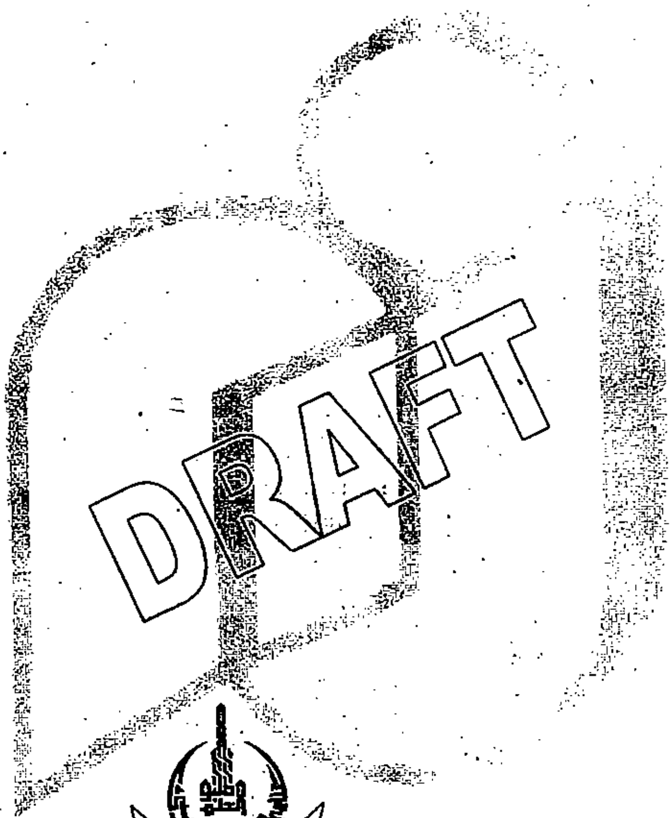
REFERENCES

1. Adams, W.H., Bourn, N.A.D. and Hodge, I. (1992) Conservation in the wider country side. *Land Use Policy* 41: 235-247.
2. FAO (1989) Sustainable Agricultural Production – Implications for International Agricultural Research. *Research and Technology Paper* 4, FAO, Rome, 152 p.
3. Giampietiro, M., Corretelli, G. and Pimentel, D. (1992) Agricultural analysis of agricultural ecosystem management, human return and sustainability. *Agricultural Ecosystem & Environment* 38: 219-244.
4. IRRI (1995) Water – A Looking Crisis, International Rice Research Institute, Los Banos, Philippines. pp. 90.
5. Janvry, A. de and Garcia, R. (1988) Rural poverty and environmental degradation in Latin America: causes, effects and alternative solution. Paper presented at the *International Consultation on Environment, Sustainable Development and the Role of Small Farmers.* International Funds for Agricultural Development, Rome.
6. Kumar, P., Joshi, P.K., Johansen, C. and Asokan, M. (1998) Sustainability of rice-wheat based cropping system in India. *Economic and Political Weekly* 33:A 182-188.
7. Ladha, J.K., Fischer, K.S., Hossain, M., Hobbs, P.R. and Hardy, B. (2000) Improving the productivity and sustainability of rice-wheat systems of the Indo-Gangetic plains: a synthesis of NARS-IARI partnership research. *IRRI Discussion Paper Series No. 40*, 31p. International Rice Research Institute, Makati City, Philippines.
8. Nambiar, K.K.M. (1994) *Soil Fertility and Crop Productivity under Long-Term Fertilizer Use in India.* 144p. Indian Council of Agricultural Research, New Delhi.
9. Yadav, R.L. (1998) Factor productivity trends in a rice-wheat cropping system under long-term use of chemical fertilizers. *Experimental Agriculture* 34: 1-18.

SAFLI

South Asia Foundation Learning Initiative

Towards Participatory Management



Department of Environmental Science

Allama Iqbal Open University Islamabad

Uttar Pradesh
Rajarshi Tandon Open University

PGD-ESD - 03
Agriculture and Environment

Block

2

AGRO-ENVIRONMENTAL RESOURCES: ISSUES & CHALLENGES

BLOCK 2 AGRO-ENVIRONMENTAL RESOURCES: ISSUES & CHALLENGES

In Block 1 you have studied about the agriculture-environment relationship. We began with a brief history of agriculture to set the context and helped you develop an understanding of the agro-eco systems. You also learnt how the introduction of high yielding varieties of cereals (mainly wheat and rice) together with an appropriate agronomic package led to manifold increase in food production.

However, our march towards increased production, in the last decade has now more or less been stalled. There are no new lands to be brought under the plough. In fact, many highly productive agricultural lands have suffered land and environmental degradation. In the years ahead, agricultural output will have to be expanded through more intensive cultivation from the same resource base without adversely affecting the environment. In this block we address the issues and challenges being faced in the management of natural environmental resources like land, water, biodiversity and energy needed for agricultural production as well as off-farm inputs such as fertilizers, pesticides and farm machinery.

In Unit 6 we focus on land and soil resources. Over-exploitative land use and soil degradation are the twin challenges facing us in the management of land and soil. We need dynamic management initiatives to ensure food security, nutritional security, environmental safety and improved quality of life. You will learn about some of the most important land degradation processes and the concept of sustainable land use. In the next unit, we take up water which is a finite resource and is becoming scarce with each passing day. Besides the cost of controlling and developing the water resource, water pollution, conservation, improvement of water use efficiency in agriculture (which is very low ranging from 30 to 50 per cent) and management of floods and droughts are becoming very sensitive issues. These require imagination and determination as well as dynamic management to handle.

In Unit 8 we discuss the components of biodiversity related to agriculture which includes plant, animal, soil organism, insect and other flora and fauna in agro-ecosystems as well as elements of natural habitats that pertain to food production. It is a crucial component of sustainable agriculture and has multiple economic, ecological and social benefits which you should be aware of. You will learn about the adverse impact of agricultural activity on biodiversity and why the conservation of agro-biodiversity is essential for sustainable development.

Next we the deal with the energy needs of the agricultural sector (Unit 9). We discuss how these can be fulfilled without polluting the environment through the use of renewable energy resources such as solar energy, wind energy and biomass energy. We also consider strategies for conserving and managing energy including the socio-economic dimensions of the issue of energy management. In the last unit of this block, you will learn about the inputs that are brought from outside the farm (called **off-farm inputs**) such as **fertilizers, pesticides,** and **farm machinery.** These inputs are usually energy intensive and produced mainly in the urban region. We discuss the problems pertaining to the use of these off-farm inputs and some possible solutions.

We hope that after studying this block, you will be able to acquire useful insights and develop a rational perspective on the question of resource management in agriculture. We wish you good luck!

UNIT 6 LAND

Structure

6.1 INTRODUCTION

Ever since the dawn of civilization, human interest in land has been to produce food, fibre, fuel and timber. Land and society have always had an intimate relationship. Land resources constitute the fundamental base of all human activities. It is unquestionably a priceless resource and is quite important to every individual and every nation. The way and the extent to which this natural resource is utilized set the pace of a nation's economic development. Unfortunately, land is getting scarcer and scarcer with each passing day, firstly, because of the burgeoning population (decreasing land-man ratio) and secondly, because of the merciless manner in which it is being used or rather abused. In recent times, we have witnessed over-exploitative land use and soil degradation that is assuming greater dimensions with each passing day. The growing demands of the society even beyond its legitimate needs (greed) and increasing inter and intra sector competition for prime land has been responsible for this situation.

Since land resource is finite, with increasing human population, the per capita land resource is decreasing rapidly. Thus, the management of land and soil calls for dynamic management initiatives to ensure food security, nutritional security, environmental safety and improved quality of life.

The terminologies 'land and soil' are interchangeable as far as its ultimate relationship with society is concerned. Today land and soil seem to be one of the abused natural resources, as people do not realize what it means to the future generations. Therefore, we need to develop awareness about these precious resources so that we can preserve them. In this unit we shall focus on land use or land cover. You will learn about the concept of sustainable land use. Besides, we will discuss some of the most important land degradation processes. You will also study the concept of soil health, how to monitor soil health and how to maintain it for future generations.

Objectives

After studying this unit, you should be able to:

- explain the terms land, soil, land use, land use dynamics, land use planning, soil degradation;
- describe the soil erosion processes and ways and means to prevent and control soil erosion;
- discuss the parameters that determine soil health; and
- discuss problem soils and issues involved in their management.

6.2 LAND USE DYNAMICS

Land is a finite resource and various sectors compete for its allocation. Therefore, the proper use of land according to its land capability could only lead to best out puts. Before we endeavor into the objectives of this unit, it would be appropriate to distinguish between land and soil, which may be used interchangeably in these units.

Land and soil

Although land and soil are closely related yet the two are different entities. **Land is a two-dimensional entity representing geographical area and the landscape.** The land resource is composed of "Soil System" along with its natural functions providing the topographic features of the landscape.

Soil is a three dimensional body with length, breadth and depth. Soil is in fact a living entity and a soil profile with well marked horizons tells the history of its formation and bears the imprint of many physical, chemical and biological processes which have led to its present form. The upper and biochemically weathered portion of the *regolith* is called soil (Fig. 6.1). Its depth may vary from one place to another.

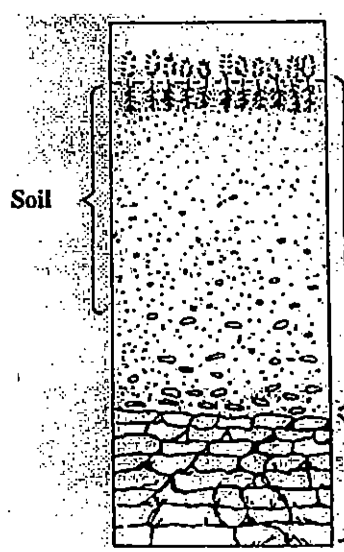


Fig.6.1: A schematic view of the soil profile showing topsoil, regolith and bedrock

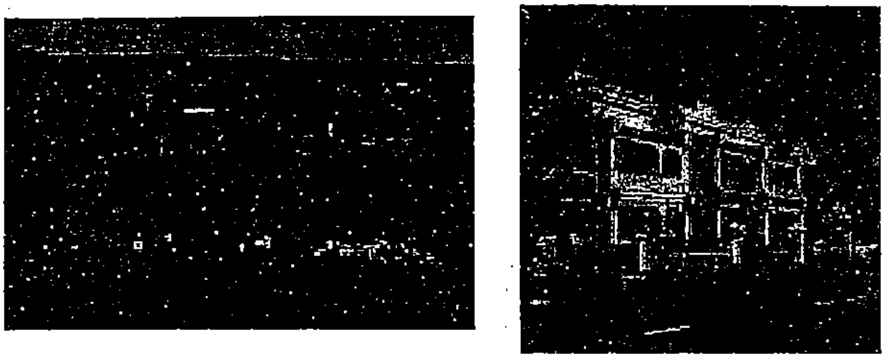
Respecting the general functions of the soil, which it has to perform, soil may be defined as

"a collection of natural bodies which have been 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 sustenance for plant" (as in Brady, 1974).

The soil system's characteristics are primarily governed by its generic origin and climatic conditions, but its physico-chemical properties vary with the use and management practices. **It takes hundreds of years to form 1 centimetre of topsoil.**

For all practical purposes soil is a non-renewable resource in a human life-span.

and use or land cover is not static. Land use is dynamic and changes both in short-rm and in long-term as well as spatially. The complex land use pattern in any area is manifestation of trial and errors of many thousand years of settlement. The evelopments in technology, increasing needs of the rising population, anticipated imatic changes, fast changing social values and new economic regimes are bringing oout rapid changes in the land use pattern. What was agricultural land in the vicinity cities is fast giving way to housing colonies; roads etc. (see Fig. 6.2).



(a) (b)

Fig.6.2: Changes in land use

and use is a product of physical environment and social and technological amework of a given society. Thus, for planning the present and future land use, a set biophysical and socio-economic variables need to be studied. In the context of griculture the physical conditions determine the extent and magnitude of usefulness arable land for different agricultural activities and the types and number of crops at can be grown on the same field during a year. Agricultural attributes, governed in large measure by the physical controls, are modified by the socio-economic onditions (See box below). We will discuss some of these physical and socio-conomic factors that affect the dynamics of land use. But before that we would like ou to understand what the technical meaning of land use is.

Factors Affecting Land Use Dynamics

Biophysical factors	**Socio-Economic factors**
Geographical setting	Population growth
Altitude and relief	Migration
Topography	Land tenancy/ property regime
Geology	Size of holding including fragmentation
Climatic factors including micro-climate, moisture zone and seasonality	Labour
Soil	Locational factors
Drainage pattern	Institutional factors
Climate variability and change	Capital
	Mechanization and equipments
	Community organizations
	Family structure
	Wage rates

The concept of land use

Land use is a comparatively new branch of economic geography. It is intimately related with demand for a particular land use. The concept of land use has been defined in various ways:

Sauer (1919) defined land use as simply the use to which the entire land surface is put. Vink (1975) defined land use as any kind of permanent or cyclic human intervention to satisfy human needs, either material or spiritual or both, from the complex of natural or artificial resources, which together are called land.

In essence, **land use studies involve principles, techniques, controlling factors, classification, capability assessment and measurement, resource appraisal, conservation, land reforms and planning of land use. The terms land use and land utilization are generally used synonymously** although there are some fine differences between the two.

Land use capability is another term used which connotes potential capacity of a given tract of land to support different types of land utilization under given conditions. The overall objectives of the studies on land use dynamics are to:

- Understand the drivers of land use change,
- Measure and forecast land use changes,
- Quantify the economic, environmental and social impacts of different land use systems to provide valuable insights on viable policy options.

Such studies help policy planners in land use planning, that is broadly governed by the following principles:

Principles of land use

- The **superiority of demand** should be the first principle of the utilization of land.
- **Physical form of the land** should be recognized while planning land use.
- **Maintenance of ecological balance** should be kept in view.
- **Natural environment** is a powerful force in determining the land use and concentration of population over a piece of land.
- Besides its production potential, land use possesses human value and satisfaction of human needs is a vital concern. Reasonable share of agricultural land in urbanization, infrastructure development, recreation, growth of utility services and industries would be vital in planning the land use.

Land use planning

Land use planning is not recent in its origin but its practice is truly recent. The ultimate goal of any land use study is to prepare plans for change in the present land use for betterment or to utilize the available land by the society in a different manner. A land use map gives a clear picture of land for deciding its future use. Any future use of the land should satisfy the three basic needs of the people e.g. *food*, *shelter* and *clothing* while maintaining the potential of the resource. Land use planning as related to agriculture should not merely be the rational use of land put to cultivation and/or bringing more land area under the plow, but should include conservation of resource from erosion, resource health and application of modern technology. Besides what is stated, scientific and rational land use planning should ensure ecological balance and a proper equilibrium between the environment and the socio-economic needs of the ɜople of the area. You may like to stop here and check whether you have grasped ıese ideas before proceeding to the next section.

AQ 1

Explain, in your own words, why we need to study the dynamics of land use.
We list below some principles of land use. Explain these in your own words.

i) Superiority of demand;
ii) Physical form of the land;
iii) Natural environment.

2.1 Biophysical Factors

ıvironment has prime importance in controlling the nature and distribution of crops ıd livestock. Since natural environment cannot explain everything that is observed, it ıpears that physical factors such as geomorphology, geology, altitude and relief, imate and soils influence the cultivation of crops and preference for a particular land e. Let us understand these factors in relation to agriculture.

eographical setting

ɜographical setting is one of the dominant parameters of physical environment. griculture in mountains, plateaus and plains would be different. Even within these oups it would vary due to presence and absence of scarps, pediments, valley flanks, ɔod plains, coastal plains, ridges, levees, dunes and oases.

› take the example of India, the Himalayas represent a rich, tropical, temperate and ɔine flora with forests of conifers, oaks, rhododendrons, and a profusion of orchids. ıe plains are of greatest importance from the point of view of culture and civilization d a source of great agricultural wealth. The northern plains are endowed with fertile ils, favorable climate and an extensive system of irrigation making this area as the ɜat agricultural tract growing vast number of crops with high yields.

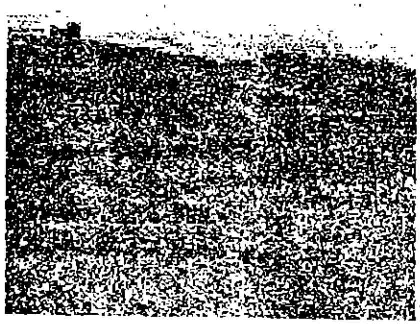



Fig.6.3: Agriculture in different geographical settings

ɜ west coastal plains are noted for their specialized crops of spices, pepper, ginger d cardamom while the east coast grows rice, palms and coconuts. The elevation of plateaus varies from 300 to 900 m. A greater part of the north-west Indian plateau covered with basaltic lava. Being rich in iron, it is conducive to production of cotton ile laterite soils are suited to tea, rubber, coffee, tobacco, groundnut and oilseeds. e slopes of the *ghats* and other highlands are covered with forests especially of ıatorial and deciduous characters.

Land in India is an assemblage of geographical conditions, which are distributed among all other countries of the world. Amongst the four major settings, plains cover the largest area (Table 6.1).

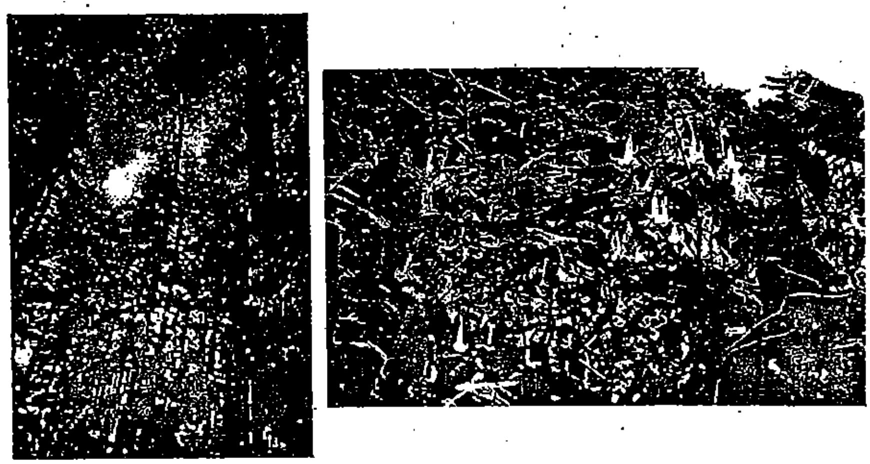
Table 6.1: Percent area under different geographical settings in India

Mountain	10.7
Hilly tracts	18.6
Plateaus	27.7
Plains	43.0
Total	100.0

Would you like to carry out a similar exercise about your region/country? You may find out the percentage of area under different geographical settings in India (see Table 6.1). You may also obtain information about crops being grown in these settings.

Altitude and relief

The land use and vegetation type are greatly influenced by *altitude* and *relief*. Perhaps, the influence of environment on land use is more pronounced where *topographical changes* are well marked. This includes rapid changes in landform, slope, degree of roughness of relief, changes in *aspect* and variation in latitude. Altitude wise areas at a height of 3,750 m and over above sea level contain alpine vegetation. In the range of 2,000 to 3,500 m above sea level temperate vegetation with deciduous and coniferous trees is most common. In still lower parts of the hills and plains, tropical vegetation is the most common although it differs from place to place according to relief and humidity (see Fig. 6.4).



(a) (b)

Fig.6.4: Vegetation type at various altitudes and relief; a) pine trees; b) tropical vegetation

Plains, which are relatively flat, are the most productive where intensive land use can be practiced. The intensity of land use and distribution of population show that as much as 75% of the population of the world lives in plains. Although all plains are not equally hospitable, yet people's preference for living in plains has resulted in dynamic land use, which is changing fast.

Geology

Geology has both direct and indirect influence on land use. The indirect influence can be explained on the basis of the following four factors:

- Ground with presence or absence of any geological occurrences.
- Parent material from which soil has developed would influence the land production capability.
- The availability of groundwater is directly related to the geology of the aquifer. Aquifers having sufficient porosity to hold water would yield more.
- Since adequate drainage is essential for sustainable land use, the character of drainage determines the land use while the drainage is dependent upon the geological formations.

The mining areas are the zones of low land use since large chunk of land goes in infrastructure related to mining, storage and transportation of ore. Subsidence of ground could be another reason of low land-use. The reclamation of mined land for agriculture is a new thrust area of research.

Climatic factors

Climate is one of the major physical factors influencing agriculture and land use. Climate is generally defined as the average state of weather. Weather usually refers to a small period of time while climate refers to average of weather over an extended period. Climate consists of elements like rainfall, temperature and length of the growing season, sunlight, frost, fog, moisture conditions, snow, hailstorms and winds.

In a wide range of India's latitudes and longitudes, there is arctic or polar climate above 4,572 m above sea level along the Himalayas but at lower levels temperate and tropical climates are prevalent. It has almost absolute aridity to a maximum of humidity. Temperature in Dras in Kashmir could be as low as – 45° C and that in Rajasthan as high as 51° C.

In a nutshell, we can say that climate has an important role in influencing the land use and cropping pattern of an area. Latitude, which determines the length of the day as well as influences the duration of sunshine and temperature and rainfall/evapo-transpiration which together determine the aridity have profound effect on natural vegetation. The effect of these factors has been combined together to reveal their influence (Fig. 6.5).

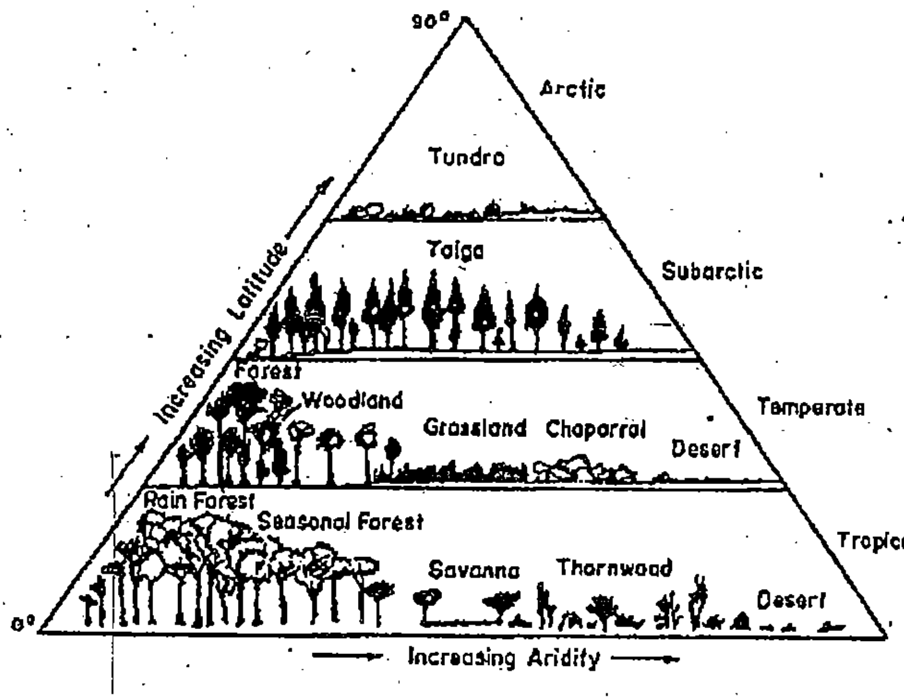


Fig.6.5: Vegetation as influenced by aridity and latitude

It is generally believed that climate does not change much though the microclimate can be modified to a certain extent through irrigation and other inputs. Contrary to this, global warming is an indicator of climatic change. It is likely to have a profound influence on soil health, productivity of agriculture and land use.

Soils

Soil is a source of practically all our food, clothing and an ever increasing list of other needs. The standard of living of the people depending on agriculture is often determined by the fertility and productivity of soils. The development of soil is largely influenced by:

- Parent material
- Climate
- Living organisms

- Topography
- Land utilization and
- Time

The characteristics of the soil are also the product of present and past climate along with the vegetation that flourished upon them. Soils in this region have been grouped under a variety of types such as alluvial soils, black soils, red soils, laterite, hill soils, forest soils, peat and muck soils etc. Alluvial soils are the largest group of soils and are in general the most productive. The physico-chemical properties of the soils determine its productivity. Texture determined by the size of soil particles and structure by the arrangement of soil particles determine largely the moisture retention and its availability to plants, which is so vital for plant growth. Human activities have many times led to the exhaustion or degradation of soils. Soil erosion, water logging, soil salinity, soil sodicity are some such problems that have occurred due to human interference.

Agro-ecological zoning

Since land use is the product of physical environment or the biophysical parameters, an attempt has been made to group these parameters to identify homogeneous zones, which have nearly similar use, constraints and remedial measures in agriculture. It is known as agro-ecological zoning.

An agro-ecological zone (AEZ) is a land resource mapping unit, defined in terms of climate, landform and soils and/or land cover and having a specific range of potential and constraints for land use. An AEZ serves as a focus for the targeting of recommendations designed to improve the existing land use situation either through increasing the production or by limiting land degradation.

Based on physiography, soils, bio-climate and length of the growing period, India has been grouped under 20 AEZs (Sehgal et al. 1992). AEZs have been further sub-divided into 60 Agro-ecological sub-regions (AESR) (Sehgal, 1995). While the AERs (Agro-ecological regions) are important to planning at the National level, for regional level planning and resource allocation, AESRs would be useful.

Step-by-step zoning procedure

The following step-by-step procedure has been proposed for AER (FAO, 1996). Although the procedure has been proposed for the Amazon Region, yet its application to other regions could be made.

Step 1: Collect maps and spatial information and enter into GIS (Geographical Information System).

Step 2: Delineate natural land units and thematic analysis of their natural resources. This should include data on climatic conditions, land form characteristics, soil conditions, land hydrology, vegetation, biodiversity values, current land use, incidence of pests and diseases, near surface mineral reserves and mining activities, rivers and their hydrology, population and land ownership etc.

Step 3: For each natural land unit, determine the biophysical land qualities and limitations.

Step 4: Identify agro-ecologically viable land utilization types and determine their bio-physical requirements in consultation with stakeholders for grouping.

You may now like to stop for a while and consolidate these ideas by attempting an exercise.

SAQ 2

a) Differentiate between land and soil. What is meant when we say soil is a 3 dimensional entity?

b) List biophysical factors driving the land use dynamics. Describe at least one factor that is causing a major land use change in and around your village/city/country.

6.2.2 Socio-economic Factors

Until the mid 20th century, the focus was on natural ecosystems where humans were not considered to be a part of the ecosystem. Now it is understood that land use is controlled by physical environment as well as socio-economic and technological framework put together. We now discuss some of the socio-economic parameters in the following sections.

Population growth and migration

The ever-increasing pressure of population on land resource results in an expansion of agriculture both horizontally and vertically. In fact increasing pressure of population on the sufficiently exploited land resource is one of the major problems in the developing countries including India.

With increasing population, the demand for food, fibre, fuel, feed, fodder and shelter has been increasing and hence increased pressure on land. In spite of all the efforts, we failed to provide enough food to the increasing population until towards the middle of the seventies. Green revolution changed the face of agriculture in our countries with widespread change in land use, crops types and intensity of cropping. Non-agricultural land use also increased. This resulted in many environmental problems due to decreasing forest areas. Governments started providing incentives for afforestation and special schemes have been prepared to green the wastelands through afforestation.

India's population, which stood at 238.4 million at the turn of 20th century, increased to 1027 million at the turn of 21st century. It is more than a four fold increase. How has the population in your country/ region grown?

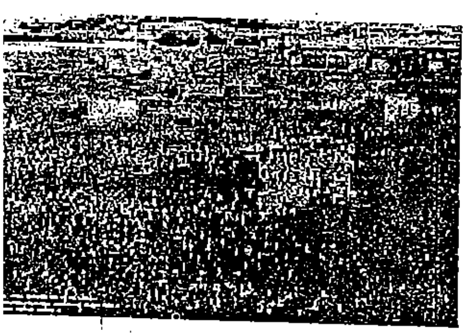


Fig.6.6: Greening of wastelands through afforestation

Peri-urban agriculture is spreading fast around centres of population concentration resulting in change in land use. Migration of people from one place to another is also leading to diffusion and dispersion of non-conventional crops to new places. We shall discuss short-term changes in land use in a later section of this unit.

Land tenancy

The ownership of the land and land tenure are two important social systems of land cultivation. The amount and nature of investments in agriculture are made keeping in view the rights of the tenure holder and tenure of the land lease. A long lease favours more inputs as well as encourages adoption of new technologies while a short-term lease does not have any incentive to invest on land improvement. The present rules disfavour long lease and therefore annual leasing has become quite common. The tenant has little interest in maintaining the quality of the land.

Size of holding, fragmentation and operational efficiency

The law of succession in countries like India, results in the sub-division and fragmentation of land holdings. While small holdings and plots make it difficult to use modern machinery, fragmentation of land holdings results in wastage of time in supervision resulting in overall operational inefficiencies. More area is lost in embankments and boundaries, which could be released for cultivation upon consolidation. Consolidation of land holdings is also being done in some regions, but as said earlier, the law of succession is again leading to fragmentation of land holdings.

Labour

Labour represents all human services, other than decision-making and capital. Shortage of labour at peak times of sowing and harvesting could impact the selection of crops to be grown. Thus, shortage of labour could lead to inter-crop shifting. Another important issue could be to keep the labour engaged for the whole year. Thus, the farmers need to devise cropping patterns in such a manner that labour is engaged throughout the year. This could impact the decisions on cropping and might have a positive effect in increasing the cropping intensity.

Locational factors

Man is both the producer and consumer of products. Thus, capital and labour need to be transported to production site while the finished products need to be transported to markets. Vegetable crops oriented peri-urban agriculture and increasing area under floriculture around the cities are also examples of land use change that is taking place because of the locational factor.

Institutional factors

The government as an institution frames laws and policies that impact the land use. Social customs and changing habits collectively determine or even force the land use. Religious institutions also have a say in deciding the land use in a given region. Financing institutions with their credit policies can lure a large number of farmers to switch over from sustenance farming to cash crops. Sugarcane industries in many parts of India have shown that with appropriate incentive, change in cropping pattern could be brought about.

Capital

Capital seems to be a definite limitation to the selection of crops or land use. The market-oriented crops give higher returns but at the same time need more investments. A large gap between the investments and returns is many times a deterrent in adopting land use that has potential of high returns.

Mechanization and equipments

Mechanization of agricultural operations takes the drudgery away. To a great extent it also substitutes for the shortage of labour. But capital requirement is more. Tractors have largely transformed the agricultural landscape. Pumps used to exploit roundwater have changed the face of agriculture and are said to be the prime factor or ushering in the green revolution.

Ecological-economic Zoning

Ecological-economic zoning (EEZ) is an alternate approach to agro-ecological zoning. It attempts to correct the over-emphasis on the physical factors for crop production in the ago-ecological zoning as in this concept socio-economic factors are also included and a wider range of land uses are included in defining a zone. It ensures an interaction between land and people who have a stake in the current and future land use. Thus, EEZ concept is more dynamic. On the other hand, it is more complex and needs to be adjusted with changing socio-economic conditions and outside influences. So far, this concept has not been applied to most developing nations and, therefore, more studies need to be ihitiated to understand its intricacies and to make it more popular.

Short-term changes in land use pattern

As per guidelines on land use prevalent in India, major uses are classified into nine broad categories

- Forests
- Area under non-agricultural land use
- Barren
- Permanent pastures and other grazing lands
- Area under miscellaneous tree, crops etc.
- Culturable wasteland
- Current fallows
- Other fallow lands
- Net area sown

Forests

There was a time, a millennium or so ago, when the broad picture of this region was that of a sea of forests with scattered islands of cultivation. The economic and cultural life centred on forests and rivers and both were considered sacred and worshipped. Tree cutting was considered as an offence. Later on, clearance of forests began to assume serious proportions. The increasing population and increasing revenue from agriculture encouraged deforestation. The scene changed altogether when the British came on the scene. An unprecedented attack on forest began because of the modern developments and expansion of agriculture. By the middle of the 19th century, depletion of forests assumed a serious dimension. In 1960-61 the forest area in India declined to 54.05 million ha, i.e., 18.1 % of the reported area which increased to 68.86 million ha in 1996-97, i.e., 22.6 % of the reported area. But we are too far from achieving an optimum area of 33 % of the geographical area under forests.

Area under non-agricultural land use

Urban population is increasing at a very fast rate. It has more than doubled in about 90 years (108.4 million in 1901 to 257.2 in 1991). For example, the urban area of Delhi in 1991 increased by 1.54 times than that in 1971 as the urban population increased by 2.32 times during the same period. It is estimated that the urban population of Delhi alone would touch the 500 million mark in 2015, which would consume about 14,000 km^2 of rural land at the rate of 20,190 inhabitants per km^2. It works out to be 0.42% of the total geographical area of the country. With increasing urban population, the area under industrial establishment and infrastructure would further expand and a large part of urbanization and industrial lands would stretch into good farmland. The area under this head has increased from 5.0 % in 1960-61 to

7.4 % in 1997-98 but fortunately; the area under the head barren and uncultivable land has decreased from 12.0 % to 6.2 % during the same period.

Arable land

The term is used to include the land, which is actually cropped during the current agricultural year, i.e., the net area sown or net cropped area. Volume of change in arable land and volume of change in the intensity of cropping together determine the potential to increase food production. Net area shown showed a slight increase from 44.6 % to 46.6 % but significant change has occurred in the gross cropped area, which increased from 152.77 million ha to 190.76 million ha giving an increase in cropping intensity from 114.7% to 134.3 %. Since the percentage of land under irrigation has a direct bearing on the cropping intensity of an area, net and gross irrigated areas have shown a similar increase.

Human beings and the land use and land cover changes

Human beings are the best catalyst who have attempted and continue to bring changes in the land use. Diffusion and dispersal of crops has been happening since the beginning of agriculture. In India, the Portuguese brought maize, chillies, tomatoes and sweet potato in the early 16^{th} century. Coffee was first introduced in India in the hills of Mysore in 1600 A. D. Tobacco was rapidly adopted in India after its introduction in 1607. Tea is indigenous to South-East Asia but its cultivation spread only after the establishment of the East India Company. These are only a few examples of crop introduction and dispersal by human beings. Recent attempts to cultivate medicinal and aromatic plants on wastelands, petro-plants in Rajasthan are other few examples of the human interference in crop diversification.

Human beings not only try to introduce crops in alien environments but also try to modify the biophysical parameters to grow crops in a more profitable manner. Introduction of irrigation is one such example, which could bring about visual changes in the vegetation in one's lifetime to see. The introduction of *Indira Gandhi Nahar Pariyojana* in Rajasthan is an example. As a result, a net reduction in forest area of 73 km^2 has been observed. Plantations of *Acacia nilotica*, *Eucalyptus* sp., *Albizia lebbeck* and *Dalbergia sissoo* have changed the vegetation physiognomy. The arid rangelands with *Lasiurus sindions* grass are being colonized by other species due to increasing moisture. Many aquatic and marshy elements of vegetation have come up. Similar effects are expected in the dry deciduous forests once the *Sardar Sarovar* Project in Gujarat is completed.

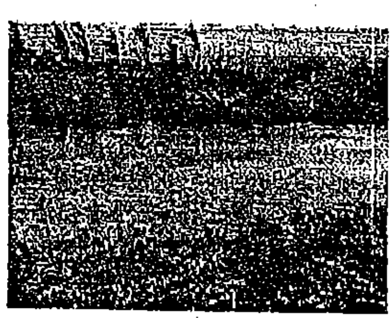


Fig.6.7: Irrigation through canals and dams

Massive governmental efforts in improvement of degraded lands and forests have introduced many native and exotic trees, grasses and legumes. Large-scale commercial plantations have changed the rural scenario even in managed and irrigated systems. Native stands of tropical pine in Madhya Pradesh and *Cryptomeria japonica* in north-east India are being changed on a large scale.

e most notable change that has been feared to occur slowly is the anticipated matic change. It is anticipated that the earth's temperature would increase. reasing emission of green house gases (carbon dioxide, carbon monoxide, nitrogen ide, ozone, chloroflurocarbons and water vapours) have led to realistic fears of ady increase in the temperature of the earth's surface. Several factors have led to increasing emission of greenhouse gases. Decreasing area under forests, increasing ustrialization, other land uses together have contributed to this state of affairs. In ler to save the earth from impending catastrophe, increasing areas need to be ught under forest. Unfortunately it is not happening.

ally a word of caution would be appropriate. Without doubt, change is an vitable consequence of development. But in the zeal of change let us not disturb the nomically important species; let us continue to preserve them for posterity. We e to learn how to use land in a sustainable manner. This is what we discuss in the t section. But before that, we would like you to attempt an SAQ.

Q 3

Explain the socio-economic factors that affect land use.
Differentiate between agro-ecological zoning and ecological-economic zoning.
Briefly describe the difficulties in the application of ecological-economic zoning.

.3 Challenges for Sustainable Land Use

ny countries amongst the SAARC nations are richly endowed with a wide diversity esources. This diversity while providing opportunities also presents challenges in aging activities and values across landscape so that the benefits from all our urces can be enjoyed for generations to come. All of us face many natural urce management challenges, including water logging, soil salinity, and water ity decline and biodiversity loss. According to the World Commission on ironment and Development (1987), a farming system or land use is sustainable, if sures that today's development is not at the expense of tomorrow's development pects. As such maintaining healthy landscapes and sustainable use of natural urces requires following efforts to prevent and reverse natural resource adation.

Land use dynamics should be in harmony with climatic, demographic, socio-economic and technological changes.

Land use/cover changes should not adversely affect the *hydrological cycle* both qualitatively and quantitatively and must avoid land degradation.

n addition to their ecosystems, land must perform critically important purification functions. The ability to provide these services could be threate d by pollution and land degradation due to inappropriate land use, or overexploitation that ransgresses capacity thresholds. For example, when wetlands are dredged and developed, or mangroves are harvested for wood and aquaculture, the environment also loses the filtering effect that these ecosystems provide. As far as possible such changes should be minimized.

Changes in land use and land cover are among the issues central to the study of global environmental change. *Biogeochemical cycles* and radiation balance must be maintained through land use to minimize such changes. Sustainable land management practices in forestry, vegetation management and agriculture provide mportant opportunities for reducing greenhouse gas emissions and enhancing greenhouse sinks.

ntensifying land use could bring in a simplification of ecosystems but must naintain the biodiversity and help protect ildlife habitat.

- The land use must sustain work and communities to maintain quality of life and the social fabric of the country.

Apparently, those responsible for developing policies for the management of land resources on sustainable basis would require wide ranging information which can help them to take decisions on the delivery of the multiple objectives of maintaining and enhancing economic activity while also maintaining and enhancing the natural and social capital of rural areas. The study of these issues requires an integration of knowledge pertaining to the economic, environmental and social impacts of changes in land use in addition to understanding the underlying processes (Iowa State University, 1961). One approach to assist land managers with these decisions has been the development of computer-based decision support systems (DSS). While such systems are demonstrably able to make analyses of multi-objective land-use planning problems, the question remains whether the answers they produce are relevant and useful to practitioners. Another important issue stems from the fact that the resources of public institutions are shrinking, and therefore private sector should be entrusted with more of the costs of land management, including increased management responsibilities for land use planning.

Sustainability has several dimensions - technological, ecological, economic, social and cultural. Any land use that harms any of the soil quality parameters is unsustainable. Sustainability also has a time dimension. Thus, sustainability of land use cannot be gauged in short-term. A long-term view needs to be assigned to sustainability. Current demographic and socio-economic trends suggest that the next 30 to 50 years will be decisive for managing economically viable transitions toward sustainable land use systems. Since sustainable land management is basic to the economic development of a nation, we can say that a land management system is sustainable only if it caters to the three pillars of sustainable development: *economic growth*, *environmental protection* and *social development*.

6.3 LAND DEGRADATION

Land degradation describes a process in which the land character is changed for the worse. In a more general way, it has also been defined as a reduction in the capacity of the soil to produce in terms of quantity, quality, goods and services. Besides, several concepts notably sustainability, resilience to degradation and carrying capacity of the soil have become important to this definition.

You know that land is covered with a thin crust of soil that has taken many thousands years to form. This crust is very vulnerable to damage and once damaged it is extremely difficult to put it back. Soil is neither a renewable natural resource nor an inexhaustible store of plant nutrients unless its fertility is replenished constantly. The problem of soil degradation is quite extensive both on global and national scales. Unfortunately, the quantitative estimates of the problem vary largely and may be confusing.

Landscapes are likely to undergo transformation in any case but nature's restorative capability takes care of these changes. However, net degradation occurs when the degradation process significantly exceeds nature's restorative capacity. In India, for example, around 188 million ha or 57% of the geographical area is estimated to be under the processes of land degradation of one kind or the other. Processes related to land degradation are:

- Soil erosion;
- Water logging;
- Chemical degradation
  - acid soils
  - salt affected soils
  - loss in soil fertility
  - mined and quarried land;
- Desert formation.

6.3.1 Soil Erosion

Soil erosion may be defined as the detachment, transportation and siltation of the soil. Certain amount of erosion, which exists in the natural environment under native vegetation, is called geologic or natural erosion. Natural / geological erosion occurs at the rate of 0.1 t ha^{-1} yr^{-1}. Such erosion is not harmful and could be important to agriculture as it includes soil forming as well as soil eroding processes. These processes maintain the soil in a favourable balance. With increasing human interference when natural vegetation and trees are cleared, natural protection to the soil is disturbed and soil erosion occurs at an accelerated pace. Depending upon the vegetation and management it could go up to 10-700 t ha^{-1} yr^{-1}. Apparently, it does not mean the loss of the soil alone but also the loss of organic matter and of the plant nutrients attached to soil particles and in the soil solution. See the box below for a complete list of anticipated losses due to soil erosion.

Nearly half of the geographical area in India is subject to soil erosion. It is estimated that on an average 16.75 tons of soil per hectare is lost annually through erosion. This amount converts to a loss of around 10 mm of the top fertile soil in about 10 years time.

Damages as a result of erosion		
Soil loss	Infrastructure damage	Water pollution
Plant nutrient loss	Sedimentation	Air pollution
Texture change		
Structural damage		
Field dissection		
Reduced photosynthesis		
Productivity loss		

Agents of soil erosion

Soil erosion is grouped under two main categories (i) Water erosion and (ii) wind erosion. Water erosion is of major concern in humid areas while wind erosion is important in arid regions.

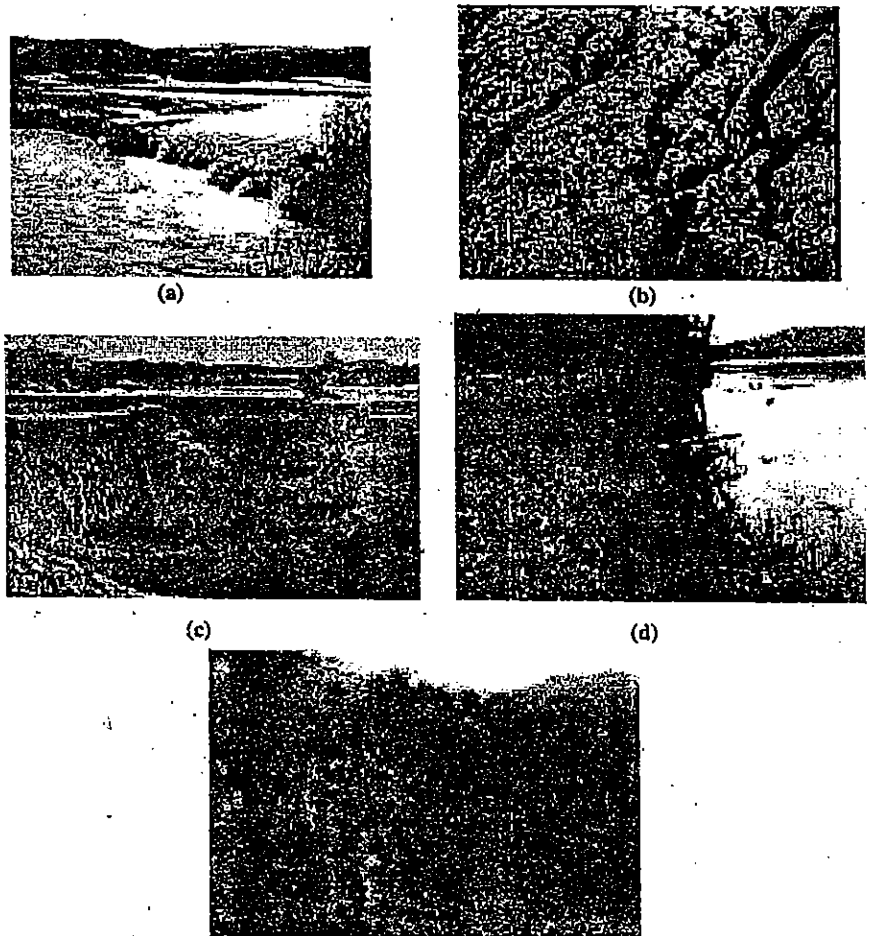
Types of water erosion

Raindrop erosion: Raindrop erosion or splash erosion results from the impact of raindrops. The falling raindrops break down soil aggregates and detach soil particles. On soils well protected with vegetation, raindrop erosion may be insignificant but for bare soils, it may splash as much as 250 tons of soil per ha.

Sheet erosion: Sheet erosion is probably the most serious kind of erosion (Fig. 6.8a). Sheet erosion, as is apparent by its name, is more or less even removal of a thin layer of the surface soil. The beating action of raindrops coupled with surface flow is responsible for the sheet erosion.

Rill erosion: As against the sheet flow which occurs only when the surface is smooth with a uniform gradient, rill erosion occurs when rain water concentrates in depressions and then begins to flow taking the path of least resistance making small channels or rills (Fig. 6.8b).

Gully erosion: Rill erosion in its advanced stage is called gully erosion (Fig. 6.8c). Unattended rills get deepened and widened over years to form gullies. The rate of gully erosion depends on the runoff producing characteristics of the watershed, the drainage area, soil characteristics, the alignment, size, shape and slope of the gully and the channels.



(a) (b) (c) (d) (e)

Fig.6.8: Different types of erosion

Stream erosion: Stream erosion is the scouring of material, which form the water channel and the cutting of banks by the running water (Fig.6.8d). Bank cutting is the most common form of stream erosion.

Landslide erosion: Since landslides are mainly caused by heavy rains. It is a common feature of the steep hill slopes (Fig.6.8e). Since soil gains weight due to heavy rains and water weakens the cohesion between soil particles, the soil yields to gravity and slides down.

Erosion by waves: Ocean and lakeshore lines are subject to cutting action by waves particularly when accompanied by high winds. The most damaging action occurs to the earthen *bunds* (dykes); sometimes a part of the *bund* is completely washed away.

Having developed an understanding of various kinds of soil erosion, you would surely like to learn about measures to control it.

Erosion control measures

The basic principles of water erosion control are:

- Reduced raindrop impact on the soil,
- Reduced runoff volume and velocity,
- Increased soil resistance to erosion.

As per the FAO Watershed Management Guide, erosion control has been categorized under the following two categories:

- Erosion control on arable lands,
- Erosion control for restoring degraded lands.

Erosion control measures on arable lands have been further grouped under control and preventive measures. In some textbooks, these measures have also been termed as engineering measures and non-engineering management options (see Fig. 6.9).

Erosion control for restoring degraded lands has been grouped under 3 heads namely inter-rill/rill erosion, land slide scar and gully erosion control.

To have a detailed discussion on each alternative would be out of the scope of this unit. Therefore, a brief description of some strategies under various groups is included.

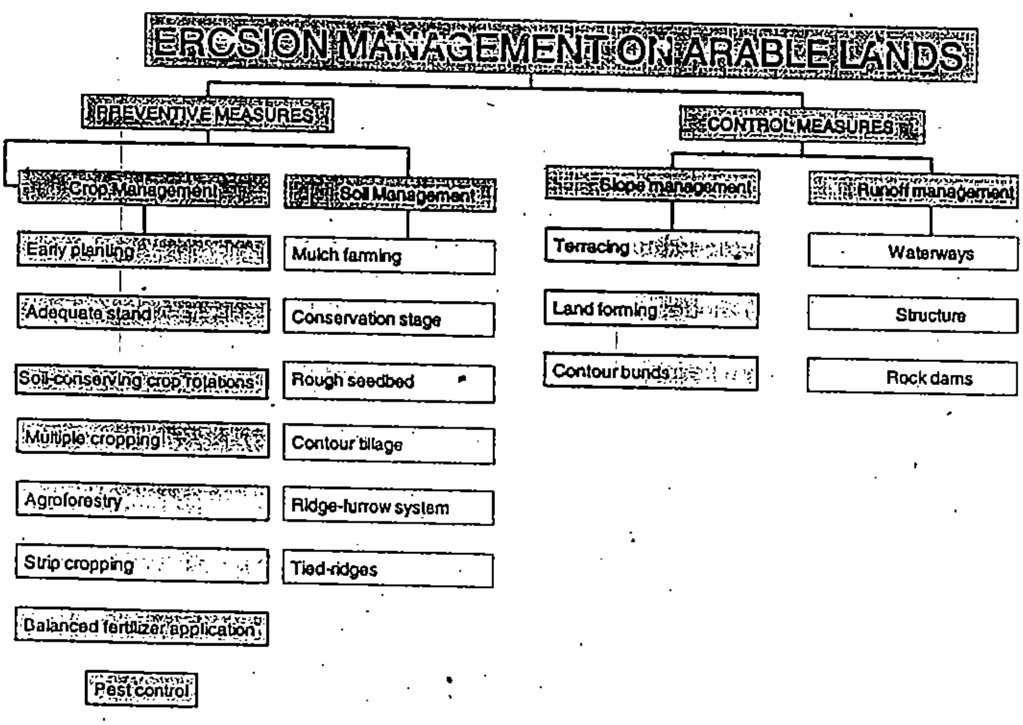


Fig.6.9: Flow chart showing preventive and control measures for soil erosion on arable lands (Source: *as reproduced by Honore, 1999 from FAO report)*

Erosion control measures for arable lands

Diversion drains

In case a part of the catchment is proposed for treatment and if it is feared that runoff from the unprotected uplands will cause damage to the proposed protected area, a diversion drain is constructed to divert the runoff from the upper unprotected area to reach the protected area.

Terracing

Terracing is probably the most effective of supplemental erosion control practices. It is practiced on steep hill slopes, generally steeper than 6-7% (see Fig.6.10). Terracing decreases the length of slope but in certain designs it modifies the degree of slope as well.

Fig.6.10: Terracing

While designing a terrace, terrace spacing, terrace grade length and terrace cross-section are designed to conform to soil, soil depth, rainfall, slope and farming practices. Five kinds of terraces are commonly adopted.

i) **Level bench terrace:** In paddy growing areas, uniform ponding of water is essential to conserve water and obtain optimum yield. These terraces are made like a tabletop by cutting and filling to allow uniform ponding of water. These kinds of terraces have been formed even on slopes as small as 1% to grow paddy. As such, these terraces are also referred as paddy terraces.

ii) **Inwardly sloping terraces:** These terraces are constructed for crops susceptible to water logging. The terraces are constructed with an inward slope to drain off the excess water as quickly as possible. These terraces have a drain on the inner side to dispose off the water to a drainage way. These are mostly suited to high rainfall areas with steep slope and permeable soils.

iii) **Outwardly sloping bench terraces:** Since farmers carry out the levelling operation in phases, an outwardly sloping bench is a step towards the construction of level or inwardly sloping terrace. These terraces are constructed on soils of medium to low permeability. A graded channel is provided at the lower end to dispose off the excess water.

iv) **California type or Puerto Rican terraces:** If a bench terrace is constructed at one go, the productive soil depth might get shifted resulting in overall loss of productivity. Thus, in this kind of terraces, mechanical or vegetative type barriers are provided on the original hill slopes and with each ploughing, soil is pushed downward to finish the construction in 2-4 years time.

v) **Broad-base Terraces:** Broad-base terraces are also called ridge terraces or broad-base bunds. These are also called drainage-cum-absorption terraces. These terraces are constructed for up to 10% land slope, where permeability of the soil is low and contour cultivation is insufficient to control surface runoff and soil erosion and the field is dissected by gullies or depressions. In this case bunds are constructed on strict contour with a provision of waste weir. Commonly used dimensions of a broad based terrace at Bellary are shown in Fig. 6.11 (Singh et al. 1981).

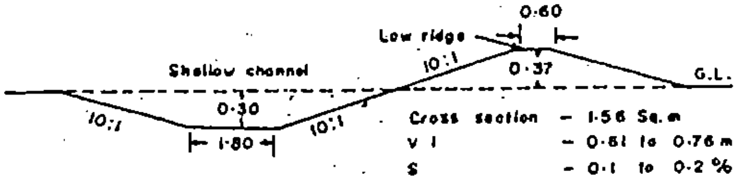


Fig.6.11: A sketch of a broad- base terrace showing dimensions of important components

ıtour bunding

the most popular soil conservation measure in India. The practice consists of structing narrow-based trapezoidal embankments (bunds) on contours to impound ɔff water behind them so that all the water is absorbed gradually into the soil file (Fig. 6.12). Contour bunding is recommended for low rainfall areas 00 mm) with slopes ranging from 2-8%.

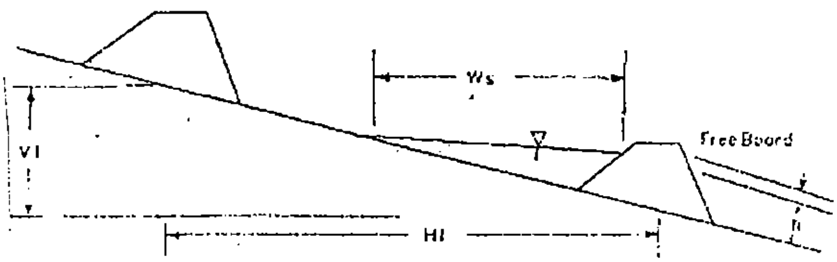
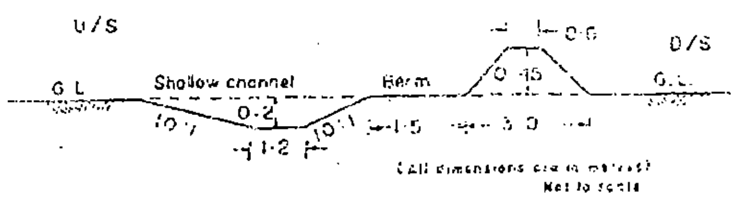


Fig.6.12: A diagram showing cross-section details of contour bunds

ıded bunding

ded bunds are constructed in relatively high rainfall (>800 mm) or in highly ıermeable soils of low rainfall regions such as deep black soils. The major ective is to lead the excess water out of the fields to avoid water stagnation. The ded bunds or terraces are constructed along a pre-determined longitudinal grade ead of along the contour. These are narrow based versions of the channel terraces ere the design of the channel rather than the embankment is important. The channel uld be wide and shallow so that mean flow velocity is less and channel could be tivated without disturbing its shape (Fig.6.13).



ig. 6.13: A sketch of graded bund showing commonly used dimensions of channel and bund

assed waterways

e grass-lined waterway is one of the basic conservation practices. Grassed terways and outlets are natural or constructed waterways shaped to required nensions and vegetated for safe disposal of runoff from a field, diversion terrace or ıer structures. Vegetative waterways could be of different shapes and sizes. Most mmon shapes are trapezoidal, parabolic and triangular.

rplusing structures

order to protect the structures from breaching and for avoiding surface stagnation, ainage of excess water is an essential component of soil conservation works. These structures known as surplusing structures are provided in a staggered manner in depressions at 0.3 m above the contour. Clear overfall stone weir, channel weir, cut outlets, pipe outlets and ramp-cum-waste weir are some such structures commonly used in contour bunding (see Fig. 6.14).

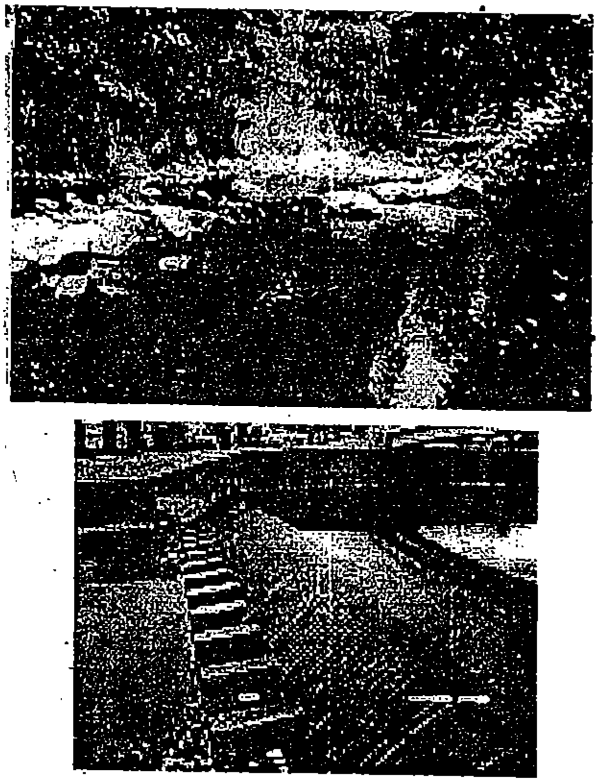


Fig.6.14: Some surplusing structures

Agronomic measures

The protection through vegetative shield, forest cover, grasses, crops and mulches etc. are some important measures to prevent soil erosion. Crops with canopy can intercept a part of rainwater energy so that control of splash in well cultivated or grassy fields helps in preventing erosion. Some of the practices are described below.

- **Cover crops:** Erosion from cultivated fields can be reduced if the land has enough crop canopy during the rainy season as it gives a protective umbrella to the land. Legumes in general provide better cover and protection to land as compared to open-tilled crops. Strip-cropping of erosion resistant crops along with cereals can conserve rainwater and reduce the velocity of runoff. Cowpea, *moong*, *urad* and *dhania* are some such crops.

- **Time of crop planting:** Sowing of crops need to be planned in such a manner that crops develop enough canopy and roots before heavy rains are anticipated to minimize erosion.

- **Crop geometry:** Optimum plant population and crop geometry can play a very important role in providing optimum crop cover. A denser population would curtail soil erosion but may cause severe competition for moisture and nutrients. A closer spacing of rows across the slope can curtail erosion.

- **Contour farming:** Contour farming refers to the tillage practices of applying all treatments along the contours be it in agriculture, pasture or rangeland. In arid and semi-arid regions, it helps in rainwater conservation while in humid regions it prevents soil erosion. The furrows between the ridges developed during contour :illage act as mini-barriers across the flow path of the runoff.

Tillage: Low intensity tillage or the minimum tillage favours consolidation of soil through better structure as against the fine seedbed concept commonly used by the farmers. Zero tillage concept, which is now slowly picking up can impart erosion resistance to the land.

Root distribution: Roots act as a binding force. Studies have revealed that grasses are the best soil protective vegetation as both the runoff and soil loss gets reduced (see Table 6.2).

Mulching: Mulching is commonly used to control evaporation and to minimize weed infestation. The materials such as saw dust, manure, straw, leaves or stubble trash can be used for mulching. Residue incorporation or trash farming in which crop residue are cut and partly mixed with the soil and partly left on the soil surface is also a form of mulching.

e 6.2: Runoff and soil loss as influence by grasses on 9% slope on silt, clay loam soil at Dehradun (India)

atment	Rainfall (mm)	Runoff as % of rainfall	Soil loss (t ha^{-1})
odon dactylon	1250	27.1	2.10
ıral grass cover	1250	21.2	1.02
: fallow	1250	71.2	42.40
: fallow ploughed	1250	59.5	155.95

trip, mixed and inter-cropping: Strip cropping is the practice of growing ternate strips of different crops in the same field. It implies that strips are along ie contour. The strips of crops should be of sufficient width to be convenient to ırm, yet not so wide as to permit excessive soil loss.

nother approach is through mixed/inter cropping where more than one crop is rown in the field simultaneously. One or two subsidiary crops are mixed with a ain crop. A legume crop is generally included as one of the subsidiary crop nce it provides a good cover.

gro forestry: Agro forestry has become quite popular in recent past. It is quite a seful land use on slopes. Growing of multipurpose trees (MPTs) can further ıhance the usefulness of this approach.

ıay like to stop for a while and fix some of these ideas in your mind. Attempt an

---

3

hat is soil erosion? Differentiate between sheet erosion and rill erosion.

fferentiate between preventive and control measure for water erosion. List at ıst four preventive and two control measures, which you think, can be easily opted.

st different kinds of terraces. Explain the difference between inwardly sloping d outwardly sloping terraces.

Erosion control for degraded lands

On account of limitation of slope, shallow soils, flooding, stoniness and climate, many eroded lands cannot be put to arable use. However, with erosion control, these lands can be utilized for development of pastures and afforestation. Under this category gully erosion and its control seem to be of utmost importance.

Gully erosion control and reclamation

Although gully erosion starts as small rills, it slowly develops into deeper crevices. We have all heard of ravines. Ravines are a form of severe gully erosion. After the gully erosion is initiated, the development of gully is accelerated by erosion of the bed, sliding and mass movement of sides and waterfall at the gully head. The gully head progresses towards the upstream side. Classification of gullies has been given in Table 6.3 (Samra and Narain, 1998).

Table 6.3: Classification of gullies

Description	Specifications		
	Depth (m)	Bed width (m)	Remarks
Very small	3 or less	<18	Side slopes vary
Small	3 or less	>18	Side slopes vary
Medium	3-9	>18	Side slopes 15%
Large (deep & narrow)	3-9	<18	Side slopes vary
	> 9m	Variable	Side slopes variable but mostly steep or vertical

Closure to biotic interference is probably the first step in the reclamation of gullies. Basic principles of gully control are:

- **Diversion of runoff:** Diversion of runoff that has caused the gully to form, if diverted through diversion drains would go a long way in controlling the gully erosion.

- **Vegetative methods:** Artificial vegetation of gully beds and banks accelerates the process of stabilization of the gully. Grasses are established both on the beds and sides either by seeding or sodding. *Dicanthium annulatum*, *Cenchrus ciliaris* and *Apluda mutica* are few grasses that come up naturally or could be sodded.

- **Temporary structures:** Temporary structures for gully control helps to retard the flow of water as well as reduce the channel erosion. Brushwood check dams, loose rock dams, rock filled dams and woven wire dams are commonly used structures.

- **Permanent structures:** Permanent structures viz. chute spillways, drop spillways and drop-inlet or pipe spillways are constructed. Chute spillways are used at the gully head for the safe conveyance of water to the gully bed. The drop spillways are used along the gully bed while the drop inlet spillways are used at appropriate locations in the gully to store water.

Wind erosion

Wind erosion is a common phenomenon of the arid and semi-arid regions, where the rains are scanty and erratic, thereby leaving the land surface dry with more or less no vegetation. As a result of turbulence and velocity of wind, the material on the surface of the land is loosened and lifted, slid or bounced along the surface of the ground and is deposited at some other place. Such process of soil movements is known as wind erosion (Fig. 6.15).

Fig.6.15: Wind erosion

The following factors affect wind erosion:

- Soil moisture (greater the moisture, lesser are the chances of wind erosion);
- Wind direction and velocity;
- Temperature;
- Soil structure and roughness of the surface;
- Length of the eroding surface;
- Vegetation cover or crop residues.

During wind erosion, movement of particles could be categorized into surface creep, altation and suspension. Surface creep is the sliding or rolling motion limited rincipally to the larger, heavier soil particles or aggregates. On the other hand, soil noved by saltation process is chiefly composed of the particles ranging in diameter rom 0.1-0.5 mm, which bounce on soil to detach other particles. Suspension results rom air turbulence that lifts particles into rapidly moving air-stream above the round. Very fine dust particles (< 0.1 mm diameter) remain in suspension and are arried away long distances.

'ontrolling wind erosion

asic principles to control wind erosion are to:

- Reduce wind velocity near the ground level;
- Remove abrasive material from the wind;
- Reduce soil erodibility.

- **Trees and shrubs**

Shelterbelts and **windbreaks** are important wind erosion control measures. Besides erosion control, these help the crop by improving the microclimate and by protecting the crop from the onslaught of wind carrying soil particles. A shelterbelt is a wide belt of trees planted in several rows at right angles to the prevailing wind direction.

On the other hand, a windbreak is a narrow belt of trees planted in one or a few rows in a field or in one or more sides of a farmstead to provide protection from the wind. The density, height and length of windbreaks affect this effectiveness. The species used for windbreak should be so chosen that these are of different heights. The tallest of the species needs to be provided in the middle while the low trees and shrubs should be provided along the end rows of the windbreak. It has been established that more or less a conical cross-section provides the best protection as well as increases the zone of protection.

Fig.6.16: a) Shelterbelt; b) windbreak

- **Tillage practices**

During summer fallow, till the land with equipment that only provides roughness to the land and leaves clods on the land surface. As far as possible, equipments that pulverize the soil should be avoided.

- **Strip cropping**

Wind strip cropping is a useful method to control wind erosion. In this method, strips of crops like pulses or grams or tall growing sorghum or pearl millet are alternated with low growing crops like groundnut or *ragi*. These strips are laid across the direction of wind.

Fig.6.17: Strip cropping

- **Stubble mulching**

While harvesting crops, the stubble should be retained at least up to a height of 0.3 m. If possible the straw should also be left on the land. Stubble mulch tillage requires careful handling of the crop residue from harvest through planting time. The objective of this kind of tillage is to ensure enough residues on the surface of the land to protect soil from wind erosion. Wherever possible and practicable, retain grasses on the land surface.

- **Mechanical Measures**

Erosion control structures such as contour bunds or terraces along contour provide beneficial support to cropping practices besides control of wind erosion. The sand dunes stabilization program can help in checking wind erosion.

;AQ 5

ı) In what areas is wind erosion most likely to occur?

›) What are the easiest ways to prevent and control wind erosion?

;.3.2 Soil Health

;oil health or soil quality integrates the physical, chemical and biological components ıf soil and their interactions. Therefore, to capture the holistic nature of soil quality or ealth, all the parameters should be measured (Table 6.4).

;able 6.4: Important physical, chemical and biological parameters for assessing soil health / quality

Physical	Chemical	Biological
;oil depth	Electrical conductivity	Microbial biomass
;ulk density	pH	(c & n)
ıfiltration rate	Total organic carbon	Soil respiration
oil aggregate stability nd size distribution	Total and different forms of N	Soil enzyme acticity, Fungal hyphae length Erogosteral concentration
oil penetration resistance	Available phosphorus and potash, micro-nutrients	Population of earth worms
oil slaking	Cation exchange capacity	Nematodes
Vater holding capacity	–	–

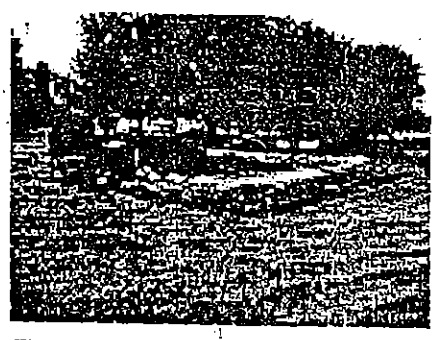


Fig.6.18: Healthy soil produces a good crop

.s such, one can compare the soil quality under various management options. But efore any actual soil quality assessment is made, it may be important to characterize ıe site. The objective is to gain as much information as possible. A soil quality site escription sheet (Table 6.5) must be completed during a soil quality assessment xercise.

Table 6.5: Soil quality evaluation for site description

Site Description		**Date:**
Map Location	**State**	**Country**
Geographic Location	**Longitude:**	**Latitude:**

Field or site location
Land owner
Soil Information
Soil Series
Slope %
Erosion
Mean Annual Temperature
Mean Annual Precipitation.

Present Management
Cropping System
(Rotations, cover crops, etc.)
Fertilizers/Pesticides
(N inputs, pesticide use, etc.)
Tillage, Residue Cover
(Type, depth frequency, timing, % cover, etc)
Irrigation
(Pivot, gravity, amount and timing, etc)
Other

Past Management History
Cropping System
(Rotation/fallow history, etc.)
Fertilizers/Pesticides
(N inputs, pesticide use, etc)
Tillage/Residue Cover
(Past tillage, frequency and type)
Irrigation
(Past irrigation, how long?)
Unusual Events
(Floods, fires, land levelling)

Soil quality assessment is an important task in sustainable land resource management. Although the basic framework is presented here, to make use of this as a normal practice in land and water resources management, research organizations in every country should generate/compile a database on the following:

- Reference values for indicators revealing full potential of the soil within the soil's inherent capacity.
- Baseline values for major soil groups under present management.
- Development of a field soil kit to permit rapid on-site assessment of basic soil quality indicators.
- Finally but not the least, it is important to identify a national organization which would work with other national/state organizations in development, acquisition and dissemination of soil quality information. It should act as a repository of all data collected on this aspect in the country

oil Productivity and Soil Health

.n integrated index of all the soil quality parameters is the soil productivity. Any dverse change in soil productivity would reveal some changes in at least some of the oil quality parameters.

.3.3 Problem Soils

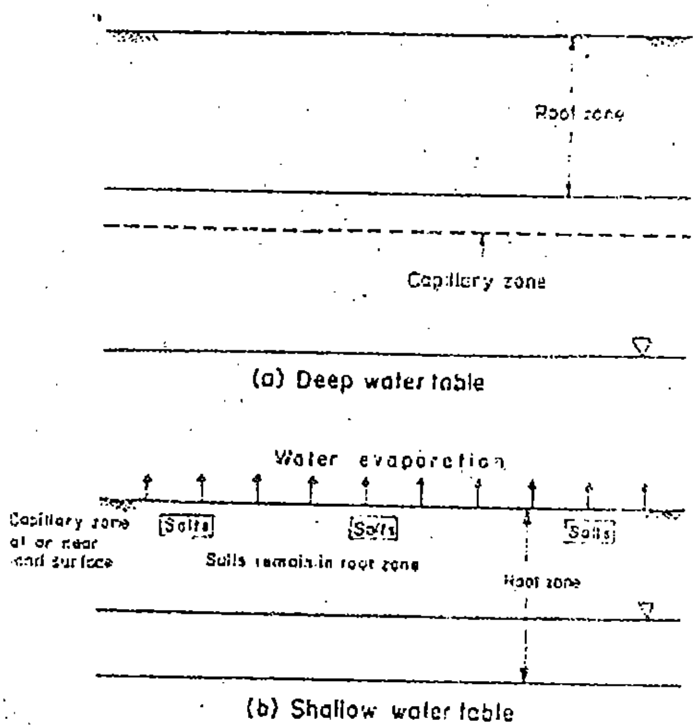
oil degradation has emerged as a major problem of concern since it adversely affects ie soils capacity to produce food and sustain rural livelihoods (see Sec. 6.3). Many of ie soil degradation problems remain invisible in the short run but noticeable declines farm productivity occur in the long-term so much so that because of uneconomic oduction, fields are taken away from the plough. A brief description of some oblem soils and their management is discussed in the following sections.

alt Affected Soils

hen the content of salts in soils exceeds the permissible limits, it affects the crop owth. The soils in that event are called salt affected soils. Most salt affected soils e found in arid and semi-arid regions where on an annual basis evaporation exceeds e precipitation. Although soils in these regions inherently contain the salts, the llowing processes abate the salt build-up.

Introduction of irrigation through inter-basin transfer of water: Besides transporting water, huge quantities of salts are transported along with it. Since water gets evaporated or is taken up by the plants, salts remain in the profile and continue to build-up unless adequate natural drainage exists or artificial drainage is provided to maintain the salt balance.

Rise in water table, in the absence of adequate drainage: This is an inevitable consequence of introduction of irrigation. In case the water table is deep, capillary zone is much below the soil surface and water cannot evaporate even if there is atmospheric demand. As the capillary zone enters the root zone, plants take up water or it gets evaporated while most salts are retained in the root zone or the soil surface (Fig. 6.19).



.6.19: A schematic diagram showing accumulation of salts as a consequence of shallow water table

- As said before, use of saline groundwater for irrigation also accelerates the salt build-up in the soil profiles.
- Salt could also be brought into the area through subsurface flows or could be deposited through wind blown soil mass.

Classification of Salt Affected Soils

Salt affected soils are classified on the basis of salt concentration (normally measured by electrical conductivity (EC) of the soil saturation extract at 25°C and the sodium adsorption ratio (SAR) or exchangeable sodium percentage (ESP) of the soil solution. The most widely accepted criterion for categorization of salt affected soils is given by United State Department of Agriculture, USDA (Richards, 1954).

Saline soils: These soils have an EC_e more than 4 dSm^{-1}, pH_s less than 8.2, an ESP less than 15 and a preponderance of chlorides and sulphates of sodium, calcium and magnesium. Since a white inflorescence is deposited at the soil surface, these soils are also designated as white saline soils.

Fig.6.20: Saline soils

Sodic soils: Sodic soils also designated as alkali soils, have a pH_s more than 8.2, ESP of 15 or more and a preponderance of carbonates and bicarbonates of sodium. The EC_e may be high if originating from salts capable of alkali hydrolysis; otherwise it should be less than 4 dSm^{-1}. At high pH, organic matter present in the soil is dissolved and it is brought to the soil surface through capillary rise, giving the surface a dark brown or black colour. As such, these soils have also been referred to as black alkali soils.

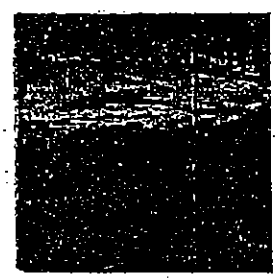


Fig.6.21: Sodic soils

Saline sodic soils: Saline sodic soils have pH greater than 8.2. EC_e greater than 4 dSm^{-1} and ESP greater than 15. These soils are formed due to a combined process of salinization and sodification.

For a quick overview of the differences between saline and sodic soils, you could refer to Table 6.6.

Table 6.6: Characteristics of sodic and saline soils

Characteristics	Sodic soils	Saline soils
EC_e (dS/m)	Variable	4.0 or more
ESP/SAR	15 or more	Variable
pH_s	8.2 or more	< 8.2
Chemistry of soil solution	Carbonates and bicarbonates always present	Dominated by chloride and sulphate
Main adverse effect on plants	Sodicity of soil solution	High osmotic pressure of soil solution
Geographical distribution	Associated with semi-arid and sub-humid climates	Associated with arid and semi-arid climates
First step for reclamation	Lowering or neutralization of high pH using amendments	Removal of excess electrolytes through leaching

Source: *Abrol and Gupta (1991)*

Soil Salinity and Plant Growth

Excess salinity affects crop growth in three ways. First and the most important is that with increasing amount of salt, the water in the soil becomes less and less available to the plants even though the soil might contain enough moisture. It is because the osmotic pressure of the soil solution increases with the increase in salt concentration and the plants are unable to extract water as readily as they can from a relatively non-saline soil. In addition to the osmotic effect of salts in the soil solution, at high concentration, absorption of an individual ion may prove toxic to the plants. For example, some constituents of salts e.g. chloride, which at moderate concentration is harmless to most crops, may be toxic at higher concentrations to some crops, e.g. citrus and grapes. In addition, some elements like lithium, boron are toxic to many crops even though they may be present only in very less quantities. Thirdly, preferential absorption of one ion may also retard the absorption of other essential plant nutrients necessary for the normal growth of plants. It is believed that the adverse effects are usually due to cumulative effects of these factors although one may be dominating others in many cases.

Soil Sodicity and Plant Growth

With increasing ESP (or pH), the soil physical properties are adversely affected which causes the following problems for plants:

- Less air and water enters the soil resulting in poor environment for root growth.
- Internal drainage is restricted resulting in temporary water logging.
- Formation of surface crust affects root emergence.
- Compacted topsoil and sub-soil creates problems for root penetration and cultivation.

Plant Tolerance to Salts

Tolerance of plants to salts varies widely. Most tolerant are the halophytes also called salt plants. The examples are: River saltbush (*Atriplex amnicola*), quailbush (*Atriplex lentiformis*), *Suaeda fruticosa* and *Salicornia bigelovii*.

Non-halophytes, to which all crop plants, belong, also show inter and intra-genic variability in their salt tolerance. Based on a large number of field studies and assessment through models, crop salt tolerance tables have been prepared. Two such tables describing the relative tolerance of crops to soil sodicity and salinity are reported (Table 6.7 and Table 6.8).

Table 6.7: Tolerance of crops to various levels of sodicity problem

Range of ESP	Crops
10 – 15	Safflower, mash, peas, lentil, pigeon pea, *urd* bean
15 –20	Bengal gram, soybean, maize
20 – 25	Groundnut, cowpea, onion, pearl millet
25 – 30	Linseed, garlic, guar, lemon grass, pamarosa, sugarcane, cotton
30 – 50	Wheat, raya, sunflower, berseem, shaftal, senji, blue panic, gutton panic
50 – 60	Barley, sesbania, para grass, Rhodes grass, matricaria
60 - 70	Rice, Karnal grass

Note: *Relative crop yields are only 50 percent of the maximum in the indicated alkalinity range*

Table.6.8: Crop groups based on response to salt stress

Sensitive Group		Resistant Group	
Highly sensitive	**Medium sensitive**	**Medium tolerant**	**Highly tolerant**
Lentil	Radish	Spinach	Barley
Mash	Cowpea	Sugarcane	Rice (transplanted)
Chickpea	Broad bean	Indian mustard	Cotton
Beans	Vetch	Rice (direct sowing)	Sugar beet
Peas	Cabbage	Wheat	Turnip
Carrot	Cauliflower	Pearl millet	Tobacco
Onion	Cucumber	Oats	Safflower
Lemon	Gourds	Alfalfa	Taramira
Orange	Tomato	Blue panic grass	Karnal grass
Grape	Sweet potato	Para grass	Date palm
Peach	Sorghum	Rhodes grass	Ber
Plum	Minor millets	Sudan grass	Mesquite
Pear	Maize	Guava	Casuarina
Apple	Clover, *berseem*	Pomegranate	Tamarix
		Acacia	Salvadora

Source: *Gupta et al. (1995)*

Chemical Amelioration of Sodic Soils

Reclamation of alkali/sodic soils requires neutralization of akalinity and replacement of sodium ions from the soil-exchange complex by a more favourable ion i.e. calcium.

This can be accomplished by the application of chemical amendments that directly or indirectly furnish or mobilize Ca^{2+} ions for the replacement of Na^{+} ions. The chemical amendments used for amelioration of these soils can be broadly grouped into 3 categories.

) Soluble sources of calcium: Gypsum ($CaSO_4 - 2H_2O$), calcium chloride ($CaCl_2$) and phospho-gypsum

i) Sparingly soluble calcium salts: Calçite ($CaCO_3$) and

ii) Acids or acid formers: Sulphur, sulphuric acid, sulphates of iron or aluminium, pyrites, lime-sulphur.

The effectiveness of acids or acid forming amendments depends mainly upon the presence or absence of $CaCO_3$ in the soil. In the absence of $CaCO_3$, use of acid or acid forming amendment would not be useful.

Gypsum Requirement (GR)

The dose of amendment depends upon the level to which exchangeable sodium is to be replaced and the depth of the soil to be reclaimed. It also depends upon the nature of the soil, its stage of deterioration and crops to be grown. This amount is generally known as gypsum requirement (GR) of the soil. The GR is the equivalence of gypsum, which should be added to reclaim the soil. In normal circumstances, a 50% of the GR calculated for a depth of 15 cm should suffice to reclaim a land. If amendments other than gypsum are to be used, their quantity can be determined with the help of data reported in Table 6.9.

Table 6.9: Equivalent quantities of some common amendments for sodic soils reclamation.

Amendment	Relative quantity
Gypsum ($CaSO_4\ 2H_2O$)	1.00
Calcium chlorides ($CaCl_2\ 2H_2O$)	0.85
Sulfuric acid (H_2SO_4)	0.57
$^+$Sulfur (S)	0.19
$^+$Pyrite (FeS_2: 30%S)	0.63

These quantities are based on 100 percent pure materials. If the material is not 100 percent pure, necessary correction must be made. Thus, if the gypsum is only 80% pure the quantity to be applied will be 1.00 x 100/80 = 1.25 tonne.

hundred percent oxidation is assumed. In practice this rarely happens such that these amendments are much less effective than the others listed.

In the Indo-Gangetic alluvial plains, the soil pH values are well correlated with the soil ESP (Exchangeable sodium percentage) values. Since pH can be measured easily in the laboratory, it has been widely used as a diagnostic tool for the appraisal of alkalinity problem and for evaluating the gypsum requirement. For barren sodic soils of the Indo-Gangetic plains, the dose of amendment might vary from 10 to 15 t ha^{-1} (Fig. 6.22).

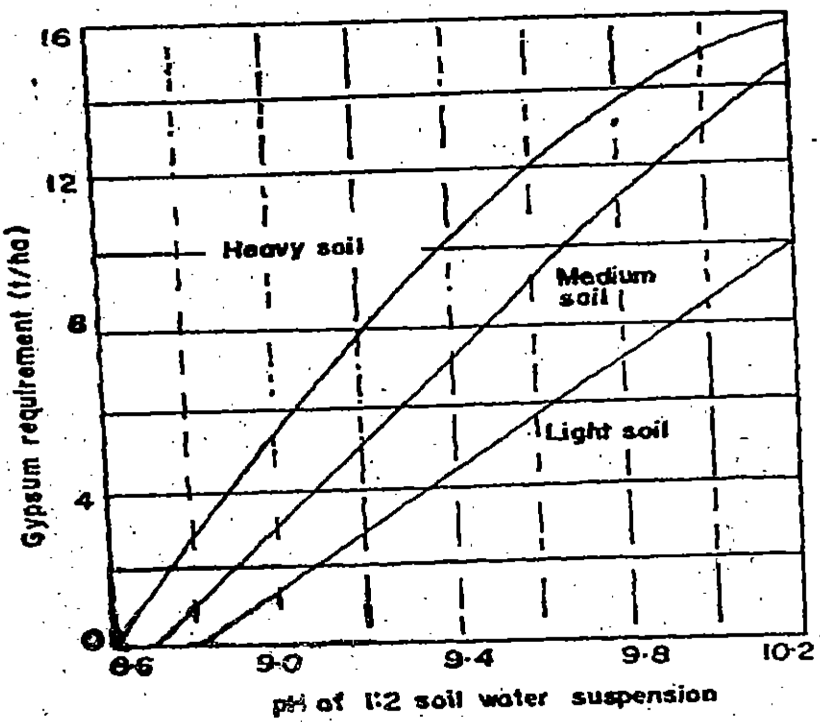


Fig.6.22: Gypsum requirement as related to pH and soil type (Abrol et al. 1973)

Management of Salt Affected Lands

Management of salt affected lands requires engineering, chemical, agronomic and cultural interventions. On-farm land development through dyking (bunding), land levelling, field layout for scientific application of irrigation and drainage, provision of a good quality source of water (tube well) and subsurface drainage in case groundwater is shallow are some of the important engineering interventions. An irrigation channel at the end of each field and a drainage channel at the tail end should be provided in a well-designed field layout.

Chemical interventions and leaching

Chemical intervention is only required in the case of sodic and saline-sodic soils. *Leaching* for 8-10 days followed by amendment application and transplanting rice crop thereafter would meet the leaching requirement of sodic soils. If adequate quantities of water are applied, leaching alone can reclaim saline soils (Table 6.10). The amount of water applied varies from one soil to another. Light textured soils usually require less water to reduce the salts to the same level compared to a heavy textured soil. As a thumb rule, 1 cm of water needs to be applied to reclaim 1 cm of soil for heavy textured soils. Thus the total quantity of water could be calculated by multiplying the depth of the water to the depth of the root zone to be reclaimed (Table 6.10).

Table 6.10: Leaching requirements of soils for one time reclamation

Soil Type	Leaching requirement (cm/cm of soil depth)	Water requirement to leach 60 cm of soil profile (cm)
Coarse textured	0.5 – 0.6	30-36
Medium textured	0.6 – 0.8	36-48
Heavy textured	0.8 – 1.0	48-60

Note: *The above requirement is to leach down 80% of the initially present salts*

Agronomic and cultural interventions

Crop management includes selection of crops and cropping pattern, cultural operations such as weeding and hoeing and application of timely and adequate nutrition. Some of the general recommendations in this regard are:

- Select more tolerant crops during first few years of reclamation. As the reclamation proceeds, sensitive crops could be grown.
- Seed rate for cropping in saline/sodic environment should be around 25% more than the recommended rate for normal soils. In the case of transplanted crops, the plant density could be increased by decreasing plant-to-plant distance as well as by increasing the number of plants per hill.
- Nutrient application should be on the basis of soil test values. Generally, 25% higher dose of nitrogen is recommended than the normal land both in case of saline and sodic soils. In sodic soils phosphorus and potash are available in adequate quantities for first few years and therefore, their application should be made strictly on soil test reports to save on cost. Zinc application is very essential in the reclamation of sodic lands.

Acid Soils

In general a soil with pH less than 7.0 could be designated as an acid soil. For the purpose of characterization and classification, acid soils may be defined as those having pH less than 5.5 in 1:1 water extract (USDA, 1975), a low cation-exchange capacity and a low base saturation. The pH range in mineral soils and the degree of acidity and alkalinity are shown in Fig. 6.23. Apparently acid soils are categorized as slight, moderate, strong and very strongly acidic depending upon the pH of the soil.

Acid soils occupy about 30% of the total geographical area of India. These are found to occur in the Himalayan region, the eastern and north-eastern plains, peninsular India and the coastal plains. Acid sulphate soils, which are singular in character amongst the acid soils with attendant problems, occur in the tropics, in low-lying coastal land formerly occupied by mangrove swamps. Such soils are found in the Kerala state of India.

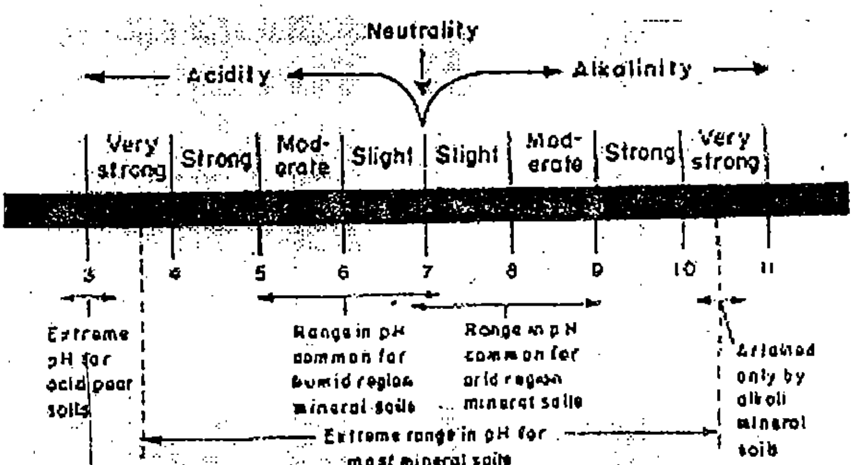


Fig.6.23: Diagram showing degree of acidity as influence by pH

Fig.6.24: Acid soils

Acid soils occur under varying climatic conditions. Their formation depends on specific conditions of climate, topography, vegetation, parent material and time for soil formation. A distinction between acid soils with aluminium toxicity and acid soils without aluminium toxicity is made if the aluminium saturation of the CEC is more than 60%. It would usually happen at pH<5.0.

Physico-chemical and Biological Characteristics

High percolation rate of water and nutrients, crust formation particularly in red soils and aggregate instability are some of the important physical impediments in the management of acid soils. Common chemical problems being a low pH, a low CEC, nutrient imbalance, a low level of base saturation, a high Al, Fe and Mn saturation percentage, a high P fixing capacity and a clay fraction consisting of rather surface inactive minerals. Besides physico-chemical properties, biological properties are also adversely affected at low pH. The activity of non-symbiotic free-living bacteria, non-symbiotic free-living BGA and symbiotic rhizobia decreases with increasing acidity.

Soil Acidity and Crop Growth

Since soil reaction affects physical, chemical and biological properties of the soil, it adversely affects the crops grown on acid soils. Although, the cause of soil acidity damage to crops is rather complex but some direct and indirect effects could be identified.

Direct effects

Acid soils often contain excess of soluble forms of aluminium and manganese. With increasing acidity, because of high solubility, these increase to toxic levels (Table 6.11). Excess Aluminium restricts root growth and uptake and translocation of nutrients, causes cell division, reduces respiration, nitrogen mobilization and glucose phosphorylation of plants. Manganese toxicity causes black necrotic spots or streaks on leaves of cereals. It also causes chlorosis of leaf margins and cupping of leaves of canola and legumes. Soil acidity also directly affects the survival and growth of rhizobium bacteria especially associated with alfalfa and sweet clover, which are sensitive to acidity.

Indirect effects

Reduced availability of plant nutrients especially phosphorus is an important cause of yield decline in acid soils. The fixed phosphorus in acid soils is usually retained in less available forms than in slightly or non-acid soils.

Table 6.11: Effect of pH on nutrient availability to plants

Nutrient	pH
Iron, manganese and zinc	Tend to become less available as pH is raised from 5.0 to 8.0
Molybdenum	Higher the pH, higher the availability
Phosphorus	Easily extractable by plants at pH 6.5
Aluminium, iron and manganese	Solubility increases at pH 5.0 or less to be toxic to plants
Bicarbonate	At high pH, it interferes in uptake of other Ions

The anticipated crop production losses as a result of increasing acidity are shown in Table 6.12.

Table 6.12: Expected loss of productivity due to acidic nature of soils

pH	Degree of acidity	Loss of productivity (% of normal)
> 6.5	Nil	Nil
5.5. – 6.5	Slight	< 10
4.5 – 5.5	Moderate	10-25
3.5 – 4.5	Strong	25-50
< 3.5	Severe	> 50

.iming of Acid Soils

ʌost chemical problems encountered in the management of acid soils can be managed imply through amelioration by liming, which improves base status, inactivates Al, Fe .nd Mn in soil solution and reduces P fixation markedly. If an acid soil with pH of .round 5.0 is limed to a pH of say 6.5, following chemical changes are anticipated.

The hydrogen ion concentration would decrease.
The hydoxyl ion concentration would increase.
The solubility of iron, aluminium and manganese would decrease.
The availability of phosphate and molibdate would increase.
The exchangeable calcium and magnesium would increase.
The percentage base saturation would increase.

lesides, these chemical changes, lime stimulates the heterotrophic soil organisms. ʌost of the favourable soil organisms particularly that fix nitrogen from the air both on-symbiotically and the nodules of legumes are stimulated by liming.

low much lime to apply

'his depends upon a number of factors. Some of these are:

Soil factors: initial pH, texture and structure, amount of organic matter;
Depth of soil to be reclaimed;
Crops to be grown;
Kind and fineness of lime used; and
Economics.

ources of lime

.mong the naturally occurring sources of lime, calcite, dolomite and stromatolitic mestone are important. While calcite and dolomites have other industrial uses, .romatolitic limestone, a poor grade lime is neither pure calcite nor dolomite.

everal industrial wastes such as steel mill slag, blast furnace slag, lime sludge from aper mills, press mud produced from sugar mills with carbonation process, cement iln wastes, precipitated $CaCO_3$ from fertilizers factories could be used as mendments to reclaim acid soils. Besides, the use of by-products makes this lternative an eco-friendly exercise.

iming materials and fineness

alcium carbonate or mixtures of calcium and magnesium carbonate are commonly sed to lime soils. Since these occur as limestone rock, it is essential to ground it to :t as an effective amendment. Effective Neutralizing Value (ENV) increases with icreasing fineness of liming material. The efficiency factor for limestone size 'action that passes through 60 mesh sieve is taken as 100%.

ffect of liming in acid soils of Chhotanagpur region in India clearly showed that gnificant effect of liming is received in the case of wheat and maize crop but not on ce (Mandal, 1976). Mandal et al. (1975) observed that favourable effects of lime on 'op yield are evident for five years. Split application did not give any beneficial 'fects.

Other management options

Selection of crops and cropping sequence: The most economical alternative to manage acid soils is to grow acid tolerant plant species and cultivars. Rice has certain tolerance to acidity since rice fields are flooded. In medium and low lands, farmers have no other choice but to grow rice because fields remain ponded with water during monsoon season. Minor millets and finger millet are quite tolerant to acidic conditions. Medium tolerant crops are the Bengal gram, lentil, groundnut, maize, sorghum and field peas. Soybean, pigeon pea and cotton are quite sensitive to acidity.

Application of fertilizers: As far as possible, the use of acidifying fertilizers for crop production on acid soils should be avoided.

Agro forestry: Agro forestry is an emerging option to resource management in acid soils of the hilly agro-ecosystem. An ecologically sound and economically viable model has been prepared at ICAR Research Complex for NEH Regions, Shillong (Prasad et al. 1981). This model recommends the following practices:

Location	Crops/ trees	Soil conservation measure
Lowest 1/3	Agricultural crops	Bench terracing
Middle 1/3	Horti-pastoral system	Half-moon terracing
Top 1/3	Agro-forestry	Contour bunding

You may now like to stop for a while and attempt an exercise. Try the following SAQ.

SAQ 6

1) Differentiate between saline, sodic and acid soil. Explain the role of acid forming amendments in the reclamation of sodic lands. What are its limitations?

2) Draw a sketch showing the pH and degree of acidity for soils. How does the availability or non-availability of elements at low pH affect crop production?

Chemically degraded lands / Soil fertility maintenance

Soil fertility also influences land productivity, one of the major functions of the soil. Soil fertility refers to the inherent capacity of a soil to supply essential nutrients to plants in adequate and right proportion for their optimum growth. It is in fact a key component that determines the productivity potential of a soil. Thus, management of soil fertility demands:

- Careful identification of lacunae in nutrient disorders.
- Monitoring changes to identify areas and degree of nutrient deficiency.
- Alleviation of nutrient deficiencies through sound and proven practices of nutrient, water, crops, energy and soil management.

Soils of India are generally poor in fertility, since the continuous cropping for many centuries without adequate addition of nutrients have depleted the soils of their finite nutrient resources. The introduction of High Yielding Varieties (HYV) of cereals during late sixties played havoc with soil fertility, as farmers could not match the withdrawal of nutrients by HYV by supplementing from inputs. Soil-test summaries indicate that 98 per cent of the Indian soils have low to medium available P, 60 per cent soils have medium K status, while N continues to be universally deficient. About 47 per cent soils are deficient in Zn, 12 per cent in Cu and 4 per cent in Mn (Takkar nd Biswas, 1998). Boron and Mo are also limiting the crop productivity in few states. Phenomenal increase in S deficiency has been reported in recent years particularly under intensive cropping systems where high-analysis fertilizers devoid of S, are used.

The basic principle, however, is to keep an account of gains and losses of each nutrient element and supply the depleted nutrient in adequate amount and in a form that is readily available to the plants both in the short and long-term basis. Apparently, this can only be achieved through the use of a five-pronged strategy:

- Optimum application rates;
- Balance fertilization;
- Efficient use;
- Dynamics of gains and losses and accordingly fixation of nutrient application rates over a period of time; and
- Integrated nutrient management (INM)

Soil Test Rating Charts

Many methods and approaches have been tried and standardized to get a precise or workable basis for predicting the fertilizer requirement of soils for crops or cropping sequences. For the ease of application, standardization of soil test methods and developing soil-test rating charts approach has been used in India (Table 6.13).

Table 6.13: Rating chemical fertility status of soils

Nutrient	Rating		
	Low	Medium	High
Organic C as a measure of available N (%)	< 0.5	0.5 – 0.75	> 0.75
Available P (kg ha^{-1})	< 11.0	11.0 – 25.0	> 25.0
Available K (kg ha^{-1})	< 120.0	120.0 – 280.0	> 280.0
Available S (kg ha^{-1})	< 20.0	20.0 – 40.0	> 40.0
Available Zn (mg kg^{-1} soil)	< 0.6	0.6 – 1.2	> 1.2
Available Mn (mg kg^{-1} soil)	< 3.0		
Available Fe (mg kg^{-1} soil)	< 4.5		
Available B (mg kg^{-1} soil)	< 0.5		

Source: *Takkar and Biswas (1998)*

Soil Organic Matter

Soil organic matter (SOM) is the key component that modulates soil physical, chemical and biological functions and reflects the overall state of soil quality/health. It plays a multitude of roles in soil, but most importantly, it is the source of nutrients and energy to soil biota, whose activities create the distinction between an agglomeration of lifeless minerals and a soil. Most Indian soils with the exception of hill and mountain soils under forest cover are poor in organic matter (Goswami et. al 2000). The following factors could be ascribed for the reduced content of SOM:

- Continuous cropping with inadequate inputs of organic and inorganic fertilizers; inputs of plant C are generally less in agriculture than in nature.
- Complete removal of above ground portion of crops.

- Erosion induced loss of topsoil rich in organic matter.
- Natural loss through degradation/decomposition aided by soil microbes and high temperature.
- Burning of crop residue.

The sustainability of soil fertility and agricultural production systems depends on maintaining the reserve of soil organic matter at the minimum levels necessary to protect the soil and maintain productivity. Building organic matter status of soils and to maintain it at appropriate levels as dictated by the climatic conditions of the area would go a long way in maintaining the soil health. With this we come to an end of this unit and summarise its contents.

6.4 SUMMARY

In the present unit you have been introduced to soil, a natural resource. You have studied the dynamics of land use, land degradation, soil erosion, soil health, salt affected soils, acid soils and chemically degraded nutrient deficient soils. Some of the salient points discussed in this unit are:

- Dynamics of land use is dictated by biophysical and socio-economic factors.
- A comprehensive land use plan will enable us to develop a sustainable land use and identify hot spots that are vulnerable to degradation due to inappropriate land use. It is also a weapon to fight the anticipated global climate change by manipulating land use to serve as carbon sinks.
- Agro-ecological zoning is a good tool to plan land use at national and/or regional level. However, attempts should now be made to use ecological-economic zoning, which is a complex but a better alternative.
- Short-term dynamics of land use in India reveals that we are far away from the sustainable land use since area under forest is at a much lower level than the optimally desirable level.
- Natural soil erosion is an integral part of the nature while accelerated soil erosion is a menace to our limited land resource. Nearly 50% of the geographical area is prone to accelerated soil erosion.
- Water and wind are two agents causing soil erosion. Ravines are the worst form of water erosion.
- Diversion of water, terracing, contour bunding, and graded bunding are some of the engineering control measures for arable lands.
- The cost of engineering measures could be reduced by the synergy of preventive and engineering measures. Some of the preventive measures are adopting proper cover crops, time of crop planting, crop geometry, contour farming, zero tillage, mulching, cropping and agro forestry.
- Diversion of runoff, use of vegetative methods, construction of temporary check dams, loose rock dams and woven wire dams and permanent structures such as chute spillways, drop spillways and drop inlet spillways to reclaim and manage gully erosion.
- Wind erosion, a common phenomenon of the arid and semi-arid regions, could be controlled through planting shelter belts and windbreaks and adoption of tillage practices and mechanical measures. Stubble mulch tillage is an important tillage practice to minimize wind erosion.

- Physical, chemical and biological parameters together determine the soil health. Any adverse change in one or more of these parameters would undermine sustainability of a given land use. Soil productivity is an index of soil health, which integrates many factors controlling soil health.

- Three kinds of problem soils have been discussed in this unit while water logged soils, which are also a kind of problem soils, would form a part of the next unit.

- Basically salt affected soils could be categorized as saline, sodic and saline sodic. Sodic and saline sodic soils require some kind of amendment for reclamation whereas saline soils do not require any amendment. Gypsum and pyrites are commonly used amendments.

- Plants differ in their tolerance to salts. Therefore, during initial years of reclamation, it is useful to grow relatively more tolerant crops. One can switch over to more sensitive crops during later years when the lands are reclaimed.

- Management of salt affected soils requires an integrated approach (we also call it a package) consisting of engineering interventions, chemical interventions, agronomic and cultural interventions.

- Acid soils, a characteristic of sub-humid and humid climates are characterized by low pH. At low pH, physical, chemical and biological properties of soils are adversely affected resulting in poor yield.

- Like salt affected soils, acid soils need lime as an amendment. Besides lime application, selection of crops and cropping sequences tolerant to acidic conditions, avoiding acidifying fertilizers and adopting agro forestry can play an important role in managing acid soils.

- Continuous cropping specifically of high yielding varieties depleted soils of its finite reserve of nutrients. Imbalance in the use of fertilizer and ignorance of the farmers about micronutrients compounded the situation.

- The fertility of the soils can only be maintained by application of nutrients at optimum rates in a balanced manner after thorough understanding of gain and losses by the crops.

- Organic matter content of the soils is a very good indicator of soil fertility. Integrated nutrient management (INM) and residue management can play important role in maintaining the soil organic matter.

6.5 TERMINAL QUESTIONS

1. Explain the basic principles of land use. What impact would superiority of demand have on our land use pattern?

2. What do you understand by sustainable land use? List major challenges in implementing a sustainable land use.

3. Differentiate between contour and graded bunding.

4. Name two important parameters from each amongst the physical, chemical and biological parameters giving a brief explanation how it could be adversely affected due to a certain land use.

5. How can we maintain the long-term fertility of the soils? List the steps to maintain soil organic matter at an optimum level.

REFERENCES

1. Abrol, I.P. and Gupta, R.K. (1991) Salt affected soils and their management. In : Proc. National Training Course On Field Drainage for Control of Groundwater and Soil Salinity. CSSRI, Karnal. 1-37.

2. Anonymous (1989) Global Warming and Climatic Changes. Perspective from Developing Countries. Proc. Of the Int. Conf. (Gupta, S. and Pachauri, R.K. Eds.). Tata Energy Research Institute, New Delhi.

3. Brady, N.C. (1974) The Nature and Properties of Soils. Macmillan Publishing Co. Inc. New York (8th Edition).

4. FAO (1996) Agro-Ecological zoning guidelines. FAO Land and Water Management Div. FAO, Rome. 90 pp.

5. Goswami, N.N., Pal, D.K., Narainswamy, G. and Bhattacharya, T. (2000) Soil organic matter – Management issues. International Conference on Managing Natural Resources for Sustainable Agricultural Development in the 21st Century, New Delhi, pp. 87-96.

6. Gupta, S.K., Dinkar, V.S. and Tyagi, N.K. (1995) Reclamation and Management of Waterlogged and Salt Affected Areas in Irrigation Commands – A Manual. Ministry of Water Resources, New Delhi and CSSRI, Karnal, 144 p.

7. Honora, G. (1999) Our land, ourselves: A practical guide to watershed management in India. Indo-German Bilateral Project on Watershed Management, pp. 212.

8. Iowa State University (CAEA) (1961) Dynamics of Land Use: Needed Adjustments. Iowa State University Press. Iowa, USA (63:33 K1)

9. Mandal, S.C. (1976) Acid soils of India and their management. In Acid Soils of India, Their Genesis, Characteristics and Management. Bulletin Indian Soc. of Soil Sci., New Delhi. 11:191-199.

10. Mandal, S.C., Sinha, M.K. and Sinha, H. (1975) Acid Soils of India and Liming. Tech. Bulletin 51. Indian Council of Agricultural Research, New Delhi, 126 pp.

11. Prasad, R.N., Ram, P., Barooah, R.C. and Ram, M. (1981) Soil Fertility Management. Bull 9. ICAR Res. Complex for NEH Region. Shillong.

12. Richards L.A. (Ed.) (1954) Diagnosis and Improvement of Saline and Alkali Soils. *USDA Hbk. 60*, 160P.

13. Samra, J.S. and Narain, P. (1998) Soil and water conservation. In 50 years of Natural Resource Management Research (Singh, G.B. and Sharma, B.R. Eds.). Indian Council of Agricultural Research, New Delhi. 145-176.

14. Sauer, C.O. (1919) Mapping and utilization of the land. Geographical Review, 8:47-54.

15. Sehgal, J.L. (1995) Land resource appraisal for land use planning to meet the challenges of the 21st century. J. Indian Soc. Soil. Sci., 43: 504-528.

16. Sehgal, J.L., Mandal, D.K., Mandal, C. and Vadivelu, S. (1992) Agro-Ecological Regions Map of India (Second ed.). Technical Bulletin. NBSS&LUP Pub. No. 24. NBSS&LUP, Nagpur.

17. Singh, G., Venkatarmanan, C. and Sastry, G. (1981) Manual of Soil and Water Conservation Practices in India. Bull. No. T-13/D-10. Central Soil and Water Conservation and Training Institute, Dehradun. 433 p.

8. Takkar, P.N. and Biswas, A.K. (1998) Fertility management of Indian soils. In 50 years of Natural Resource Management Research (Singh, G.B. and Sharma, B.R. Eds.). Indian Council of Agricultural Research, New Delhi. 115-144.

9. USDA (1975) Soil Taxonomy. Agricultural Hannbook No. 436. SCS, USDA, Washington, DC, USA.

0. Vink, A.P.A. (1975) Land Use in Advancing Agriculture. Springer-Verlag, Berlin Heiderlberg, New York.

1. World Commission on Environment and Development (1987) Our Common Future. Oxford University Press, U.K.

UNIT 7 WATER

Structure

7.1 INTRODUCTION

All human activities require fresh-water, which needs to be made available in adequate amounts at the right place and at the right time. This is why all early civilizations flourished along rivers. As far as agriculture is concerned, land and water are the two most vital natural resources. We have discussed some issues related to land and soil in Unit 6. In this unit, we take up the issue of water resources. Unfortunately, in arid and semi-arid regions, in densely populated countries and in most of the industrialized world, the competition for scarce water resource has already set in. Water resource is under tremendous stress today. It has been well said that the next world war might be fought for water. Signs of cold war on this resource both in India and abroad have already emerged. Since water resource is finite, per capita water resource is decreasing rapidly.

Water withdrawals are made both for consumptive uses such as irrigation or for non-consumptive uses such as hydropower, domestic and industrial purposes, navigation and tourism. Besides, some water needs to be drained to the sea for eco-system maintenance. On a global scale 70 % of the water withdrawal is for consumptive purposes. Although a part of the water is returned to the rivers/groundwater, most of the water for non-consumptive uses is returned back with degraded quality.

It is a paradox that in spite of impending water crisis, of which all of us are aware, water is used most luxuriously or wastefully. While water use efficiency in agriculture is less than 50 % in most irrigation commands (could be as low as 30 % in some cases), the wastage of water is equally discernible in the domestic and industrial sectors. Following a rainstorm, water is drained into rivers as if it would not be needed any more. Surprisingly, within few days cries of water scarcity are heard. With increasing groundwater development, a paradoxical situation is developing in many parts of the world. On the other hand, groundwater storage in many areas is increasing raising the water table at an alarming rate. Besides the loss of water through capillary rise, it leads to soil salinization.

If water is managed inadequately, its quality can degrade, jeopardizing the future use of water. Moreover, its availability for specific use may reduce or it may not be available at all. Although we are becoming conscious of water quality, our contribution to these efforts has been minimal. Our rivers, which were revered in the past, become sewer drains during the non-monsoon months. Groundwater is being polluted indiscriminately by industries.

Fresh water is a finite resource having spatial and temporal variability. Besides the cost of controlling and developing the water resource, water is a sensitive subject. Any minor change in policy would result in gainers and losers. Therefore any change is likely to be welcomed and opposed depending upon the gains and losses. Since water sustains civilized human life, it has many facets all of which cannot be covered here. In this unit, we introduce you to the hydrological cycle. You will learn about the quantity and quality aspects of water. Since too much or too little water, or both affect production and productivity, you would be familiarized with issues related to floods, water logging and drought. Finally we introduce the concept of Watershed Management. In the next unit we discuss the issues involved in conserving biodiversity.

Objectives

After studying this unit, you should be able to:

- discuss the relevance of water for increased production and productivity in agriculture;
- describe surface and ground water resources and their interdependence;
- analyse the extremes in the availability of water leading to floods and droughts;
- describe the adverse effects of water logging on soil health and remedial measures;
- comprehend the water quality concerns especially related to agriculture; and
- explain the concept of watershed management.

7.2 THE HYDROLOGICAL CYCLE

The total amount of water in the hydrosphere has been estimated at 1500 million km^3, which if spread over the entire surface of the earth, would rise to 3000 m above the surface. Only 5% of this water is fresh in nature, the remaining being saline. Of this only 20% is in the liquid form, the remaining being in frozen form. Thus, only 1% of the water in the hydrosphere is available for use. Around 99 % of this water is in the form of groundwater. These global average values may vary from one continent to another, from one region to another or from one country to another. But it is abundantly clear that water has multifarious uses in various sectors of economy, each competing with the other to get a lion's share of this scarce quantity. In such a situation, it is necessary that limited water resources are exploited and used in a judicious manner.

When we talk of water resources of the hydrosphere, our main interest is in the transfer of water from one form to another. Since the total amount of water in the hydrosphere is constant, it is clear that this transfer occurs in the form of a continuous cycle or a series of cycles. Moisture constantly circulates between land, ocean and the sky. The cycle has neither a beginning nor an end. This is known as the hydrological cycle. The major elements of this cycle over a region are shown in Fig.7.1. (See Fig.7.2 for a pictorial version of hydrological cycle).

The term precipitation includes all forms of water that is received by earth from the atmosphere. It includes rainfall, snow, frost, drizzle and hail etc. On a global scale some 110,000 km^3 of water is received. The vegetation intercepts a part of the precipitation while a part is retained as soil moisture. Most of it gets evaporated (70,000 km^3) and is known as **green water**. Of the green water 18,000 km^3 is being exploited for agriculture while the remaining meets the water needs of all non-irrigated vegetation, including forest and woodlands, grassland and rain fed crops.

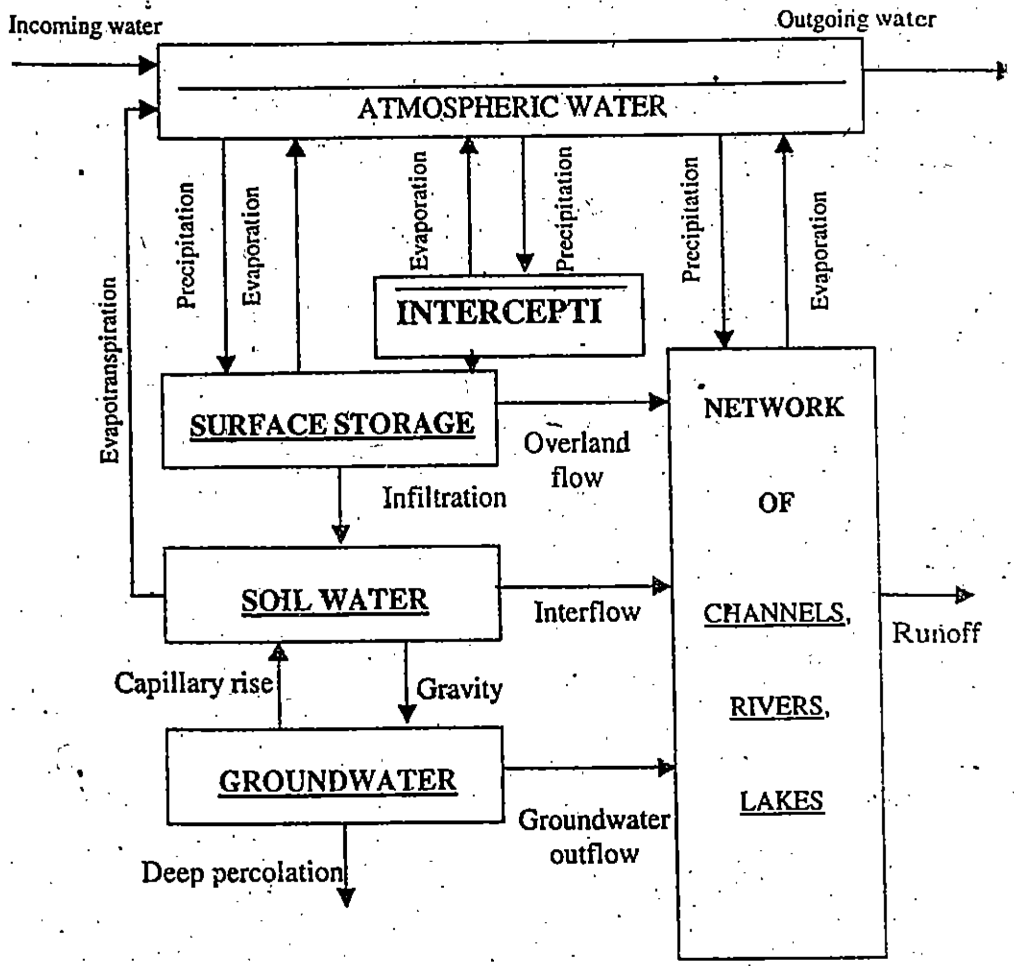
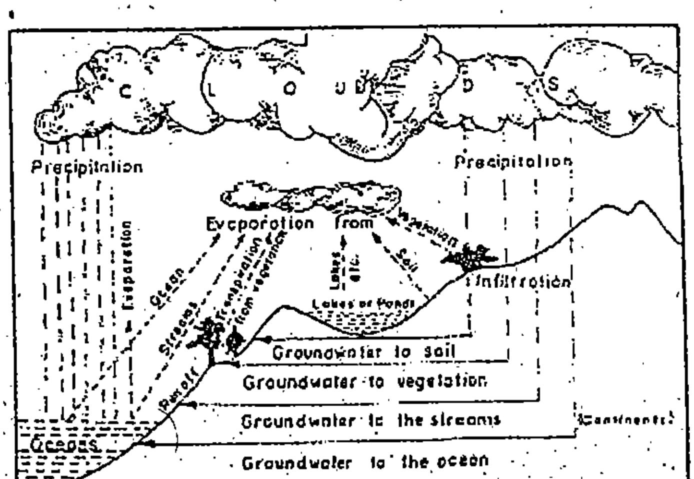


Fig.7. 1: Flow diagram showing various components of the hydrological cycle

The remaining 40,000 km^3 remains on the earth as blue water or ground water and flows to the sea or lakes unless stored, transported and exploited to meet human needs. Only 12,500 km^3 of this water is accessible for human use as per the present technologies available.



Hydrologic Cycle

Fig.7.2: Hydrological Cycle

In the hydrological cycle, soil acts as a reservoir and water is always in transitory storage in soil. Considerable time may elapse before this stored water flows underground to stream or is returned to the atmosphere by evaporation. Eventually, however, all water temporarily stored in the soil must enter the transitory part of the hydrological cycle by percolating to underground streams or entering into atmosphere by evaporation. There are many opportunities to influence the hydrological cycle and affect water conservation in agriculture. We discuss this issue in the next section. But first you may like to concretize the understanding of hydrological cycle by attempting an exercise.

SAQ 1

a) What do you understand by the hydrological cycle?
b) Explain the role of soil in the hydrological cycle.

7.3 WATER RESOURCES AND AGRICULTURE

A greater part of human requirement, food, fibre and accessories for shelter are met from agriculture. Logically, a major part of human water use is in agriculture. On a global basis, 70% of the water withdrawals are claimed by agriculture. On regional basis, and particularly in arid regions, it might go as high as 90% of the total water withdrawals. Since rain fed agriculture cannot be expected to keep up with growing demand for food because of environmental constraints, within the agriculture sector, the largest share of water is claimed to roughly irrigate about 250 million ha of irrigated lands worldwide. The importance of this water allocation could be gauged from the fact that 40% of the total food and agricultural commodities are produced on these irrigated lands, which is only 17% of the total cultivated area. The remaining 60% is produced by 83% of the cultivated area. According to statistics from India and other parts of the globe, a 50 to 200% increase in agricultural production could be obtained upon introduction of irrigation. In today's perspective, irrigated agriculture seems to be the only weapon to fight with to produce additional food for the 800 million undernourished today and 2 billion more people expected to join us by 2025.

Accessible blue water needs to meet some of the essential requirements such as water for drinking by human and animals, for hygiene, sanitation, municipal use, for industrial establishment, aquatic life and environment. All these requirements would also have a quantum jump because of increasing population, increased standard of life and changing eating habits of the populace. Apparently agriculture has to compete with these sectors that have a higher potential and precedence. These sectors can pay more for water than agriculture. Thus increasingly, agriculture has to leave its share of fresh water to other sectors and rely upon water used once by these sectors.

Performance of agriculture under irrigation depends to a great extent on the timely and adequate supply of good quality water. Safe, reliable and adequate quantities of water are also needed for livestock and for processing operations. As such, a large infrastructure to supply water is needed to achieve these goals. Operation and maintenance cost of this infrastructure is also quite high. Pricing of water should be so fixed that at least it covers the cost of operation and maintenance.

It is assessed that to develop irrigation on one ha of land in India presently costs Rs. 100,000 or more.

While irrigated agriculture consumes the largest amount of water, yet it is known to be the most inefficient sector in the use of water. The water use efficiency in some cases being as low as 30% a major fraction of the water is wasted and adds to the groundwater storage. Water use efficiency has many facets. Resource saving, financial saving and environmental benefits are all linked to the improved water use efficiency.

World Water Vision has projected that with increasing efficiency 40% more food products can be produced by 15-20% additional water. By improving the water use efficiency, financial savings would occur in operational cost of pumping, treatment of water and wastewater and additional income would be generated as a result of expanded area under irrigation. Environmental benefits would also emerge from reduced problems of water logging and soil salinization, increased discharge for in stream use, and reduced pollution of groundwater or surface water resources. Whatever agricultural advances are made, the fact remains that to grow more food we require more water whether the agriculture is rain fed or irrigated. It is estimated that by 2025, demand for water in agriculture sector would increase by 15-20%. Some of this water can come from rainwater harvesting in arid and semi-arid regions. Exploitation of shallow saline water aquifers and use of grey and black waters could be other sources that could increase water for use in agriculture.

Categories of Water and their Role in Agriculture

Available global or regional water for use in agriculture have been grouped in five categories besides a category based on implication of export-import of agricultural products.

Category of water	Source	Potential for use in agriculture or remarks
Blue water	Sea, lakes, rivers, canals, etc.	Extensively used for irrigation. Its availability is likely to decrease with increasing competition from other sectors.
Green water	Soil moisture and water in plants	Mostly used by plants and agricultural crops particularly forest, grass lands and rain fed agriculture.
Fossil water	Groundwater	Used for domestic and agricultural uses. Its availability to agriculture would decrease with time as a result of competitive demand from other sectors.
Grey water	Wastewater from bathroom, kitchen and washbasins.	Potential for use in crop production. Suitable for kitchen gardening and irrigating lawns.
Black water	Domestic sewage/Industrial waste	Potential for use in crop production. 21st century water resource for agriculture. Cleaner technologies required to avoid heavy metals/pathogens entering human chain.
Virtual water	Water used in producing grains/animal product	Export-import of food grains/animal product indirectly results in export-import of water. One kg of rice or wheat export means export of 2000 litres of water for rice and 800 litres of water for wheat. It is going to assume importance in export-import during the next few decades.

So far you have learnt how improving the efficient use of water can help one in better management of this resource. The question is how to do it? We look into the issues involved but first you may want to answer the following question:

SAQ 2

What are the major benefits of improving water use efficiency? Give examples of each.

Strategies for Increasing Productivity of Water in Agriculture

A five-pronged strategy is required to meet the increasing demand of water to meet the food needs of the world.

- Improved agricultural technologies to increasing water productivity: more crop per drop;
- Harnessing new resources of water to augment existing water resources;
- Water conservation;
- Water reuse;
- Improving water institutions and stakeholders participation for improved water governance.

India is home to 18% of the world's human population and 15% of the animal population, but owns only 3.7% of the world's water resources.

Let us see how these strategies can be used to manage water resources.

7.3.1 Development of Surface Water Resources

Development of surface water resources like tanks, ponds, wells etc. has been a major thrust area in the past few decades and therefore, huge investments have been made in most countries. It has been estimated that due to extreme variability in precipitation, which disallows assured storage of all the water and due to limited storage space available in hills and plains, it may not be possible to store all the water that is available as runoff.

Although great strides have been made in developing the irrigation potential, some issues have cropped up, which require immediate attention.

- The cost of creation of irrigation potential is increasing exponentially.
- The gap between the potential created and potential utilized is huge in all developing countries. For example, it is provisionally assessed at 4.6 million ha in India which means at the present cost of potential creation, more than Rs. 460 billions has been locked.
- In spite of huge investments being pumped in creating irrigation potential, the production and productivity of irrigated lands is abysmally low. An average productivity of 2.5t ha^{-1} is considered low by any standards and it seems there are some inherent lacunae in our irrigation planning and providing necessary support and infrastructure.
- As per recent assessment many million ha of agricultural lands have gone out of cultivation because of spread of water logging and soil salinization. Apparently, besides loss in production at current prices, it has locked a huge investment (Rs.560 billion in India). It is believed that a large chunk of the area in commands might be experiencing these problems to varying degree, affecting production and productivity.

7.3.2 Groundwater Development

Groundwater resource that can be replenished is mostly derived from precipitation. Of the total rainfall, about half percolates into the ground, out of which only one fourth joins the groundwater. A part of this water regenerates into streams but simultaneously, there is net addition of water through streams and irrigation.

Because of the uneven distribution of groundwater structures, a paradoxical situation is developing. While in many blocks water table is declining, in other areas the water table is rising. Since the rising water table is clearly correlated with saline/sodic groundwater areas, water logging and soil salinization are also developing in these areas. Thus, efforts to tap and use poor quality groundwater for agriculture need to be upgraded.

SAQ 3

Outline the major issues involved in the development of surface and ground water resources.

7.4 WATER STRESS CONDITIONS

Weather plays a positive role in the production of crops. But at times, it also plays havoc and destroys the crops and vegetation. Floods in South Asian regions, which usually follow excessive rains cause misery to human and animal population, affect infrastructure and adversely affect crop production and productivity.

7.4.1 Floods

Floods usually occur whenever the intensity of rainfall exceeds the rate of disposal of runoff in the catchments. They also occur when the river in the downstream cannot accommodate the large volumes of inflow and spills over from the riverbanks or breaches inundating the low-lying areas along the course of stream flow. Flood damage due to overflow is more common along banks of major rivers. Construction of dams provides some respite from floods. Flash floods due to cyclonic storms in coastal districts of these countries are quite common. Flood events coupled with high wind velocity cause enormous losses.

Agricultural Production and Floods

Floods have both positive and negative effects on agriculture. One of the positive effects is that silt carried by floods gets deposited on agricultural fields. This silt could raise the fertility of agricultural land enhancing future production. On the contrary, partial to complete damage of production could be anticipated during the flood event depending upon the severity of the floods, duration of flood, type of crops grown and the growth stage of the crop at which flood event has occurred. For example, cereal crops and sugarcane crop can tolerate flood events better than pulse crops. Similarly, damage would be more, if flood events occur at germination / seedling stage or reproductive stage than at other stages. Silt deposited on the plant leaves can significantly lower the photosynthetic activity in the plants resulting in lower productivity. Besides in some cases, silt from already eroded lands is brought and it might lower the productivity upon deposition rather than raising it.

Since floods cause severe damage to agricultural crops and human habitations, it is best to devise measures for flood control. We should all know certain basic principles underlying these measures.

Principles of Flood Control

Several preventive and curative measures have been adopted to minimize flood damage. In any strategy, one or more of the following basic principles are involved.

- Treatment and management of watershed to reduce runoff. Most soil conservation measures help in flow regulation or reduced runoff.
- The retention of part or whole of the runoff. Construction of multi-purpose reservoirs and detention basins fall in this category.

- The diversion of a part or whole of the runoff. Flood ways or river diversion schemes are a part of this strategy.

- The confinement of floods to a certain part of the flood plain. Levelling, bank stabilization, strengthening embankments, construction of embankments around densely populated or highly industrialized urban areas utilize this principle.

SAQ 4

a) How do floods affect agricultural production?
b) Explain the basic principles of flood control.

7.4.2 Water Logging

Water logged soils occur in almost all climatic zones particularly in monsoon climatic regions. Due to simplicity, the definition proposed by Clayton has been adopted in many countries, which defines **a land as water logged if the water table is within ± 150 cm of the ground surface.** Apparently it accounts for both the surface and subsurface water logging. Thus, the word water logging is used to designate stress due to water stagnation or the shallow water table since similar conditions could occur as a result of any of the two causative factors. However, to designate the problem of water stagnation on the land surface, besides water logging, surface stagnation and flooding have also been used synonymously. Occurrence of deep submergence depths caused by floods are generally excluded from water logging since the causative factors as well as the solutions to such a problem could be different.

Surface Stagnation

Areas in humid and sub-humid regions, particularly heavy textured soils, are prone to surface stagnation during monsoon season. Besides the degree and duration of water stagnation is increasing even in semi-arid areas due to inadequate provision of drainage in developmental activities, poor maintenance and upkeep of drainage systems, encroachment of wetlands and rising water table in irrigation commands. The problem may or may not be accompanied by shallow water table. Surface drainage alone can help to reclaim these lands.

High Water Table

Problem of rising water table is usually experienced in irrigated lands when surface irrigation is introduced without providing for adequate drainage. In such a situation rise in water table is an inevitable consequence. For example, recent experiences in India reveal that in the Indira Gandhi *Nahar Pariyojana*, the water table has risen at the rate of 1m per annum (Fig.7.3).

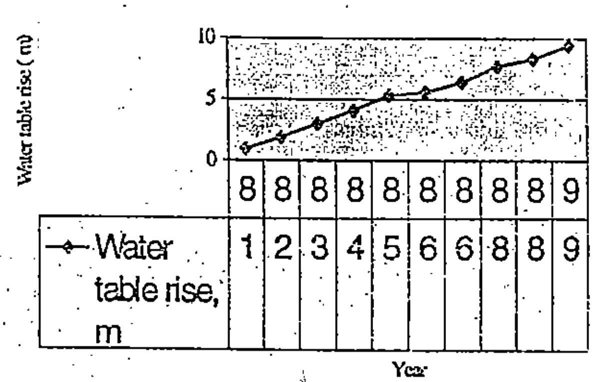


Fig.7.3: Rise of water table in IGNP

As a result, water logging and soil salinity appeared much earlier than anticipated. The problem is generally associated with the problem of surface drainage although shallow water table is more critical to crop damage. As such, investments need to be made both on surface and subsurface drainage. Field investigation would only reveal the most optimal solution to the problem. You may wonder what is involved in such investigations. Let us find out.

Field measurement/laboratory investigations need to be undertaken to ascertain the kind and degree of the problems.

- Standing water or wet spots in parts of the field where crop stand is poor.
- Open wells, gravel pits and deep channels are observed, which show the depth to groundwater. If soil horizons are reached which are wet and contain black or red mottles, one can assume that soils are poorly drained at this level.
- Salts present in the form of a white crust on the soil surface also reveal problem of water logging. Since the problem of water logging could occur even in the absence of such a crust, its absence does not mean that there is no problem of water logging.
- A general yellowing of the crop can be noticed in areas affected by water logging, soil sodicity and soil salinity.
- Vegetative cover is a good index to depth to water table in many areas. Trees such as willows, cottonwood and poplar often thrive in high water table areas. Reed grass and sedges are also common.
- Absence of surface drains or their condition (full of vegetation or plugged up) could also indicate the problem of water logging/ drainage.

Field Measurements to assess the Problem

Under field situation, water logging is measured/assessed through physical measurement of the depth to water table using open wells, tube wells or observation wells. Depth to water table in the range of 0-1.5 m would usually indicate the problem of water logging although it would depend upon the soil and crop characteristics. A relatively shallow water table may not be a problem in a coarse textured soil but even a relatively deeper water table could cause problem in a fine textured soil.

Under field situation, Oxygen Diffusion Rate (ODR) is a good measure of the oxygen deficiency. ODR is measured with an oxygen diffusion rate meter. The oxidation - reduction potential (redox potential, RP) of the soil is also used as an indicator of the problem of water logging. In practice the RP of the soil is measured with an oxygen meter using an Ag-AgCl reference electrode.

Water Logging and Crop Yield

Principally, water logging inhibits aeration, resulting in excess of CO_2 and decline in O_2 concentration in the root zone. Besides, water logging adversely affects mineral nutrition, causes imbalance in uptake of plant nutrients and aids in several chemical and biological reactions leading to production of toxic ions in the root zone. As a result of one or a combination of these factors, crop yield is adversely affected. The yield is also affected because of inhibited leaching and secondary soil salinization due to shallow water table. Cropping intensity is much less in water logged saline lands compared to non-affected areas. The choice of crops is also limited.

Water logging often leads to delay in sowing of crops because it is difficult to till the land when wet. If heavy machinery is used on wet lands it would adversely affect its ıysical properties. Since, each crop has some optimum date of sowing, any delay in ›wing would lower the productivity.

ęsides what has been stated above, the excess water and the resulting continuously et root zone can lead to some serious and fatal diseases of the root and stem (Poysa al. 1987).

/ater Logging/ Soil Salinity and Socio-economic Implications

ot only the farming community but also the non-farming communities feel its lverse impact in one-way or the other. In fact, as a result of the twin problems, the hole region is caught in an economic quagmire (Table 7.1).

Table 7.1: Anticipated losses due to water logging

Agriculture	Landscape and infrastructure	Socio-economic
Decline in agricultural production	Damage to infrastructure	Increased socio-economic disparity
Restriction on crops	Landscape degradation	Increased expenditure on health related services
Decline in product quality	Decline in eco-system health Damage to soil health	Migration from rural to urban areas Increased gender disparity

he obvious question that may have come to your mind is: How do we take care of ıis problem?

Ianagement and Reclamation of Water logged Lands

ince water logging is a widespread problem under different agro-climatic conditions, ›veral options have been field tested to minimize its adverse effects. Some of the ıanagement options are: land forming (bed plantation, raised and sunken beds), crop ›lection in favour of tolerant crops (Table 7.2), skipping or delaying irrigation so that ›ops can draw a part of their water requirement from the shallow water table, ›plying less water per irrigation, cultural practices such as hoeing and weeding ıcluding chemical control of weeds, application of additional doses of nutrients ırough soil or foliar application and mulching to minimize secondary salinization.

'able 7.2: Tolerance levels of crops to high groundwater table (Groundwater at 50 cm)

Tolerance level	Crops
<u>High tolerance</u>	Sugarcane, potatoes, rice, willow, plum, broad beans strawberries, some grasses
Medium tolerance	Sugar beet, wheat, oats, citrus, bananas, apple, barley, peas, cotton pears, blackberries, onion
Sensitive	Maize, tobacco, peaches, cherries, olives, peas, beans, date palm

mproved Drainage: The only way to Ameliorate Water logging

ıadequate drainage is the principle cause of the water logging and therefore, solution f the problem is also through improved drainage. Productivity of agricultural lands an only be sustained if drainage improvements are undertaken on cropland currently ffected by submergence or high water tables. Farmers who have heavy textured soils, oils with plow layer, which commonly develops in lowland rice-wheat system, alkali lands with poor water absorption characteristics or those who rely mainly on surface irrigation should have adequate surface drainage facilities to remove excess water If the recharge to the groundwater is more than the discharge and natural drainage is unable to take care of this recharge, such a situation calls for providing subsurface drainage. Subsurface drainage may be accomplished either through the construction of open trenches or through buried clay or concrete tiles or perforated pipe. It must, however, be realized that most crops have an optimum depth to water table to get optimum crops.

In the monsoon climatic conditions an integrated drainage system consisting of appropriate capacity surface drains aided by appropriately spaced subsurface drainage or vertical drainage could reclaim the affected lands in the shortest possible time. Such a set-up would allow cultivation of lands in the first year itself while the full potential of yields could be realized in 2-3 years.

Surface Drainage

It is defined as the process of removal of water from the land surface by means of surface flow. The amount of water to be removed is expressed in units of mm day^{-1}. The system that is designed to improve surface drainage of an area is known as surface drainage system.

In order to provide relief against recurring floods and to save the crops from damage, surface drains have been implemented at regional scale in many regions. But because of the underlying principle that collectors and main drains are provided by the state while field drains are to be constructed by the farmers, drainage systems have worked well only as flood control measure. The crops continue to suffer adversely because of lack of field drains, which are rarely constructed by the farmers. Improved surface drainage alone could help to increase the yield by 10-25% or even more in some cases.

Subsurface Drainage

Surface drainage can only remove surface stagnation of water; as such it would prevent/delay the rise in the water table. To control the water table in areas where water table is already in the root zone, some kind of subsurface drainage is very essential. Removal of excess groundwater to control the groundwater table is known as subsurface drainage. A system that is designed to control the water table is known as subsurface drainage system. Subsurface drainage can be accomplished through several ways. Most promising are:

Horizontal subsurface drainage or pipe drainage: Drainage is accomplished by laying pipes with holes, which collect and convey the excess water to collector and main drains. Some of the standard layouts to construct effective drainage system are shown in Fig. 7.4. Horizontal pipe drainage is an effective intervention to control water table, improve aeration and help to leach down the excessive salts from the root zone.

Vertical Drainage: Tube well or wells act as drainage structure in this kind of drainage system. Encouraging farming community to install tube wells for irrigation, which also act as vertical drainage systems seems to have worked well under the Indian conditions.

Bio-drainage: Plants like Eucalyptus that consume water luxuriously are grown to lower the water table. This system of drainage can be successfully adopted in preventing the rise in water table.

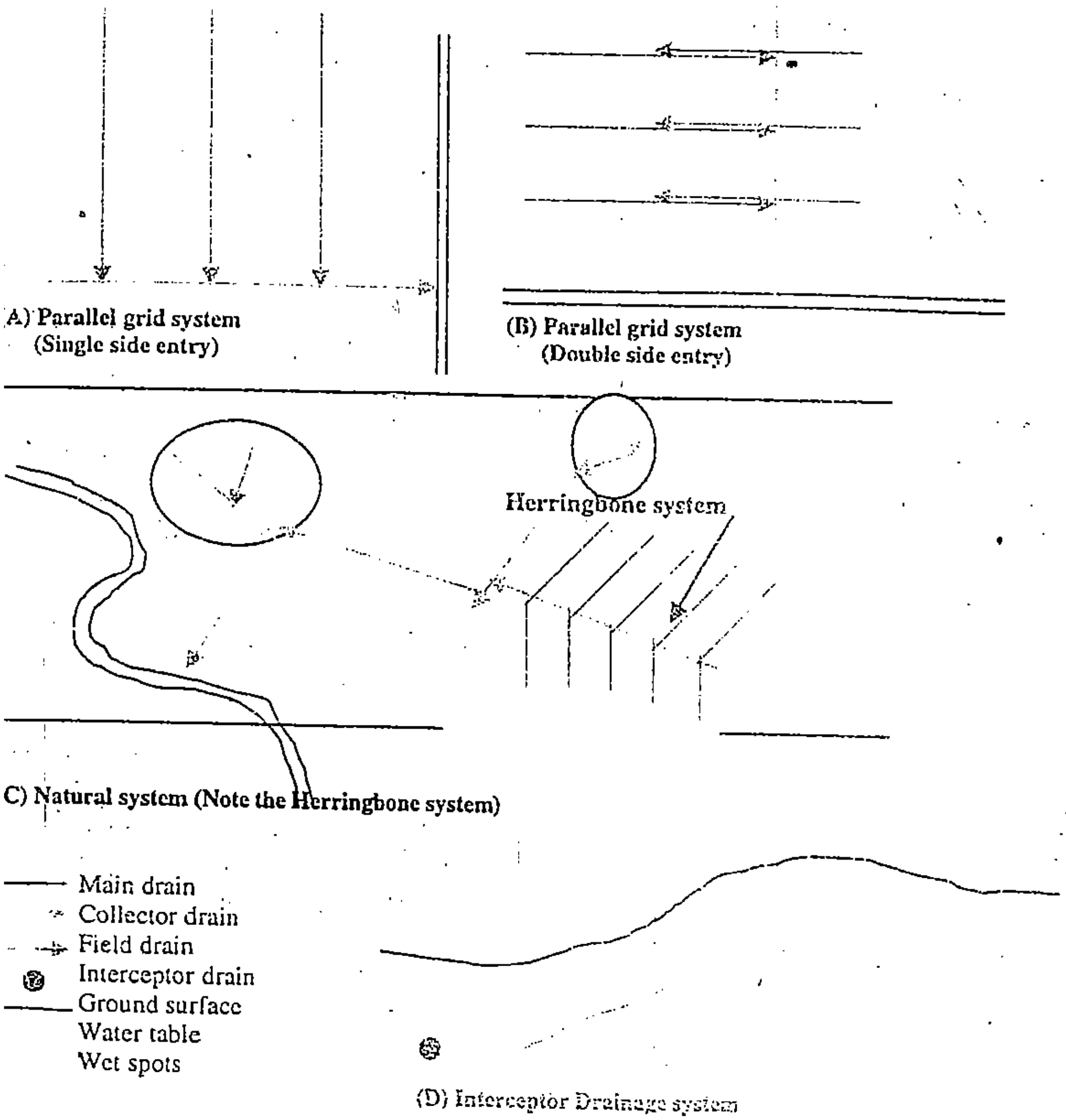


Fig.7.4: Standard layouts for drainage systems

SAQ 5

i) How has water logging been defined? Why Clayton definition is commonly adopted to classify water logged lands?
ii) List the causes of yield decline in water logged lands.

Along with floods, droughts occur frequently in some parts of South Asian Countries. Therefore, we now discuss its implications for agriculture.

7.4.3 Drought and Agriculture

Many attempts have been made to define drought in terms of precipitation or in terms of deficiency of water to crops. Depending upon the time of occurrence of drought, drought has been categorized into three categories as follows:

- Early-season drought resulting from delayed start of the rainy season or prolonged dry spell after early or normal start;

- Mid-season drought; and
- Terminal drought due to early cessation of the rainy season.

From a purely agricultural point of view, climate alone cannot define drought since soil properties and crop/ soil management practices also influence plant survival. From this point of view, a drought is defined as a period in which lack of water reduces growth and final yield of crops in a region. Crops have the capacity to use soil water initially stored in the root zone. The soil water in the matric potential range of –0.3 bar to –15.0 bar (-30kPa to –1500 kPa) is available to the plants. This range is between the field capacity and the permanent wilting point. If this water is enough to meet the water requirement of the plant for the drought period, crops can survive the drought. Drought tolerant plants however can use soil water below –15.0 bar. Since the matric potential at this limit decreases rapidly in most soils, it is expected that very little water would be available for agricultural crops beyond permanent wilting point. In that case plants lose vigour, get wilted and meet a premature death.

A plant's ability to survive dry conditions depends, besides the severity of drought, on the plant's characteristics. On the basis of these characteristics plants have been divided into three groups namely:

Drought escapers: These are plants with a short growing period. These plants escape drought by germinating, growing and producing in a very brief life span. These plants can mature if there is enough moisture to germinate the seed. Most desert ephemerals are included in this category.

Drought evaders: These plants have intensive deep root system as well as systems to restrict water loss by reducing evapo transpiration. They also adjust to drought conditions by reducing leaf area or closing leaf stomata.

Drought endurers: These plants endure the drought by means of storing water in some organs (cacti) or by shedding leaves and becoming dormant such as mesquite.

From the agricultural point of view, most crops must come from drought evading group. Since drought is not a regular phenomenon, farmers usually opt for high yielding crops and varieties rather than going for drought resistance characteristics, which might yield less.

SAQ 6

List the three categories of drought. Categorize the kind of plants based on their characteristics to tolerate drought.

Having developed a scientific understanding of drought, you may like to learn about the strategies to tackle drought.

Strategies to Mitigate Drought Conditions

A three-pronged strategy could be adopted to mitigate the adverse effects of drought on plants.

- Efficient conservation of rainwater through comprehensive land management techniques such as by adopting mechanical and vegetative structures, tillage practices and creation of water resource through rainwater harvesting and storage. Inter-plot water harvesting, construction of dead furrows, sowing across the slope and ridging, contour farming, graded border strips and raised bed and sunken systems are some of the successful strategies adopted for rain water conservation under various rainfall patterns and soil types. For rainwater harvesting, check dams and farm ponds could be constructed to meet the crop requirement at most critical period.

Adoption of improved crop management technologies such as off-season tillage, timely planting of crops, use of improved crop varieties, intercropping, double cropping, weed control to minimize competition for water and nutrients, contingent crop planning with varieties suitable for late sowing, mulching, timely and adequate nutrient application, deep seeding and spray of urea could be applied depending upon site specific situations.

The third strategy is to develop alternate land use system for maximizing productivity of food, fibre, fodder and fuel. The planning should be based on land capability classes. Some of the promising land uses are: Agri-silviculture for soils in land capability class IV with annual rainfall up to 750 mm, silvipasture involving a tree component with perennial grass or legume species for land capability class V and higher, agri-horticulture in land capability class II to IV receiving average annual rainfall more than 750 mm.

e now discuss the issue of water quality that is equally important in the management water resources.

.5 WATER QUALITY

ire water rarely occurs in nature. By the time a raindrop reaches the surface of earth, fferent kinds of gases and suspended materials of the atmosphere mix with it. Water ing a universal solvent, many kinds of salts gets dissolved in it as it moves over the nd surface or gets percolated into the ground. The kind of salts present in the water a great extent would depend upon the parent materials of the soil encountered roughout its course. Chemical and biological pollution through point and non-point urces also determines the quality of water.

uality of water has different meaning for different people. The quality standard for inking purposes would be entirely different than quality standards for other omestic uses. Industrial quality standard for different kinds of industry would vary. ithin agricultural sector, the water quality standard for aquaculture would be fferent than for crop production or for animal husbandry. Apparently, the quality of ater must be evaluated on the basis of its suitability for the intended use.

.5.1 Water Quality Evaluation for Agriculture

hysical, chemical and biological measurements provide valuable tools to assess ater quality problems. From the agricultural point of view, a series of eleven water uality parameters are important to evaluate water quality viz. silt content, irbidity, dissolved oxygen, total dissolved solids, pH, faecal coliform, faecal nterococci, toxics, micro-invertebrates and biochemical oxygen demand.

.5.2 Water Quality for Crop Production

o classify water with respect to their suitability for irrigation, four parameters are in ogue.

- Total salt concentration given by its Electrical Conductivity (EC).
- Relative proportion of sodium to other cations given by Sodium Adsorption Ratio (SAR) of the water.
- Residual Sodium Carbonate (RSC)
- Toxicity

Electrical conductivity refers to the reciprocal of the electrical resistivity. Resistance is expressed in Ohms of a metallic or electrolytic conductor, which has a cross-sectional area of 1 cm^2. Electrical conductivity being reciprocal of resistance is expressed in mhos per centimetre. For convenience, small units such as millimhos cm^{-1} or micromhos cm^{-1} are used to designate EC of water. Currently EC is expressed in dSm^{-1}, which is equivalent to 1 millimhos cm^{-1}.

pH: It is a measure of the degree of acidity or alkalinity of water. Waters having pH less than 7 are acidic while with pH above 7.0 are alkali in nature. However, such waters may not be confused with alkali waters having RSC > 2.5. As such pH has a limited role in determining the water quality. A pH range of 6.5-8.4 is considered good for growing most crops.

Sodium Adsorption Ratio: It is the relative concentration of mono valent cation sodium over the divalent cations calcium and magnesium. It is given by the relation:

$$SAR = \frac{Na^+}{[(Ca^{++} + Mg^{++})/2]^{1/2}}$$

Here concentration of cations is expressed in meq L^{-1}.

Residual sodium carbonate: It is defined as the excess of carbonates and bicarbonates over calcium and magnesium as per the following relations:

$$RSC = (HCO_3^- + CO_3^{2-}) - (Ca^{2+} + Mg^{2+}), \text{ expressed in meq } L^{-1}.$$

Since high RSC of water is a cause of the build-up of alkalinity in the soil, these waters are designated as alkali waters. These have RSC > 2.5 and may or may not have high SAR.

On the basis of these 3 parameters, the quality of water has been grouped into 3 main classes: good, saline and sodic. Saline and sodic classes have further been categorized in 3 groups each (Table 7.4) with increasing problems in their use for crop production.

Table 7.4: Grouping of poor quality water

Water quality	EC_{iw} ($dS\ m^{-1}$)	SAR_{iw} $(mmol\ l^{-1})^{1/2}$	RSC (meq l^{-1})
A. Good	< 2	< 10	< 2.5
B. Saline			
i. Marginally saline	2-4	< 10	< 2.5
ii. Saline	> 4	< 10	< 2.5
iii. High-SAR saline	> 4	> 10	< 2.5
C. Alkali waters			
i. Marginally alkali	< 4	< 10	2.5 – 4.0
ii. Alkali	< 4	< 10	> 4.0
iii. High-SAR alkali	variable	> 10	> 4.0

SAQ 7

Explain the terms Electrical Conductivity (EC), Sodium Adsorption Ration (SAR), Residual Sodium Carbonate (RSC).

Harmful effects of Saline Water

aline water per se is not harmful to the plants. The harmful effects of saline water rrigation are mainly associated with accumulation of salts in the soil profile and are nanifested through non-availability of water to plants due to increased osmotic otential, poor and delayed germination and slow growth rate. Excessive salts in root one can induce early wilting and the effects are almost similar to those of drought. ome of the visual symptoms are that the plants look stunted; leaves are smaller but hicker and often have dark green colour as compared to plants growing in a salt free oil irrigated with good quality water.

Harmful effects of Sodic Water

odic water, on the other hand, adversely affects soil physical properties. The ncreased exchangeable sodium percentages (ESP) resulting from their long-term use eads to breakdown of soil structure due to swelling and dispersion of clay particles. ine textured soils remain dispersed and puddled when wet and hard when dry. These oils do not easily attain proper soil moisture conditions for cultivation. A thin crust s often formed at the soil surface, which acts as a barrier to water penetration and eedling emergence. Increase in soil pH reduces the availability of a number of plant utrients like nitrogen, zinc, iron, etc. It also results in decreased availability of alcium and magnesium and toxicity of sodium. In most cases, the yield of crops is dversely affected by a combination of these factors.

Use of Saline/Sodic Water for Crop Production

or effective and productive use of saline/sodic waters, besides the quality of water, nformation on crops, type of soil with respect to its mineral composition, soil texture, limatic conditions and the management options that can be easily adopted are ssential to determine the suitability of water for crop production. Selection of a salt olerant crop is paramount to use of saline/ sodic waters (see Unit 6). Some feasible trategies for its use for crop production are:

- Direct application
- Conjunctive use

n conjunctive use, any of the following two strategies can be used:

- Blending of saline/alkali waters with canal water
- Cyclic or rotational use of saline/fresh waters

Direct Application

Crop tolerance to salinity varies a great deal amongst the crop plants and to a lesser xtent amongst their genotypes. These inter and intra-genic variations in salt tolerance f plants can be exploited to select crops/cultivars that produce satisfactorily under a iven root zone salinity. In general, the oilseed crops requiring less water can tolerate vaters of relatively higher salinity, whereas most of the pulses are sensitive. Vegetable crops are the most sensitive. Tolerance limits also vary with soil type. Comparatively speaking, high salinity waters can be used in coarser soils than heavy exture soils. Thus, depending upon the soil type a crop can be selected that can vithstand the salinity of water.

ince improved irrigation practices can help to use relatively high salinity water than an be applied with surface irrigation techniques, sometime a switchover from surface rrigation to sprinkler or drip irrigation can help in directly using saline water to roduce many crops of interest.

Conjunctive use of Fresh and Saline/Sodic Waters

Highly saline/sodic waters cannot be used for crop production directly; such waters can be used in conjunction with fresh canal water. The successful strategies for the use of poor quality saline/sodic waters are through mixing or blending and cyclic use.

Saline waters of high salinity cannot be used directly for crop production since salinity build-up in the root zone would be quite fast and detrimental to crops. These waters can be used in conjunctive mode. Blending involves mixing two waters of different qualities to obtain water that is suitable for crop production. The salinity/sodicity of the mix water after mixing should be within the permissible limit, based on soil type, crop to be grown and climate of the area.

The cyclic use, also known as sequential application or rotational mode, facilitates effective conjunctive use of fresh and saline/sodic waters. In this strategy, canal water is replaced with saline/sodic water in a pre-decided sequence/cycle. A major advantage of the cyclic strategy is that steady state salinity conditions in the soil profile are never reached. It is due to the fact that the quality of irrigation water changes over time.

Sequential application: In this technique, canal and saline/sodic waters are applied in a pre-decided sequence. For example alternate irrigation with canal and saline/sodic water could be one sequence.

7.5.3 Management Practices

Several cultural practices and management options can help to improve the crop productivity when saline/sodic waters are used for crop production. Apparently, these management practices aim at preventing the build-up of soil salinity/ sodicity and toxic ions in the root zone. These practices also control the salt balance in soil-water system as well as minimize the damaging effects of salinity on crop growth.

Pre-sowing Irrigation: From the point of view of salt tolerance, in most crops, the period of germination and seedling emergence is the most critical stage. Failure of the crop at this stage scales up to poor crop stand. As a result, one ends up with considerable decrease in yield.

Seed Rate: To ensure adequate plant population to compensate for mortality or poor tillering, seed rate, which is around 25% more than the seed rate recommended for cultivation of crops with normal waters, is recommended.

Nutrient Management: When saline/sodic waters are used for irrigation, balanced use of essential nutrients is very important to achieve optimum productivity. While it would be appropriate to apply nutrients as per regional recommendations for normal soils/waters or on soil test basis some additional points should be considered.

- Application of 25 per cent extra nitrogen is needed as compared to the normal conditions.
- Soils irrigated with chloride rich waters (saline) respond to higher dose of phosphorus, because chloride ions depress the availability of soil phosphorus to plants. The phosphorus requirement of crops is, therefore, enhanced to nearly 50 per cent more phosphorus than the recommended dose under normal conditions.
- In the case of saline water, the recommended doses of potassium and zinc based on soil tests values should be applied. However, for sodic waters Zinc sulphate @ 25 kg ha^{-1} should be added to supply additional zinc, particularly to the *rabi* crop.
- For high yields, organic materials such as green manures/ FYM should be used. They do not only supply nutrients to the plants, but also play an important role in improving soil physical properties. As such, their application enhances leaching of salts accumulated in the root zone.

Irrigation Practices: Low depth high frequency irrigations are the preferred mode of irrigation with saline water. Since improved irrigation techniques allow easy application of water in this manner, switch over from surface to sprinkler or drip irrigation is recommended.

Application of Gypsum

The sodicity hazard of the sodic irrigation waters on the soil can be mitigated by neutralization of the RSC of irrigation water with gypsum. If the RSC of the irrigation water is 2.5 or less, the water is considered to be of good quality and in that case it is not necessary to add gypsum or any other amendment. However, for every additional 1 me L^{-1} RSC to be neutralized, agriculture grade gypsum (70% purity) @ 90 kg ha^{-1} should be added for each irrigation of 7.5 cm depth. The quantity of gypsum to be added is, thus determined by the RSC of irrigation water and quantity of water required for irrigation during the growing season or on yearly basis.

Toxic Water

In addition to total electrolyte content, plant responses are also governed by the concentrations of different ions in soil solution. The toxic accumulation of sodium in plants due to use of high SAR water is reported. Chloride ions are more toxic than sulphate ions. Increased mg/cal ratio affects the uptake and transport of calcium due to antagonistic effects.

Trace elements or heavy metals cause growth reductions due to toxicities. Since very few experimental evidences have been generated to provide any firm guidelines, suggested maximum concentrations of trace elements in water as reported by National Academy of Science (1972) are still used (Table 7.5).

Table 7.5: Recommended maximum concentrations of trace element in irrigation water

Element	Symbol	For water used continuously on all soils (mg L^{-1})	For use up to 20 years on fine textured soils of pH 6.0-8.5 (mg L^{-1})
Aluminium	Al	5.0	20.0
Arsenic	As	01	2.0
Beryllium	Be	0.1	0.5
Boron	B	–	2.0
Cadmium	Cd	0.01	0.02
Chromium	Cr	0.1	1.0
Cobalt	Co	0.05	5.0
Copper	Cu	0.20	5.0
Fluoride	F	1.0	15.0
Iron	Fe	5.0	20.0
Lead	Pb	5.0	10.0
Lithium [1]	Li	2.5	2.5
Manganese	Mn	0.2	10.0
Molybdenum	Mo	0.01	0.05[2]
Nickel	Ni	0.2	2.0
Selenium	Se	0.02	0.02
Vanadium	V	0.1	1.0
Zinc	Zn	2.0	10.0

[1] Recommended maximum concentration for citrus in 0.075 mgL^{-1}.
[2] For only acid fine textured soils or acid soils with relatively high iron oxide contents.

7.6 WATERSHED MANAGEMENT

A watershed is a topographically delineated natural unit of area that is drained by the common stream. A small watershed could be of few hectares that drain into a small stream (Tideman, 1996). This small watershed forms a part of a larger watershed which in turn could form a part of still larger watershed, until the watershed becomes a major river basin draining millions of square kilometres of land. A schematic view of a sub-watershed and a small watershed is shown in Fig. 7.5. The elevated line that forms a division between two areas drained by separate streams is marked with two sided arrows.

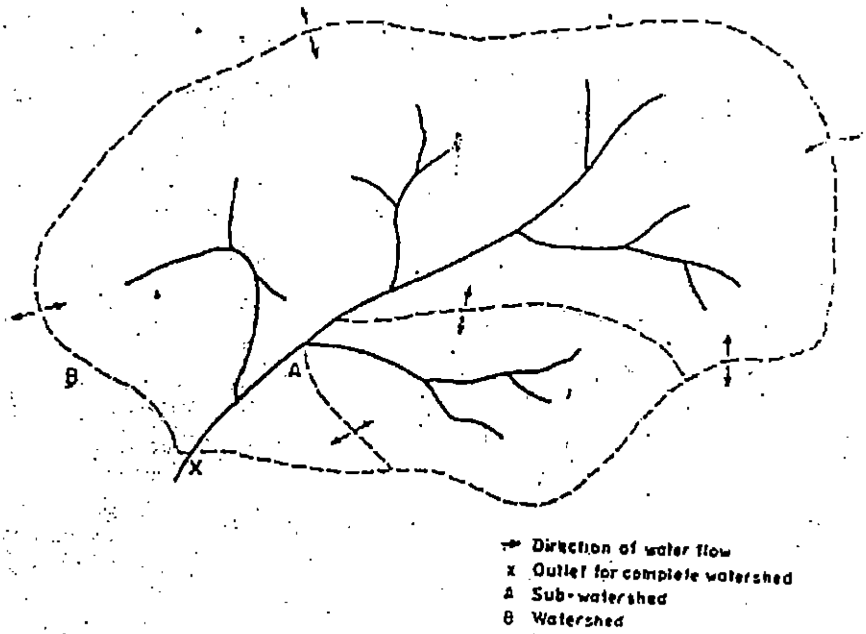


Fig.7.5: A view of sub watershed within a watershed

In the watershed approach, development is not confined to agricultural lands alone. but covers the area, starting from the highest point of the area to the outlet of the *nalah* or the natural stream. Similarly, in terms of resource development, it starts from the most important one, that is water and extends to soil, vegetation, fuel, livestock and all associated components. In the watershed, different measures are adopted and executed in each of the topo-sequences according to the land capability. Now, a watershed is not only made up of its physical and natural resources but also includes human resources. Therefore, its management entails rational utilization of land and water resources for optimum production with minimum hazard to natural and human resource.

Watershed management has been defined as an integration of technologies within the natural boundaries of a drainage area for optimum development of land, water and plant resources to meet the basic minimum needs of the people in a sustainable manner. The watershed management approach clearly realizes the linkages between uplands and the down stream areas, i.e., actions of upstream users affect those living downstream.

Some general technical objectives of a watershed management programme could be as follows:

- To rehabilitate the watershed through sustainable land use, to carry out conservation practices to minimize erosion, increase the productivity of the land and water.
- To develop water resources for domestic and irrigation purposes, etc.

- To manage the watershed to minimize/mitigate natural disasters like floods or drought.
- To develop the watershed for economic uplift of the region.
- A combination of one or more of these general objectives.

Principal factors Influencing Watershed Operations

Physiography: Size, land slope and drainage pattern of the watershed influence runoff volume and its rate. Besides, slope of the land has major implications for land use. The drainage pattern of an area refers to the design of the stream courses and their tributaries. The slope of the land, lithology and structure influences it.

Soils and Geology: It determines the amount of water that would percolate (also determine the run off) and the need for treatments to improve percolation. It would also determine the anticipated silt load from the watershed area.

Land Use: It affects the rate of run off and soil infiltration rate.

Vegetative Cover: The change in the type and quality of vegetative cover is an important non-engineering intervention as these together influence runoff, infiltration rate, erosion and sediment production.

Climate: Precipitation is the most important factor as it determines the design peak runoff rates for various structures, runoff rate and volumes and the erosion hazard. Evapo transpiration is another important factor that determines the crop water requirement.

Socio-economic Factors: Demographic and sociological features, land tenure system, farm structure, attitude and behaviour of farmers, all influence the success of a watershed management programme. While preparing a watershed management plan, socio-economic baseline survey is an essential pre-requisite.

SAQ 8

a) Define watershed. Explain the term with a free hand sketch.
b) Define the term watershed management.

7.6.1 Watershed Management Plan

A watershed management programme is essentially a rural development programme. A multi-disciplinary approach in planning is essential to derive optimum benefits out of such a programme.

Basic Information

To start a watershed management programme in a systematic manner, basic information on all the following components is necessary:

- Location
- Size and shape
- Climate, physiography, runoff and soil erosion problems
- Population and livestock
- Water resources and their utilization potential
- Land utilization, cropping systems, yield, land capability
- Socio-economic utility and land ownership
- Market facilities, health related facilities and other institutions

Basic resource inventory before the intervention through watershed management should also be prepared to help in monitoring and evaluation of the programme.

Development Components

On the basis of the information generated, it would be prudent to identify the priority problems and clearly spell out the kinds of intervention and development activities that should be initiated. All these efforts could be made through discussions with the stakeholders. Some of the important activities are: soil conservation measures, water harvesting, groundwater recharge, changes in land use if necessary, water management including drainage, improvement in fuel-fodder production system including horticulture.

Some of the situations, problems and solutions have been listed in Table 7.7. However, there are no hard and fast ground rules and solutions since for the same situation and problem, the solution might vary from one location to another.

Table 7.7: Some common situations, problems encountered in watershed management and their possible solutions

Situation	Problem	Solution
1. Hill slopes (bare denuded, slopy), soil thin, texture-light)	Soil erosion, moisture conservation, retention of runoff and disposal. Establishing vegetation.	Contour trenching, bunding, terracing-afforestation, silvipasture, and agro-forestry.
2. Steep land slopes (denuded, eroded thin vegetation)	Runoff control, retention and disposal, stabilization and densification of vegetation.	Control and graded bunding grassy waterways, water harvest, contour cultivation, horticulture, agro forestry, pasture, strip cropping.
3. Medium to low slope agricultural lands	Soil and water management, water retention, runoff, control and reuse	Contour cultivation, strip cropping, buffer strip and boarder strips
4. Moderate to low slope and plain irrigated lands	Water management	Land levelling, design and layout of irrigation system, irrigation depth and interval control. Disposal of drainage water
5. Plain agricultural lands and lowlands	Drainage disposal and reutilization	Surface and subsurface drainage, recycling
6. Sand dunes on sea shores	Wind erosion stabilization of sand dunes, prevention of formation of sand dunes	Wind break, shelter belt establishment of vegetation, dune stabilization
7. Stream bank and gullied lands	Soil erosion, storage and disposal of excess water	Stream bank protection, gully control, protection of farm ponds, vegetation
8. Denuded and degraded forests	Soil and water conservation, afforestation	Prevention and control of felling forest trees, controlled grazing, stopping shifting cultivation, afforestation, silvipasture, agroforestry

Building a Suitable Organization

A dynamic and vibrant organization that is multi-disciplinary and flexible in nature should be initially constituted. While specialist divisions could handle the execution of plans, the command and authority must come from a single authority. The constitution of the organization must provide for enlisting the co-operation of local people. The ideal solution could be a watershed development agency at the unit level or a watershed authority with well-identified line departments to undertake the project under the overall supervision of the watershed authority. In the latter approach, watershed development agencies should be created as the programme proceeds to make it sustainable. To upgrade the skills of the people in the organization, regular training programmes should be a part and parcel of the organizational rules and regulations.

Costing and Finance

Since the economic level of the stakeholders is usually low, institutional financing, subsidies and outright grants are essential to make a watershed programme successful. Moreover, many activities are carried out on community lands or for community purpose.

Follow up, Maintenance and Monitoring and Evaluation

After the plan is implemented, an improved production plan is superimposed to get maximum benefits. Farmers are educated to maintain the structures. In order to assess the impact, regular monitoring and evaluation is essential. It would only determine the replication potential of the interventions and/or determine the shortcomings/gaps in implementation.

7.6.2 Challenges and Opportunities in Watershed Management

The potential of watershed management in meeting the basic needs and in poverty alleviation has been proved beyond doubt, yet the success stories are very limited. In order to overcome the shortcomings, the following issues must be addressed in the future.

People's participation

Small farms, which are a characteristic of rural India, forbid any attempt by individual farmers to improve their land to have a visible impact on land and water management. In most instances, participation of the community is indispensable. A top-down approach has failed globally and that is why a bottom-up approach in which stakeholders are involved from the planning stage itself has become quite common for the success and sustainability of a programme.

Capacity building

Most organizations operating in watershed management programmes lack the confidence since the field-level staff engaged by them can neither comprehend the magnitude of task nor have the technical and organizational skill to satisfy the people when they question them on the relevant issues relating to the project. Training, a priority area, does not receive the kind of attention it should receive in preparing the staff to meet the stakeholders with confidence.

Monitoring of Impact

A major concern of many projects has been lack of adequate monitoring of the progress and impact of the programme. Either the programme lacks facilities, or it defies the capacity of the project staff. Moreover, the monitoring of socio-economic impact lacks proper indices. Appropriate feedback is not available that would help to rectify the programme.

Flexibility and Co-ordination

The standardized, target-oriented blue print approach has been the hallmark of most programmes as these are run solely by the government organizations. Watershed management programmes call for flexibility and innovations and local non-governmental agencies/organizations need to be involved. Duplication of efforts due to lack of co-ordination is another grey area in watershed management programmes.

Sustainability and Replicability

Some tangible improvements have been reported in the existing conditions following interventions. Since such efforts lacked integrated, comprehensive and multi-faceted approach, anticipated success could not be achieved. Since long-term sustainability of the programme is not kept in view during planning, reversion to original conditions has been reported from many programmes following project withdrawals. As stated earlier, a rigid blue-print approach cannot be adopted. Replicability of programmes in regionally homogeneous areas, say, at the micro-watershed level, must be attempted, if watershed management programmes are to make a real head way in the country.

We now summarize the contents of this unit.

7.7 SUMMARY

In this unit you have studied water, a natural resource that together with soil studied in the previous unit, determines the food and nutritional security of the nation. You have been introduced to hydrological cycle, and rôle of water in agriculture, floods and drought, water logging, water quality parameters, water quality for agriculture and watershed management. Salient points that emerge from this unit are:

- Water is a finite resource, which can, however, be replenished.
- The South Asian countries are fortunate to have ample resources of water, yet its spatial and temporal variability calls for its management through storage and distribution.
- Burgeoning population, increased living standard and environmental considerations have put tremendous stress on this resource.
- Increasing sectoral competition would snatch a part of the allocation of fresh water to agricultural sector. Since the demand in agriculture would increase, agricultural sector has to look for alternate resources of water as well as go in for 'more crop per drop'.
- There is a mismatch between the potential created and potential utilized. It means, investments made on creation of the potential are not utilized and the investment is blocked.
- Introduction of irrigation has been a mixed blessing; while crop yields have improved by 50% to 200% , the mismanagement of water has resulted in the problem of water logging and creation of wet deserts.
- Flooding is an extreme event in which the adage "Water-water everywhere but not a drop to drink" applies well. Nearly 40 million ha area is prone to floods while annually on an average 7.5 million ha area is affected to various degrees of flooding.

- Flood control measures are based on the four principles of runoff reduction, retention, diversion and confinement. Since 1954, an area of 15.8 million ha has been provided with a fairly good degree of flood protection.
- Water logging could occur either due to surface stagnation of water or due to rise in the water table. Both adversely affect aeration resulting in depletion of O_2 and increase in CO_2 in the root zone.
- Some toxic ions may be produced in the root zone as a result of water logging or it might affect the absorption of certain plant nutrients compared to others causing nutrient imbalance in the plants. In most cases, adverse effects are due to combination of these factors although reduced aeration dominates in many cases.
- Crops differ in their tolerance to water logging. Selection of crops, which can tolerate water logging, is one of the ways to manage waterlogged lands. Besides land management, high seed rate, application of higher doses of plant nutrients, raised and sunken bed system to grow crops could help to avoid the adverse effects.
- While management could help in the short-term, long-term solution of the problem is improved drainage. Surface drainage is an essential pre-requisite to avoid surface stagnation and reduce the rate of rise in the water table. Lands with shallow water table also require some kind of subsurface drainage to control water table.
- Horizontal pipe drainage, vertical drainage or bio-drainage and their combinations can be used to lower the water table.
- Soil salinity and water logging are twins. When both the problems have invaded the area, horizontal pipe drainage could be a quick and cost-effective technology to reclaim the lands.
- Drought is another extreme, which affects large areas in the region. Moisture stress due to drought could wipe out crops from fields and even affect the productivity of irrigated lands since only limited water is available in irrigation commands.
- Depending upon the mechanism of tolerance to drought, crops have been categorized as drought escapers, drought evaders and drought endurers. Drought resistant crops yield less.
- With increasing pollution of water resources, water quality degradation has assumed a serious dimension. Degradation in water quality indirectly affects the quantity, as the degraded water cannot be used for specific purposes depending upon the kind and extent of degradation.
- Silt, turbidity, dissolved oxygen, total dissolved solids, pH, faecal coliform, faecal interococci, toxic elements, macro invertebrates and bio-chemical oxygen demand are some of the parameters that determine the physical, chemical and microbiological properties of water.
- Water quality for agriculture is determined through Electrical Conductivity (EC), sodium adsorption ratio (SAR), residual sodium carbonate (RSC) and toxic elements. Based on their effect on soils and crops waters have been grouped as fresh, saline, alkali (sodic) and toxic waters.
  - Saline water per se is not harmful to plants. It is the accumulation of salts in the root-zone that leads to build-up of osmotic potential that makes water unavailable to plants. Poor and delayed germination and slow growth occur due to salinity build-up.

- Alkali or sodic water on the other hand influences the physico-chemical properties of the soil and has adverse effect on crop growth. Breakdown of soil structure, formation of a thin crust at the soil surface, difficulty in attaining proper soil moisture condition and build-up of soil sodicity/pH are some of the adverse effects of continuous application of sodic waters.

- Saline/sodic waters can be used for crop production through proper selection of crops and through application of appropriate management options. Use of sprinkler and drip irrigation can help to use relatively high salinity water to the same crop compared to surface irrigation. Low depth high frequency irrigations are helpful in managing salts.

- Highly saline waters can be used through conjunctive mode with fresh water. For this purpose blending (mixing saline and fresh waters) and cyclic use strategies are commonly employed.

- Besides the conjunctive use, several cultural practices can be employed to obtain optimum yield. Pre-sowing irrigation with fresh water, application of 25% more nitrogen than recommended for normal lands and waters, use of farm yard manure and green manures, high seed rate are some such practices.

- In the case of alkali water, application of gypsum or any other calcium containing amendment could be employed to neutralize the residual sodium carbonate.

- Since water, soil and vegetation can be effectively managed with watershed as a unit, watershed management concept has come to stay for planning and managing the natural resource.

- A watershed management programme is undertaken to rehabilitate the watershed, to minimize soil erosion, to develop, conserve and efficiently utilise the water resource, to minimize natural disasters in the watershed or a combination of these objective. However, the ultimate aim is to develop the watershed for economic upliftment of its inhabitants.

- A well-conceived watershed management plan should be prepared before implementation of any programme. It must consist of collection of basic information and socio-economic resource inventory, identification of suitable development components in line with the objectives of the programme, identification and building a dynamic and vibrant organization, cost evaluation and maintenance.

- Since, there are only few success stories of watershed management programmes in India, people's participation, capacity building, monitoring, flexibility and co-ordination and sustainability and replicability have been discussed to understand the challenges that are ahead in making watershed management programme a people's movement.

7.8 TERMINAL QUESTIONS

1. What do you understand by the statement "Water is a scarce natural resource"?
2. Development of surface water resources has been a mixed blessing. Briefly explain the statement.
3. List at least four management options to manage water logged lands.
4. What do you understand by the term drought? Briefly describe the three strategies to mitigate drought conditions.

5. List the various objectives that could be an integral part of a watershed management programme. List important information that needs to be collected before initiating a watershed management programme.

6. What are the major features of a suitable organization for implementing watershed management programmes?

REFERENCES

1. Mooley, D.A. (1995) Rainfall analysis for India. In: Agricultural Droughts: Data Base Management, Lecture Notes of SERC School in Agrometeorology. IMD and IITM, Pune. 257-276.

2. National Academy of Sciences (1972) Water Quality Criteria. Environmental Studies Board, National Academy of Sciences/Engineering.

3. Poysa, V.W., Tan, C.S. and Stone, J.A. (1987) Flooding stress and the root Development of several tomato genotypes," Hort. Science, 22: 24-26.

4. Sharma, B.R. and Paul, D.K. (1998) Water resources of India. In 50 years of Natural Resource Management Research (Singh, G.B. and Sharma, B.R. Eds.). Indian Council of Agricultural Research, New Delhi. 31-48.

5. Tideman, E.M. (1996) Watershed Management; Guidelines for Indian Conditions, Omega Scientific Publishers, New Delhi. 372 pp.

UNIT 8 BIODIVERSITY

Structure

8.1 INTRODUCTION

The enormous variability in life forms and their associations is generally referred as **biodiversity.** Biological diversity or "bio-diversity" was first conceptualised by Edward O Wilson in 1988. The term biodiversity has gained popularity for the past one and half decade, especially since the declaration of Agenda 21 at the Earth Summit in Rio de Janeiro, Brazil, in 1992. In the Convention on Biological Diversity (CBD) at earth summit, all participating Governments agreed on an "Official" definition of biological diversity as:

"The variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems." Therefore, biodiversity is the variety of the life forms including their genetic make up and all kinds of their assemblages.

The biodiversity related to agriculture and which is fundamental to food and nutritional security, includes plant, animal, soil organism, insect and other flora and fauna in agro-ecosystems as well as elements of natural habitats that pertain to food production. It has multiple economic, ecological and social benefits and is a crucial component of sustainable agriculture.

In the earlier two units we had discussed the issues related to land and water management and their role in determining the food and nutritional security. A rapidly growing human population, with its need for more food, water, energy, space and other resources threatens the survival of our fellow species. In this unit we discuss the components of biodiversity and its importance in agriculture. We also explore the forces that threaten agro biodiversity and the various strategies for preserving it. We provide necessary information that would generate interest in conserving agro-biodiversity in a broader perspective for a sustainable form of development, which envisages the integration of economic, social and environmental goals. These goals coincide with the provisions of CBD and also underscore the importance of meeting interests and protecting the rights of the people.

Objectives

After studying this unit, you should be able to:

- explain the importance of biodiversity and the need for its conservation;
- suggest ways of protection of biodiversity rich areas;
- identify and conserve key components of biological diversity in agricultural production systems;
- implement target incentive measures which have positive impacts on agro-biodiversity, in order to enhance sustainable agriculture;
- encourage development of technologies and practices that increase productivity and also arrest degradation and reclaim, and restore biological diversity;
- help empower indigenous and local people to build capacity for *in situ* conservation and sustainable use of agricultural biodiversity;
- encourage evaluation of impact on biodiversity from agricultural development projects;
- promote partnership among different stakeholders;
- promote appropriate research and services for farmers, with genuine partnership;
- promote research and development on integrated pest, soil and nutritional management for maintenance of biodiversity both at macro and micro level;
- encourage regulations or measures to encourage appropriate use of agrochemicals; and
- study impacts of various projects on agro-biodiversity and of intensification on ecosystem and biomass.

8.2 COMPONENTS OF BIODIVERSITY

The complexity of the diversity in life is manifested in variety of forms and functions of organism and their communities. Basically, this diversity of life is divided into three fundamental hierarchical categories that describe different living systems that can be measured in different ways. These categories are species, genetic and ecosystem diversity.

8.2.1 Species Diversity

Species diversity refers to an enormous number of individuals belonging to interacting groups or populations of distinct species or sub-species. It can be assessed in terms of species or the range of different types of species an area contains. The number of species in a region - its 'species richness' is often used as a measure of species diversity. A more precise measurement, 'taxonomic diversity', considers the relationships of species to each other. For example, an island with two species of birds and one species of frog has more taxonomic diversity than an island with three species of birds but no frogs (UNEP, 1995). Thus even though there may be more species of beetles on earth than all of the insects combined, they do not account for the greater part of the species diversity because they are so closely related.

Some estimates of biodiversity indicate the presence of 10-30 million species on the earth (Stork, 1993), of which 73 percent are bacteria, 18 percent flowering plants. Insects account for about 76 percent of all animals, and of all insects, about 60 percent are arthropods (Fig.8.1). Of the total species, 1,719,183 are described (UNEP Global Diversity Assessment, 1995) and of these 250,000 species belong to higher plants (14.5%). Of the 250,000 higher plant species only about 5,000 have been studied in detail.

existence of larger organisms dependent on the continued availability of the micro-organisms.

Agriculturally, approximately 7000 species of plants are consumed globally, of which 150 have entered world commerce and 103 account for 90 percent supply of human food and nutrition (Prescott-Allen and Prescott-Allen, 1992). Of these, three crop species- maize, wheat and rice give 60% of the calories and protein obtained from plant systems by human beings (Wilkes, 1983). For instance, India is 7th in number of domesticated plants and animals (Koshoo, 1995). It has 334 wild relatives of crop species (Arora, 1991). Additionally, the native tribes use another 1,532 wild edible plant species. These include 145 species of roots and tubers, 521 of early vegetables/green, 101 of bulbs and flowers, 647 of fruits and 118 of seeds and nuts (Gautam and Singh, 1998). In addition, nearly 9,500 plant species of ethno-botanical uses have been reported from the country, of which around 7,500 are for ethno-medicinal purposes and 3,900 are multipurpose/edible species (Anonymous, 1998).

Box 8.1 India – A Megadiversity Center

India is considered one of the 12 "mega-diversity centres", housing an estimated 8 percent of the world biota described so far. It contains two of the 25 biodiversity "hotspots", the Western Ghats and Eastern Himalayas, with thousand of endemic flora and fauna. The Indian flora and fauna represent nearly 12 and 8 percent of the global floral and faunal diversity respectively. The floristically rich, India has about 141 endemic genera belonging to over 47 families of higher plants. As per Botanical Survey of India (BSI), India has 46,214 plants species (MoEF, 1998). Of these, about 17,500 (7,000 species in north east region alone) represent flowering plants (7% of the world flora); 37 % of them are endemic. Of the endemic species (4,950), the largest number (about 2532) of species are located in the Himalayas followed by peninsular region (1,788 species) and Andaman Nicobar Islands (185 species) (Paroda et. al., 1999). India is a treasure of wild economic plants, particularly wild edible and medicinal plant species, which are largely utilised locally in several *Ayruvedic* preparations. It also holds half of the world's aquatic floral diversity.

8.2.2 Genetic Diversity

Genetic diversity refers to the variation in terms of genetic make up within species, which is transferred across generations. The number of possible combinations of genes and of the molecules making up the genes is immense. Genetic variation occurs to varying degrees in most species of plants and animals. It could refer to the differences in genetic makeup among different populations of the same species (such as the thousands of traditional rice varieties in India) or to genetic variations among individuals within a population of a single species (which is high among Indian rhinos and very low among African cheetas). Individuals belonging to a species share, by definition, certain characteristics, but genetic variation determines the particular characteristics of individuals within the species. This variety of genetic material within species has enabled distinct species to evolve through natural selection. In general, species that inhabit large areas and interbreed throughout the whole area have a higher rate of gene flow and show few or no localised characteristics; however, species living in small isolated areas have low rates of gene flow and, as they adapt over time to their particular environment, they develop into distinct, localised populations. Genetic diversity measurements were applied mainly to domesticated species and populations held in zoos and gardens, but now are also being applied to wild species.

Gene is the functional unit of heredity; the part of the DNA molecule which codes for one polypeptide and so for some characteristic feature.

Gene flow is the physical movement of genes through the area where a population lives. In animals, genes flow when animals move around. Plants cannot do so but their seeds, gametes, pollen and spores can move. Thus pollination and seed dispersal both lead to movement of genes within a population.

In India around 583 crop plants are reported to be cultivated (Anonymous, 2000). This includes 168 species earlier reported under Hindustani centre, one of the eight **Vavilovian centres** (refer to Unit 1) of origin and diversity (Zeven and Zhukovsky, 1975). India is the centre of origin of several crop species like, rice and minor millet in cereals, pigeonpea in pulses, sugarcane in cash crops, bitter gourd, amaranths in vegetables, coconuts in plantations crops etc. In addition, the Chinese, Moguls, Arabs, Spaniards, Portuguese and British introduced many crops. The introduced genotypes were grown in diverse agro-climatic conditions, subjecting them to various climatic pressures, and natural and farmer's selection leading to establishment of diverse genotypes adapted to different agro-climatic conditions with diverse constellation of desirable genes. Hence, India became a centre of diversity for a large number of crops species like rice, wheat, barley, minor millets, pigeonpea, chickpea, mungbean, urdbean, horsegram, mothbean, ricebean, clusterbean, sesame, okra, eggplant, cucumber, melon, jute, cotton, several forage grasses, ginger, turmeric, pepper, cinnamon, cardamom, citrus, banana and plantains, jackfruit, mango, tamarind, jamun and tuber crops like sweet potato, taro and yams etc. Native resources are also available in *Coleus* species, sword bean, velvet bean and several plantation crops like areca nut and coconut. Diversity also occurs for several minor fruits, such as berries and nuts. Thousand of varieties of important native or introduced staple food crops, vegetables, fruits, spices, fibre, forage and medicinal plants have developed in India under *in situ* condition making it one of the important centres of genetic diversity for these crops (Singh, 2002).

8.2.3 Ecosystem Diversity

This refers to the variety of association among organism and with the environment for utilising resources. Ecosystems differ in the species composition of their communities (association of species), and also in their physical structures. Conventionally, the world's ecosystems are broadly described in three categories, terrestrial, freshwater and marine. Most of the standard biodiversity estimates have been made on different types of terrestrial ecosystems. It is generally believed that 80 percent of all species are terrestrial and that tropical rain forests hold major proportion of species diversity. However, the taxic diversity of marine ecosystems seems to be enormously greater with doubly more phyla than that of the terrestrial ecosystems (Ray, 1988). Recent deep-sea explorations indicate that the exuberant diversity of the floor communities might rival the tropical rain forests (Rex et al., 1993). Studies of ecosystem diversity are carried out on different scales: from one ecosystem to an entire region containing many different ecosystems. Regions containing a great variety of ecosystems are rich in biodiversity, but individual ecosystems containing endemic species also make a significant contribution to global biodiversity.

8.2.4 Importance

Biodiversity is very important for survival of humans, biosphere and earth. The importance of biodiversity can be measured by considering economic (food, fibre, fuel etc.), ecological (regulating ecosystem function), cultural-anthropological, recreational and aesthetic uses. Economically, biodiversity is a fundamental basis of agricultural production and food security system. Ecologically it is a valuable ingredient of ecological stability. Aesthetically, there are many habitat and species that are attractive from recreation and tourism point of view, while many ecosystems or production systems are important for appropriate management of environment, because of their ability to absorb pollution, maintain soil fertility, micro-climate, recharge of water and in providing other invaluable services. Plant biodiversity is also important from moral, cultural, religious, aesthetic, social and scientific point of view. Many plant, and their parts are used in rituals. To name a few-flowers of *Hibiscus, Datura* and *Euphorbia ligularia*; leaves of *Aegle marmelos* (bael), *Eragrostis cynasuroides* (Kusa grass), rice, til, tulsi, chenopods, and odorous roots of *Dolomiaea macrocephala* (dhup). Humans are also dependent on nature for wood for timber and fuel and the increased demands for shelter and fuel have led to extensive deforestation in many parts of the world. It is estimated that four out of every five of the top 150 prescription drugs used in the US have had their origins in natural compounds. An example is aspirin a derivative of salicylic acid, which was first taken from the bark of willow trees. The process of such discoveries still continues. For example, taxol, a promising anti-cancer drug, was first extracted from a tree found in the wild: *Taxus baccata*, the pacific yew.

Agricultural biodiversity is an evolutionary divergent and highly inter-related component of biodiversity dealing with agro-ecosystems and variation in agriculture elated plants, animals, fish, insects, microbes, avians etc. It is fundamental not only or fulfilment of food needs, but also several other provisions; like fodder, fibre, fuel, nedicine etc., and provides farming system the means to recycle nutrients, reduce iests and disease problem, control weeds, maintain good soil and water conditions, iandle climatic stresses while producing agricultural products necessary for human urvival. Therefore, agricultural biodiversity is a cornerstone of stability and the basis of livelihood and sustainable development.

nspite of the growing realisation about biodiversity being fundamental to agricultural roduction and food security as well as ecological stability, it is being rapidly eroded nd is disappearing throughout the world because of several developmental changes, icluding agriculture. Several of these changes jeopardise productivity, threaten food ecurity as well as social structure and the environment.

AQ 1

Where are the regions of high and low species diversity?

) What is genetic diversity? Give an example each of low and high genetic diversity.

.3 IMPORTANCE OF BIODIVERSITY FOR AGRICULTURE

iodiversity has been fundamental to agriculture and food provisions for centuries. It is provided farming systems with the capacity to evolve over the last 12,000 years. ood production depends on a variety of managed agro-ecosystems that benefit from atural resources both on farms and in surrounding habitats such as forest, grassland id aquatic ecosystems.

s you are aware, biodiversity related to agriculture is referred to as agro-biodiversity. encompasses- genetic resources that are essential living material of plants and imals: edible plants/ crops, including landraces varieties and hybrids; livestock and iible fishes/ aquatic organisms; soil organisms vital for soil fertility and structure; aturally occurring insects, bacteria and fungi which serve as predators of pests and seases; agro-ecosystems like polyculture/ mon culture, irrigated/ rainfed, small/ rge that are valuable for nutrient cycle stability and productivity; and the wild latives of crop plants.

iere are approximately 75,000 species of edible plants world-wide (Wilson, 1988); it over the course of human civilisation, only about 7000 plant varieties have been ed for food (Juma, 1989). Of these, 3000 domesticated species are being edominantly used to provide various provisions required for human survival. There also remarkable diversity and abundance of insects, fungi, and other organisms that : valuable to the productivity of agro-ecosystem. Arthropods are the most abundant iss of animals and contribute in a major way to biomass and agro-ecosystem lance. Soil, a crucial resource, is like a living organism, made up of insects, crobes and other creatures and is essential for food production. Soil organisms ve a complex role in soil processes, for example, to enhance microbial activities, crease soil fertility, aeration, accelerate decomposition, and mediate transport ocesses in soil (Stork and Eggleton, 1992)). The habitat and species outside farming stems benefit agriculture and enhance ecosystem functions, serve as a source of host ints for natural enemies and predators of agricultural pests (Brookfield, 1995).

Many rural communities, particularly tribals obtain their daily food from several wild and non-conventional foods producing species. In addition, 95% of prescriptions of traditional systems of medicines are plant based. In sum, a knowledge of biodiversity and its conservation clearly has multiple proven benefits for agricultural productivity, sustainability and food security at all scales and in all types of agricultural systems, and can benefit agriculture in following ways:

- Increase productivity, yields and food security (and consequently economic returns)
- Reduce pressure of agriculture on fragile areas, forests and endangered species (therefore restricting deforestation)
- Build stability, robustness, and sustainability of farming systems (restricting desertification)
- Contribute to sound pest and disease management and sustainable intensification (limiting use of agrochemicals)
- Conserve soil and increase natural soil fertility and health (restricting soil degradation)
- Diversify products and income opportunities from farms
- Reduce spread of risks to individuals, communities, and nations
- Help maximise effective use of the resources and environment (restore ecological health)
- Reduce dependency on external inputs
- Increase nutritional values, and provide sources of medicine and vitamins

The breakthrough in understanding and use of genetic resources (diversity) for improvement in food production came in 19th century with the discoveries of principles of inheritance of genetic diversity by the Austrian Monk, Gregor Mendel. In the 20th century, N.I. Vavilov, the Russian botanist carried out systematic collection for conservation of plant diversity. He stressed the importance of maintaining diversity and its use in breeding new varieties. Later he developed the concepts of centres of origin and plant diversity across the world.

Most of the farmers incorporate multiple species and the practices that are adapted to local resources, to conserve, use and enhance biodiversity for nutrient cycling, soil fertility, and pest management. Medicinal plants are often included for health care. The farmers use diverse systems, which provide benefits to productivity, food security, resilience, risk protection, health and income generation for people. The farmers have also developed local knowledge on use of the diverse species, practices and agro-ecosystems in traditional farming, which are dynamic and ever evolving. The traditional varieties and associated knowledge are also useful to the world outside local communities. Therefore, in addition to the above direct and indirect uses, one of the most important use of genetic diversity, particularly in domesticated species and their wild relatives is to form the building blocks in further genetic improvement of cultivated species and other economically important species to increase productivity. For example, a gene from wild tomato in the Peruvian Andes has increased the annual sale of commercial tomato by US$ 5-8 million in the US.

Therefore biodiversity has been the cornerstone of agriculture contributing to its sustainable development over the centuries. Recent advent in biotechnology and systematic bio-prospecting have further ensured identification of any plant species that may possibly have potential to be of use to humankind. Genetic engineering techniques have allowed the transfer of genes beyond taxonomic boundaries making all living organism part of genetic resources that can be used in genetic improvement of not only agricultural species, but other organisms as well. The examples include the transfer of cold tolerance genes from fish to wheat and the Bt gene from bacteria (*Agrobacterium tumifaciens*) to plants. Biotechnology is also helping in using micro-organisms in production of bio-fertilizers, bio-pesticides and mining etc., which has ven another flip to the importance of biological diversity. Human kind therefore, has (ploited plant diversity in numerous ways ever since the advent of agriculture 12,000 ears ago. This diversity has been referred as 'genetic resources', which may be efined as 'genetic material of plants, which is of value as a resource for the present id future generations of people'.

AQ 2

part from agriculture what are the other uses of plant biodiversity?

.4 LOSS OF BIODIVERSITY: THREAT TO AGRICULTURE

espite the growing realisation about the value of plant biodiversity in agricultural roduction food security and ecological stability, biodiversity associated with griculture and food production is being rapidly eroded. This alarming trend includes ss of diversity at many levels – such as erosion of plant genetic resources, livestock pecies, insects, freshwater and soil organisms, leading to a narrowing of agro-cosystems in general, jeopardising productivity, threatening food security. Related to is is the loss of biodiversity in "natural" habitats with the expansion of agriculture id developmental activities into new frontiers.

Iodern agriculture focuses on maximising yield on per unit area basis, planting niform modern varieties and using monoculture-farming systems with heavy doses agro-chemicals. Although, these changes have brought increase in the world food oduction, they have resulted in both biophysical and socio-economic problems articularly erosion of biodiversity and degradation of natural resources, which ndermine productivity and food security. Natural habitats and forests are disturbed ading to imbalances in ecology of the ecosystems. The chief contemporary cause of e loss of genetic diversity has been the spread of modern commercial agriculture. ther causes include the destruction and fragmentation of natural ecosystems, over-xploitation of resources, introduction of exotic species, human socio-economic ianges, changes in agricultural practices and land-use and natural calamities. The ain processes causing loss of genetic diversity of cultivated crop species are genetic osion, **genetic vulnerability** and **genetic wipe out**. They are not mutually xclusive, but are in fact, inter-linked by the demands of an increasing population and sing expectations. Wider adoption of improved varieties is resulting in loss of ousands of landraces or folk varieties that have a reservoir of useful genes that has istained them for centuries under adverse agro-climatic conditions. This is also iusing genetic vulnerability of high yielding varieties. While genetic erosion is adual, genetic vulnerability is the "thin ice" of narrow genetic base, which puts a op at greater risk against biotic stresses, as happened with wheat stem rust in 1954 southern corn blight in 1970 in US, and Irish potato famine in 1840 in Europe.

Genetic erosion is the loss of plant genes or genotypes that are of potential or actual agricultural value.

Genetic wipeout is total loss of genes or genotype from a population.

Box: 8.2: Loss of Genetic Diversity

is difficult to estimate how much of the genetic base of agriculturally important ecies has eroded. Since 1950s the varieties of corn, wheat, rice and other crops sponsible for the 'Green Revolution' have squeezed out the native landraces. These odern varieties had been adopted on 40 percent of Asian rice farms in less than 15 ears. Often loss of genetic diversity has dramatic impacts. For example in 1991 the orst outbreak of citrus canker disease in Brazil affected the orange trees because of eir genetic similarity. In 1970, US farmers lost $1 billion to disease which swept rough the genetically similar cornfields. The Irish potato famine in 1846, the failure a large portion of Soviet wheat crops in 1972 also resulted because of genetic milarity and such outbreaks of crop failures could also occur in Bangladesh or Sri inka or Indonesia for which a large portion of rice crops come from single maternal ants.

Overexploitation of useful genetic resources from nature without sustainable maintenance, enhancement and conservation is another factor contributing to loss of plant species, genetic diversity. For example, *Rauwolfia serpentina* (sarpgandha) from Bastar, *Blepherispermum subsessile* (Rasna) of Chattisgarh, *Hedichyum coronaicum* (Gulbakavali) of Amarkantak and *Curcuma caesia* (Kali haldi) of sal forests are on the verge of extinction because of over collection and utilisation (Kotwal and Banerjee, 1998).

Introduction of exotic species has been another serious factor contributing to depletion of diversity of indigenous species. The introduction of *Cassia* and *Acacia* spp. has put pressure on Indian avenue tree species. Invasive species (*Lantana* and *Parthinium* spp) are a great threat to biodiversity and can become a serious menace suppressing valuable local flora. Another factor referred as genetic wipe-out involves the rapid and complete destruction of crops, habitat and forests as a result of natural calamities, social disruptions or war that can instantly eliminate promising diversity. Examples are recent forest fires in Indonesia (2000), the super cyclone in Orissa (1999) and wars in parts of Africa and Afghanistan, which have caused catastrophic losses of biodiversity. Let us discuss the direct and indirect causes of the current losses of biodiversity.

8.4.1 Monoculture

The spread of monocultural production systems (cultivation of same high yielding variety of same crop over large areas) into marginal areas and policies associated with them has resulted in genetic erosion of biodiversity. For this reason, genetic diversity is not only on the decline in farming systems, but also in many areas rich in wild relatives of food crops. With predominant changes in the production systems, diversity is being eroded, as monocultures replace poly-cultural systems. Although plant breeders develop varieties based on wide diversity of plants to incorporate desirable features, the resulting improved high yielding varieties tend to be uniform destroying the very resources on which they were developed. As a consequence thousands of traditional varieties have been eliminated from use. In addition, breeders hesitate to use wild species that have high value particularly as sources of resistance to stresses, nutrition, medicine, as well as food, either because of lack of information about their taxonomy/ breeding systems or lack of ready availability.

In India, by 1968 the so called "miracle high yielding varieties" had replaced half of the native varieties, though these were not high yielding unless they are supported with high fertilizer inputs and irrigation, which often poor farmer could ill afford (Shiva, 1991). Perpetuation of this kind of production system has lead to the loss of around 5000 traditional rice varieties from Assam, which are now available only with the genebank of International Rice Research Institute (IRRI), Manila, Philippines (Jackson, 1994). At the national level the report from Ministry of Environment (1999) says that until very recently India used to cultivate around 30,000 rice varieties, which has been reduced to 50. This kind of homogenisation has increased the risk of narrowing of the genetic base of varieties leading to their increased vulnerability to pests and diseases with adverse effects on other components of the production system. For example, in Bangladesh, the promotion of HYV rice monoculture has led to loss of diversity, including 7000 traditional rice varieties and many species of fish. This is despite the fact that production of HYV rice per acre in 1986 also dropped by 10% from 1972, in spite of 30% increase in use of agrochemical per ha. (Hussain Mian, 1994).

Livestock also suffers from genetic erosion. As per one of the FAO estimates one breed of traditional livestock is lost every week some where in the world. Many traditional breeds have been lost as farmers focus on new breeds of cattle, pigs, sheep, and chicken. Of the 3,831 breeds of cattle, water buffalo, goats, pigs, sheep, horses and donkeys believe to have existed, 16 percent have become extinct and another 15 percent are under threat (Hall and Ruane, 1993). Some 474 breeds can be regarded as rare. An additional 617 breeds have become extinct since 1892.Over 80 breeds of cattle are found in Africa, some of which are being replaced by exotic breeds (Rege, 1994). These losses weaken breeding programs, which could otherwise improve livestock hardiness. Therefore, the loss of these resources means a decline in their availability and use in breeding programmes. This can reduce a farmer's food security with increased risk for availability of a variety of foods. There are evidences to show that such changes can decrease sustainability of farming systems. Loss of diversity also means less availability of resources and opportunities to increases production in future and to overcome the new challenges.

One of the major consequences of homogenisation of varieties is their increased vulnerability to pests and diseases. Historically there are records of serious economic losses because of monoculture of uniform varieties, of which the potato famine of Ireland in the 9th century that caused millions to starve is a classic example. More recently, the wine grape blight that wiped out valuable wine yards in both France and US, and the devastating *Fusarium oxysporum* attack in banana and mould infestation of hybrid maize in Zambia are some other examples (see box 8.2).

The introduction of monocultural industrialised agricultural systems has replaced polycultures, inter-cropping and agro-forestry. This has forced the farmers to accept the standardised breeds and monocultural models, eliminating mixed cropping and landraces. Hence, monoculture system has resulted in genetic erosion not only through narrowing of varieties, their vulnerability to diseases and pests, but also through narrowing of production systems that cause ecological imbalances adversely affecting natural resources.

SAQ 3

How does monoculture production system lead to loss of agro-biodiversity? Explain with examples.

8.4.2 Use of Pesticides

Although insect and fungi are usually considered to be enemies of food production there are several species that are valuable to the efficient functioning of agro-ecosystems. Many insects are beneficial to farming, for pollination, contribution to biomass, natural nutrient production and cycling, and as natural enemies of pest and diseases. Mycorrhiza, which are various species of fungi that live in symbiosis with roots of plants, are essential for nutrient and water uptake by plants. Yet, this diversity of insects and fungi is also seriously eroded in modern agricultural systems worldwide; this trend leads to increasing costs (from efforts to control pests) and declining productivity. The dependence on agro-chemicals, and particularly the heavy use or misuse of pesticides has been largely responsible for this. Agrochemicals besides killing target species also kill their natural enemies and beneficial insects. Pesticides (especially when overused) destroy a wide array of susceptible species in the ecosystem, changing the normal structure and function of the ecosystem. The disruption of agro-ecosystem balance leads to resurgence of pests and outbreaks of new pests, in addition it forces pests and pathogens to develop resistance to pesticides, which may lead to the increased use of pesticides resulting in further disruption of ecosystem. This has been referred to "pesticide treadmill".

Therefore, species richness in the soil can help increase ecosystem complexity, quality and resilience to change. In industrial agricultural systems this diversity has also been eroded by agrochemicals leading to decreased soil fertility and losses in productivity. One of the main reasons for decline in soil health include heavy uses of pesticides, soil fumigants and chemical fertilisers, which can destroy soil organisms as well as soil quality. Homogenisation of crops and varieties also reduces diversity of soil organisms depleting natural nutrients. Also, intensive tilling practices disrupt soil diversity and decline in use of natural manure, crop residues and inter-cropping, adversely affect soil health. These impacts also harm producers, for example, destruction of beneficial soil organisms like earthworm reduces the services and values of these organism for the farmer's crops. Residual effects of agro-chemicals have often adversely affected human health.

8.4.3 Deforestation

In many parts of the world, agricultural growth has contributed to natural habitat loss, particularly in forest areas and in grassland. This has generally happened through extension of agriculture systems into **frontier zones** particularly with clearing of forests and natural vegetation for increasing food production. The expansion of agriculture into frontier areas and conversion to monocultural farming systems further reduces or erodes biodiversity of flora and fauna in the habitat landscapes (refer to subsection 8.4.1). For example, the conversion of forests to monocultural pastures and introduction of homogenous livestock's have been wide spread in America and in parts of Africa, resulting in significant decline of biodiversity. These trends are tied up with the adverse effect on natural resources such as, soil erosion, soil fertility depletion, and water depletion resulting in deterioration of productivity. Nevertheless, in some regions of Kerala, there were community-based ecosystems like mangrove ecosystems, which are special ecosystems with an association of trees, shrubs, vines and epiphytes with ability to withstand regular flooding. In back waters of Cochin these have been gradually transformed into highly productive systems based on rice during winter monsoon, and prawn and fish during southwest monsoon through inter-cropping with coconut, cocoa, pepper, vine, other spices and garden vegetables. Rice, fish and prawn continue to be produced during alternate period of solar year. It has achieved conservation of mangrove, the water for production of fish, prawn and rice. In addition, new species of plants and animals are added to the diversity of the area. This has resulted in breeding important material through induced resistance, such as salinity tolerant varieties in rice. Such wise ecological management has insured food, shelter and schools for a state with the highest population density and highest rate of literacy in India. Unfortunately, the recent developments are taking its toll and the ill-advised development plans may permanently ruin such systems.

Deforestation or loss of habitat has following primary implications:

1. Loss of wild species
2. Removal of vegetation affecting breeding areas and reducing shelter and sources of food. This may also change species composition in the area
3. Fragmentation of habitats with patches of intact and degraded lands that may harm the ecosystem, change nutrient supply and microclimatic regimes and species composition. For example, in Brazil 39 percent of land has been completely converted by the expanding agriculture, while 61 percent is being adversely affected by the above consequences.
4. Reduction in the rate of forest regeneration

In addition, deforestation adds to the social costs to society because it results in:

1. Disruption of ecosystem functions such as, water supply/ filtration provisions, cycling of nutrients and benefits of beneficial insects, flora, fauna that are vital for the life.
2. Loss of diversity of natural species and their products that can adversely affect the supply of valuable natural non-timber products such as, medicines, honey, fibres, fodder, fuel, food etc.

3. The loss of biodiversity that has adverse effects on morals and aesthetic value of all life. The harm to neighbouring farms or communities can have wider implication on regional and global ecosystems. This also affects the future generation, since they will be deprived of large number of valuable genetic resources, which might be irretrievably lost with the loss of habitats.

The concern regarding the loss of biodiversity through deforestation has mostly focused on tropical forests, because they contain unusually higher number of species. The tropical forest covers only seven percent of the earth surface but they are believed to harbour more than 50 percent of the world's plant and animal species totalling around 2.20 millions (NRC, 1993). They are being lost at a rapid pace causing serious constraints to long-term well being of the earth and humanity. These species are a source of germplasm for pharmaceuticals and fibres beside food. Local people depend on these biological resources, having intrinsic ecological benefits, which are difficult to measure economically. Unfortunately, the prevalent changes of agricultural expansion are jeopardising these resources.

Further, the loss of these resources can directly undermine production and producers on individual benefit basis because they entail:

1. Loss of beneficial flora and fauna, such as insects for pollination, natural predators for pest control and organic matter for valuable nutrients of the soil.

2. Loss of genetic resources for developing new varieties and

3. Disruption of ecosystem services such as water and nutrients cycling required for sustainability of agriculture and production.

Raven (1987) has estimated that forest areas that harbour around 50% of global species will be reduced to a tenth by 2020 AD. This could lead to the loss of 50,000 to 2,50,000 species of plants and more than 800 species of vertebrates. According to International Union on Conservation of Nature (IUCN), if the current rate of species loss continued, 25% of the world species may be lost by 2050 AD. As per Consultative Group on International Agriculture (CGIAR, 1994) estimates 50,000 of currently identified species of higher plants are under threat. In India deforestation causing habitat fragmentation, destruction, over-extraction, land use for agriculture etc., has resulted in loss of 17 species in early part of century (listed by IUCN in "extinct plant species of world"). While in the last two decades exploration, inventorisation and bio-perspective assessment of the phyto-diversity of our country have lead to the identification of about 1500 rare and threatened species, of both flowering and non-flowering plant groups (http://envfor.nic.in/bsi. 2002).

SAQ 4

Give at least 3 reasons why deforestation is considered one of the important reasons for loss of global biodiversity?

8.4.4 Impact of Climatic Changes

Human activities have been substantially increasing the atmospheric concentration of greenhouse gasses. These increases enhance the natural greenhouse effect and will result in additional warming of earth's surface and lower atmosphere, which may adversely affect natural ecosystems and human kind. There is also indication that rapid climatic change due to build up of greenhouse gasses in the atmosphere is another factor contributing to loss of biodiversity. The most obvious manifestation of the climatic change is warming of atmosphere that may result in rise of sea level inundating coastal and low lying areas worldwide, increase the rate of desertification, and the frequency of catastrophic weather events, such as El nino, cyclones, forest fire etc. In the hydrosphere our oceans, shared fresh water lakes and rivers are suffering from pollution and toxic contamination on a massive scale. Dramatic decline in population of aquatic species and loss of fresh water supplies for human use are just two signs that international water resources face threats.

As temperatures rise, habitats for may plants and animals will change, depriving them of their homes and niches to which they have been adapted. For example, monarch butterflies could lose their wintering habitats in the mountains of Mexico and polar bears could be affected by the loss of sea life. Many species will not be able to migrate fast enough to keep up with shifting habitat ranges. As a result, many species could become extinct. Scientists have estimated that up to 60 percent of the northern latitude habitats could be affected by global warming.

Siberian hunters along the Arctic coast have reported thunder and lightning, which has not occurred before. They also report open waters in winter. In North America, the Glacier National Park is projected to have no glaciers by 2030. They have already melted drastically since the park was created, and many that were tourist attractions in the 1920's no longer exist. Polar bears on Hudson Bay are reported to be losing weight and having fewer pups because with less ice, the bears are trapped on land longer than usual and are unable to reach the seals that are their main food supply. Warmer temperatures have led to an explosion in the population of Spruce bark beetles, which in turn have killed 38 million trees in a four million acre spruce forest in Alaska.

Dramatic changes can also be seen in the tropics. The icecap atop Mt Killimanjaro, Africa's highest mountain, has lost 85% of its volume in the last century and is apparently going to vanish within the next 15 years. In the south pacific, there have been repeated instances of coral reefs losing their colour, a bleaching effect linked to rising sea temperature and correlated with coral death, if the bleaching is prolonged. A change of several degrees is likely to melt enough polar ice that will raise the oceans between one and two feet. This is enough to increase coastal erosion and have very serious effects on the world's mangroves and corals. Raising the sea level by three feet could produce major impacts, including on agriculture in the densely populated Nile and Ganges deltas, as well as in several low lying island nations such as Maldives. In the longer term there are more ominous sea-level rise scenarios, such as the melting of the west Antarctic ice sheet. Over the space of several centuries the ice sheet could melt, as it has done previously, and raise sea level by 10 to 20 feet, enough to flood many coastal areas.

In Asia, climate change would exacerbate current threats to biodiversity, resulting from land use/ cover change and population pressure. Risks to the rich array of living species are reported. In India, 1,250 of 15,000 higher plant species are reported threatened. Similar trends are evident in China, Malaysia, Myanmar and Thailand. With a 1-m rise in sea level, the Sundarbans (the largest mangrove ecosystems) of Bangladesh are likely to disappear completely. These coastal mangrove forests provide habitat for species, such as Bengal tigers and others like spotted deer, wild boars, estuarine crocodile, fiddles crabs etc. The disappearance of native habitats may spell disaster for the flora and fauna of the region.

Similarly, land degradation in dry-land soils and burning of biomass are globally significant sources of greenhouse gas emissions. Prolonged or frequent drought and soil degradation undermine the soil's capacity to store carbon. Frequent large-scale biomass burning reduces the carbon stored in the vegetation and trees, increasing carbon emission and can contribute to further land degradation. The international community of nations has taken action against these threats by forging the Convention on Biological Diversity, and the United Nation framework Convention on Climatic Change to fulfil specific requirement designed to reduce the loss of biodiversity and to slow the rate of climatic change.

Strategies related to renewable energy sources through biomass energy production can help reduce unsustainable use of firewood and should be researched and developed. The bio-fuel activities would restore the degraded land, while the biomass cover would help produce, harvest and utilise biomass in a sustainable manner. The carbon sink protection and the activities that may enhance improving carbon storage in biomass and soils would help to prevent or control land degradation especially desertification and deforestation. Therefore, promotion of agriculture, particularly horticulture and agro-forestry in degraded lands and conservation of plant biodiversity by protecting biodiversity rich areas and/ or by establishing field gene banks will help removing barriers to implementation of climate friendly and commercially viable technologies and reducing the cost of prospective technology.

SAQ 5

a) Why are island population particularly vulnerable to extinction?
b) How does agriculture help in restricting global warming?

8.4.5 Agricultural Diversification

Much of the agricultural research and development has focused on commercial and/ or cereal production, while family grown vegetables and legumes have been overlooked. This has changed the land use pattern. Such development with diversification of cropping pattern has focused on cultivation of commercial and cereal crops leading to replacement of legumes by uniform cereals in many countries. An analysis of the area allocated among specific crops based on a proportional (%) change from 1971 to 1991 indicates that small and medium size farms increased their proportionate allocations to wheat, oilseeds, fruits/ vegetables, sugarcane, cotton and fodder, while they decreased their allocations to rice, cereals other than rice and wheat, pulses and jute, while there was a very considerably increased allocation to fodder crops, facilitating a 'livestock revolution'. However, there was a nutritionally worrisome decrease in allocation to pulses, and correspondingly a decrease in the diversity of species and varieties grown. Such changes can be detrimental, because people in many countries depend on legumes for their protein sources in diet. In India chickpea acreage dropped to half that of wheat between the 1960's and 1970's.

For poor farmers this conversion detracted the farmer from nutritional needs of the household and they had to rely on purchase of such food, which often is unaffordable and inaccessible. More the people consume uniform standardised food they do not get the variety of vitamins and minerals that are so important for nutrition and health. The decline and extinction of landraces, traditional varieties and wild foods also means a decline in valuable nutritional resources. The growing free market system of international trade in agriculture has enabled the northern countries to eat a variety of foods produced elsewhere in limited areas. These changes have brought-in the market demand for uniform high yielding varieties which poor people of south produce, but do not have access to, as these variety are export products. Consequently, nutrition among large population of the developing world has been harmed with loss of agro-biodiversity.

The integration of freshwater prawn culture with rice farming is yet another example where diversification has led to change in land use and loss of biodiversity. Kerala and coastal Andhra Pradesh are endowed with large freshwater resources and low-lying paddy fields that have been traditionally exploited for rice cultivation. In recent times the integration of rice farming with freshwater prawn culture has given a new thrust to the economy of traditional farming. However, since the remuneration from prawn culture far exceeds than what a farmer may expect from paddy, cultivation of paddy is undertaken only to feed the prawn cultures. This has caused the discontinuation of cultivation of several varieties of rice particularly, Pokkali paddy, highly saline tolerant rice. In recent times a vast majority of the newly converted areas remains unutilised in Nellore in South India due to drought and disease problems.

One of the most influential root causes underlying agro-biodiversity losses is diversification of agriculture to green revolution model of HYV's and related industrial agriculture production system. This has promoted monoculture along with other technologies, such as irrigation, use of agrochemicals and mechanised equipments. The spread of such technologies has resulted in increased production but have provoked problems as they are inaccessible to local people and are often poorly adapted to local agro-ecological conditions. They displace indigenous practices, varieties and can increase vulnerability and risk in the farming systems. Such programs and models therefore, are provoking unanticipated problems of biodiversity losses as well as socio-economic cost. In addition, numerous policies including general agricultural development programmes, pricing, subsidies and credit packages are directly and indirectly adversely influencing biodiversity in agriculture.

SAQ 6

In what way has loss of agro biodiversity affected the nutrition of developing countries?

8.5 CONSERVATION OF BIODIVERSITY

The discussion in earlier sections clearly shows that though there is growing realisation that biodiversity is fundamental to agricultural production and food security, as well as ecological stability, it is being rapidly eroded and disappearing throughout the world because of several developmental changes, including agriculture. Several of these changes jeopardise productivity, threaten food security and result in high yield losses, as well as disrupt social structure and environment. Related to this, and equally alarming, is the loss of biodiversity in "natural" habitats with expansion of agriculture and developmental activities into new frontiers.

For instance in India deforestation, habit fragmentation, over-extraction of natural resources, conversion of land to agriculture etc., have caused loss of a large number of species during past. As per the BSI, 623 species of vascular plants are endangered since base line of 1000 threatened species of 1985 (Nayar and Sastri, 1990). Agricultural research and development policies have led to change in production systems that have worked against biodiversity and the sustainable use of genetic resources resulting in loss of traditional varieties and landraces that had survived for centuries because of their resilience against various stresses (Jackson, 1994; http, 1999).

On the basis of above discussion, it can be safely concluded that unidirectional and un-sustainable agriculture production systems conflict with conservation of biodiversity. There are cases to demonstrate multiple benefits from integrating biodiversity with agriculture. In other words, conservation and enhancement of agricultural biodiversity, essential for food production can be achieved in both small- and large-scale farms. Therefore, conservation of biodiversity either through establishing synergy between agriculture and biodiversity resolving conflicts or through integration and use of sustainable agro-ecological practices with changes in agricultural policies, institution and paradigms or through *in situ* and *ex situ* conservation approaches protecting the plant diversity in nature and in man-made structure can achieve eco-friendly sustainable development. There have been efforts in this direction both at local and global level. "Convention on Biological Diversity (CBD)" is an intergovernmental agreement, which addresses the major concerns of agricultural biodiversity and recommends implementation, actions and policies for conservation, sustainable use and enhancement of agro-biodiversity through empowerment of farmers and communities, and fair and equitable distribution and sharing of benefits accruing from the use of biodiversity.

8.5.1 Integration of Conservation and Sustainable Agriculture

To overcome the conflicts between agriculture and biodiversity there is a need to develop complementarities between them in order to ensure sustainable use of bio-resources. To meet this challenge, it requires addressing causes of the full range of problems and call for change in practices, paradigms and policies. The use of experiences and practices supporting conservation and sustainable use should be spread.

The strategies for conservation are:

i) *Address causes for agro-biodiversity losses*

Of the forces behind agro-biodiversity loss, the promotion of practices, such as monocultures integrated with industrial agriculture has been the key factor because of being supported by institutions, private companies. This scenario requires transformation along with broader socio-economic changes at grassroot level.

ii) *The key principle and practices: Conservation and Sustainable Intensification*

An overview of principles and practices of agro-biodiversity for sustainable agriculture is required. The following general principle and guidelines (Table 8.1) are important to implementing methods to enhance and conserve agro-biodiversity in varying farm systems and at various scales.

Table 8.1: Key Principles to Conserve and Enhance Agro-biodiversity

Principles	Guidelines
Agro-biodiversity conservation	It should be developed within a framework of sustainable agriculture, meaning it is linked to the integration of goals of productivity, food security, social equity, health, and ecological integrity.
Agro-ecology	It is an appropriate scientific basis for agricultural development, which upholds agro-biodiversity enhancement, and provides principles for this purpose.
Empowerment of farmers and communities	It will help protection of their rights, and ensure partnerships with other social groups, which is an important social basis that would help enhance agro-biodiversity
Adaptation of methods	Adaptation to local agro-ecological and socio-economic conditions, and building upon existing fruitful methods, are essential to meet needs and build complementarities
Conservation and regeneration	It will ensure plant/ animal genetic resources and soils, and methods for sustainable intensification (using biologically based measures) needed to protect biodiversity for present farmers' livelihoods as well as future needs and ecosystem functions.
Supportive policies and institutions	Creation of supportive policies and institutions is vital to the implementation of changes to merge agriculture and biodiversity, and to ensure rights and food security of the general public.

iii) Examples of best practices to be used for enhancing agro-biodiversity

The particular practices selected for a given region or farm need to be adapted to local conditions and therefore require flexibility for adjustment and dynamic changes so as to fit into an agro-ecosystem. The practices may be related to-

a. Ecologically oriented integrated pest management.
b. Effective disease management using components of agro-biodiversity.
c. Practices for soils fertility/ health and nutrient cycling using agro-biodiversity.
d. Agro-forestry as a component of the production system for conservation of agro-biodiversity.

iv) Incorporation of farmer's knowledge/ practices and participation

It has been observed that incorporation of traditional principles and practices in the farming system is advantageous. Many experiences have shown that systematic study/refinement and inclusion of local farming practices in agricultural research and development (R & D) through participation of local people has had beneficial effect both on productivity and conservation and therefore needs to be done consistently. In other words a "user oriented" or "farmers friendly" approach is essential to develop changes.

v) Agro-biodiversity in large-scale farming

It is a common misconception that agro-biodiversity is only possible in small-scale farming. However, there are evidences to show that crop rotation, intercropping, cover crops, integrated pest management and integrated nutrient management are being effectively used in commercial systems as well. They represent sustainable approaches for intensification.

8.5.2 Merging of Agriculture and Biodiversity Goals in Habitats

In addition to developing complementarities strategies, it is required to promote practices and policies, which alleviate pressures and conserve resources in natural habitat. Intensification of sustainable *in situ* conservation is a step to achieve such a goal, but urgent work is needed in this area following the approach listed below:

i) Use of biodiversity in sustainable intensification to avoid extensification

Agro-ecological practices, such as agro-forestry, multiple cropping, crop rotation, integrated pest management, non-chemical soil management to enhance soil health, and integration of wild species are the methods that increase efficiency of resources use in sustainable way and can increase yields and also reduce or avoid expansion of farmland (Toniolo and Uhl, 1995).

ii) Re-vegetation in agricultural lands: buffer zone, corridors, and habitat strips:

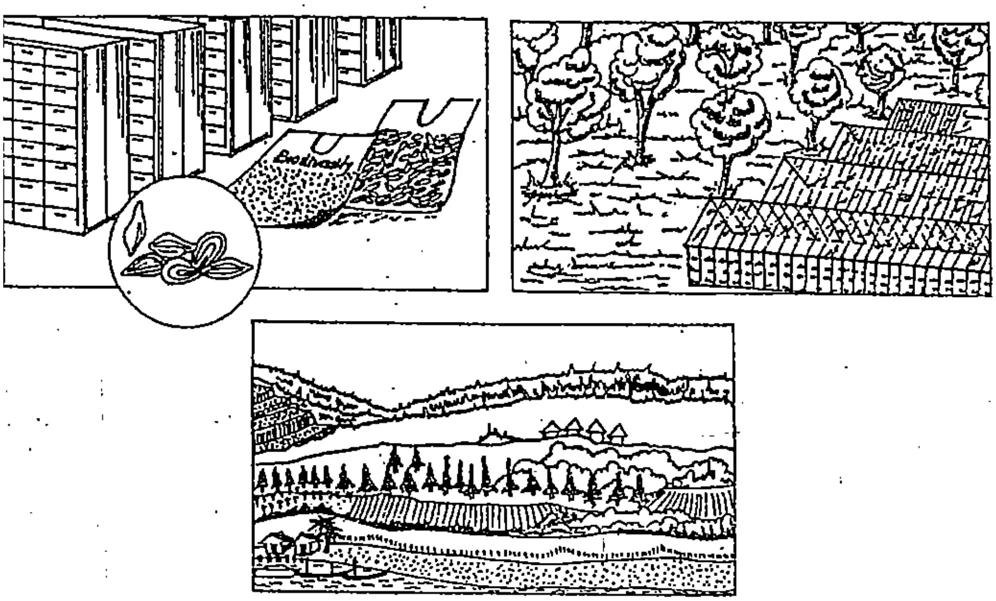
This refers to strategies for planting of native plants and trees in remnant habitat areas or forest margin. Buffer strips consist of native plants in places around existing remnants of natural vegetation to protect them from external impacts, using dense vegetation in narrow band around the edge. Corridor strips of vegetation/ trees planted between isolated habitat in remnant areas, which provide conservation "network" to enable movement of fauna and supplement habitat useful for windbreaks and erosion control.

iii) *Conservation of Species/ Habitat Tied to Agriculture*

Species collected from different habitats are also important as sources of food, particularly for poor farmers who benefit from diversity of nutritional sources. This biodiversity also provide valuable sources for crop breeding and pest control. There are a number of examples, where genes imported from traditional varieties or wild relatives of crop species from different countries/ regions have been used in the breeding programme protecting the crop from lethal/ severe diseases.(see section 8.3) In order to ensure that such areas remain accessible to poor communities and protected from agricultural intensification, tenure laws will need to be strengthened (Fig 8.2). Further, programmes for both *ex situ* and *in situ* conservation of wild species needs to be strengthened.

Ex Situ Conservation

Field Genebanks



In Situ Conservation

Fig.8.2: Approaches to Biodiversity Conservation.

***In situ* conservation**: means conservation of genetic resources within their ecosystem and natural habitat, which ensures the maintenance and recovery of viable populations of species in their natural surroundings. It is a dynamic system that allows the species/ population to respond to the changing environment and evolves to meet the new challenges. Under *in-situ* conservation the species are allowed to grow in their natural habitat by management of ecological continum. This can be a biosphere reserve protecting an ecosystem containing species living as interacting communities; a habitat park, national park, sanctuary, nature reserve, indigenous reserve, extractive reserve, managed forest, religious sanctuary, preservation plot, etc., conserving useful or endangered species habitat; or on-farm, ranches, home gardens etc., conserving and protecting useful or endangered landraces/ traditional cultivars and wild and weedy relatives. In conservation of agricultural biodiversity *in situ* approach is particularly important.

8.5.3 Ex Situ Conservation

The components of genetic material of agro-biological diversity can also be safely conserved outside their natural habitat in man made structures that have often been referred to as genebanks. These are the facilities providing support to natural perpetuation of an species or help to conserve the "genetic material" of plant origin of actual or potential value for food and agriculture. This includes reproductive or vegetative propagating material containing functional units of heredity, under conditions that are able to limit loss of viability and genetic change to minimum level, thereby supporting conservation of true to type. They can be:

Gene bank is a facility established for the ex situ conservation of individuals (seeds), tissues, or reproductive cells of plants and animals.

A. **Field Genebanks:** It involves conservation of plant(s) and is partially evolutionary in nature.

   1) Botanical gardens, arboreta, herbal garden, clonal repositories etc.
   2) Selective conservation (conservation under selective pressures)

B. **Seed Genebanks:** It involves storage of seed, the physical carrier of genetic information from one generation to the other, which can survive for years under low moisture and temperature conditions. It is static in nature.

C. ***In Vitro* Genebanks:** Conservation of cells, tissues, organs under aseptic conditions following the principle of toti-potency, subjecting the cultures to slow growth in glass or plastic containers (static in nature).

D. **Cryo-Genebanks:** Cryo-preservation of seeds, organs, sperms (pollen) or cultures in liquid nitrogen between -150 to -196^{0}C following the principle of cryogenics.

E. **DNA banks:** conserving genomic DNA, DNA libraries, DNA clones etc.
As per the objectives of conservation, the collections broadly may be of two types:

   i) *Base collections:* These are unique accessions that are closest to original samples being conserved on long-term basis for posterity. They are not for distribution.

   ii) *Active collections:* These refer to those collections, which are immediately available for multiplication and distribution for use in research and crop improvement.

cultigens

Recognising the escalating trends in the loss of plant genetic diversity, various National and International Institutions organise planned exploration missions aimed at tapping genetic variability in different agricultural and horticultural crop species, their wild relatives and related species. The collected germplasm reveals the nature and extent of variability among different species, within species, cultigens etc., and also their agro-ecological/ phyto-geographical distribution. Explorations for plant genetic resources differ from floristic surveys, which are mainly undertaken to study the flora or plants of an area or its vegetation so as to list out species diversity. Plant genetic resources collection missions require considerable knowledge of plant geography, agro-ecology, plant taxonomy/ herbarium studies, ethno-botany, crop evolution and domestication, population variation and distribution and genepool sampling etc. The safest approach to ensure the success of future plant breeding programmes is to collect and maintain as much as possible of the entire genetic diversity of both cultivated species and their wild relatives.

Effective conservation of biodiversity requires precise information about how much, where and why biodiversity is being lost. Geographical information systems and remote sensing technologies and approaches allow us to assess changes in land use and land cover. This facilitates a better understanding of the causes and consequences of such changes, which in turn would enable us to develop appropriate mitigation strategies to either curtail deleterious changes or to counter their negative effects. Analysis of remote sensing imagery together with adequate ground study provides an effective way of rapidly determining forest cover over relatively large areas. Time series analysis then can help to determine changes in forest cover and gap analysis can assess the effectiveness of protected areas in conserving biodiversity. Gap analysis would also help in pinpointing and targeting areas, for organising exploration and collection missions to collect and conserve new germplasm *ex-situ* or to recollect.

SAQ 7

What is on-farm conservation and how it is different from *ex situ* conservation?

5.4 Addressing Policies Paradigms and Protecting Rights

licy reforms are needed to bring out structure changes to confront the root
oblems, to converge agriculture and biodiversity and to ensure food security and
hts of the local people. This may involve the following steps:

Preparation of a synopsis of initiatives effecting agro-biodiversity issues

Several international and national institutions have been involved in research, development, and policy formulation that influence use of genetic resources and diversity in agriculture (Table 8.2.). For many years these institutions have dedicated significant resources in breeding high yielding varieties in the program associated with green revolution, but in last two and a half decades these organisations and others have developed initiative to conserve genetic resources. Also, in the 1990's agro-biodiversity issues have been addressed in several international conventions and agreements, largely in reaction to global problems of genetic erosion related to ecological and economic losses. At a broad level the Earth Summit in 1993 outlined a general framework to address such matters. As an outcome, a broad and legally binding CBD (Convention of Biological Diversity) was established. This convention is an important agreement to promote conservation, sustainable use and fair distribution of biological resources globally.

ble 8.2: Major Institutions and Conventions Influencing Plant Genetic Resources

cronym	Institution/ Conventions	Role/ Influence on Plant Genetic Resources
'GRI	International Plant Genetic Resources Institutes	Coordinates world network of research centres, labs, and genebank concerned with PGR (formally IBPGR)
AO-CPRG	FAO Commission on Plant Genetic Resources	Develops guidelines and norms for intellectual property rights and policies concerning plant genetic resources
AO-SIDP	Seed Improvement and Development Program	Promotes participation of governments, NGOs, and industries to develop HYVs and related inputs
'IPO	World Intellectual Property Organisation	Oversees and establishes international norms and model laws concerning patents and control of information on PGR
POV	Union for the Protection of New Varieties of Plants	International Convention (held in '61, '72, '78, '91) that establishes regulations on plant innovations/ varieties
BD	Convention on Biological Diversity (Secretariat)	International Agreement that establishes legally-binding codes of conduct, guidelines, regulations
RIP	Trade-Related Intellectual Property Rights	Provides minimum standards for member countries on IPR, patents and plant protection, under GATT
ATT	General Agreement on Tariffs and Trade	International agreement concerning international trade and commerce, including provisions on IPR
ENE ANKS	National Seed Storage Laboratories	Maintains genetic materials as a base collection for national and for the global network of genetic resources centres

Few other institutions are focused specifically on conservation programmes in this field. Seed banks are an important component of *ex situ* conservation, storage and research on edible plants, however many of them suffer poor infrastructure and maintenance. In addition, to these initiatives, many NGO's and local organisation are increasingly interested in working to enhance, conserve and insure the rights to benefits on agro-biodiversity.

ii) *Enhancing and conserving genetic resources for sustainable use*

One of the most important challenges in this field is to develop appropriate policies to conserve and enhance the genetic resources and to protect the rights and welfare of the people and nations who are the users and experts on these resources. For this a summery of suggestions in general are made regarding improving *in situ* conservation, improving *ex situ* conservation, monitoring of early warning of genetic erosion in specific locations and policies and programmes to support training and public education on agro-biodiversity.

iii) *Bringing reforms in breeding approaches and models*

Further changes are needed in fundamental paradigms and strategies for plant breeding and agro-ecosystem management, which alleviate many specific factors leading to agro-biodiversity erosion. For example rescuing wild genetic material and their use for broadening the genetic base of cultivated species would provide greater resilience against various stresses.

iv) *Changing agricultural/ economic policies to support agro-biodiversity*

This would require change in policies to address causes responsible for loss of agro-biodiversity, which may include ensuring public participation, eliminating subsidies and credit on HYV, fertilizers etc., policy support and incentive for agro-ecological methods, reform in tenure/ property system, changing consumer demand etc.

Lessons from experiences show that practices and approaches to enhance agro-biodiversity pay off for both large and small-scale farmers; they also serve interests of food security and conservation. If appropriate reforms are made in policies concerning intellectual property rights, they also can contribute to broad social interests. In sum, policies and actions to support agro-biodiversity at many levels are needed, and will lead to multidimensional economic and ecological gains.

SAQ 8

In addition to *in situ* and *ex situ* conservation, give two other measures that can contribute to conservation of biodiversity for food and agriculture.

8.6 SUMMARY

In this unit you have studied that:

- There is growing realization that biodiversity is fundamental for agriculture production and food security, as well as it is a valuable ingredients for ecological stability. Despite this the biodiversity associated with agriculture and food production is being rapidly eroded and disappearing throughout the world. This alarming loss of biodiversity is occurring at many levels, including plant genetic resources, livestock species, insects, fresh water and soil organisms thereby narrowing the agro-ecosystems. These changes are threatening the productivity, food security, resulting in high economic losses at social cost. Related to this equally alarming, is the loss of biodiversity in natural habitat with the expansion of agriculture and other developmental process into new frontiers.

- Development in agriculture has often been considered opposing conservation of biodiversity, however, it is not always true and there is evidence to show that integrated biodiversity and agriculture has multiple economic and ecological benefits; thereby suggesting that agro-biodiversity is critical for food production, ecosystem health and for economical and eco-friendly development. Recognising these concerns, the Convention on Biological Diversity (CBD) has mandated actions for nations and institutions for conservation, sustainable use and fair and equitable distribution of benefits derived of agricultural biodiversity.

- Agro-biodiversity is the fundamental feature of farming systems. Since early days, it consists of diversity at genetic, species and ecosystem level. The conservation practices followed for agro-biodiversity are part of rich cultural diversity and local knowledge.

- In spite of the importance of agricultural biodiversity it is being eroded globally and one of the main reasons is increased vulnerability of crops to pests and diseases. This situation has arisen because of monoculture production system. The monoculture production system has been further expanded to high input industrial agriculture, which has promoted use of agrochemicals leading to further loss of diversity in natural habitats including tropical forests, grasslands and wetlands and contributing to climatic changes further destroying the biodiversity at global level. The underlying reasons for this situation are complex, consisting of a mix of policies, practices and pressures for economic and agriculture growth, as well as demographic changes and disparities in the control of resources.

- Consequently conservation of agricultural biodiversity is needed. Efforts have been made in this direction both at local and global levels with the establishment of agreement like CBD. Yet much more is to be done to implement the agreements of the Convention to strengthen, expand and coordinate the initiatives for agro-biodiversity conservation and enhancement. In developing such strategies, following principles are important; agro-biodiversity conservation, agro-ecology, empowerment of farmers and communities, adaptation of methods needed to build complementarities, conservation and regeneration and creating supportive policies and institutions. These are needed at all levels. These types of policies and practices promise win-win opportunities that merge goals of agriculture and biodiversity, and will lead to socio-economic and ecological gains.

8.7 TERMINAL QUESTIONS

1. Describe the components that constitute biodiversity and how are they measured
2. What are genetic resources, describe the constituents of plant genetic resources and how do they differ from the constituents of agro-biodiversity?
3. When did the Convention on Biological Diversity (CBD) come into existence and what are its primary objectives?
4. How does biodiversity contribute to research and development of agriculture to increase food productivity.
5. How does genetic homogeneity of crop species enhances genetic vulnerability to pests and diseases? What type of agricultural practices can help minimise it?
6. What are the impacts of environment changes on biodiversity in general and agriculture in particular?
7. Explain the potential use of wild and weedy relatives in major crop species

8. What is *in situ* and *ex situ* conservation, how they can be utilised as complementary approaches for sustainable conservation and use of genetic resources?

9. Explain Vavilov's centres of origin and how do they differ from the centres of diversity.

REFERENCES

1. Anonymous (1998) Recommendation of NAAS Workshop on National Concern for Conservation, Management and Use of Agro-biodiversity. Held at Central Potato Research Institute, Shimla, 15-16 October 1997.

2. Anonymous (2000) Manual on Exploration and Collection of Plant Genetic Resources and Related Indigenous Knowledge. Agro-biodiversity (PGR) -5. National Bureau of Plant Genetic Resources, New Delhi-110 012. p. 63.

3. Arora, R.K. (1991) Plant Diversity in the Indian Gene Centre. In: Plant Genetic Resources, Conservation and Management. Concept and Approaches (eds. R.S. Paroda & R.K. Arora) IBPGR, Regional Office for South and Southeast Asia, New Delhi. pp. 25-44.

4. Brookfield, H. (1995) "Postscript: The Population-Environment Nexus". Global Environmental Change 5 (4): 381-93.

5. Consultative Group on International Agricultural Research (CGIAR) (1994) Partners in Selection. Washington, DC: Consultative Group on International Agricultural Research.

6. Gautam, P.L. and Singh, A.K. (1998) Agro biodiversity and Intellectual Property Rights (IPR) related issues. *Indian J. Pl. Genet. Resources* **11**:129 -153. (?)

7. Hall, S.J.G. and Ruane, J. (1993) "Livestock Breeds and Their Conservation: A Global Overview". Conservation Biology. 7(4): 815-25, cited in Smith, N. 1996. p. 43.

8. Hussain Mian (1994) "Regional Focus News – Bangladesh". Ecology and Farming: Global Monitor, IFOAM. January: 20

9. (http://www.envfor.nic.in/soer/chap5.html) 1999 National Report on Biological Resources: India: 1998-99

10. (http://www.envfor.nic.in/soer/chap5.html) 2002 National Report on Biological Resources: India: 2000-01

11. Jackson, N.E. (1994) Preservation of rice genes. Nature 371:470.

12. Juma, C. (1989) The Gene Hunter: Biotechnology and the scramble for seeds. Princeton NJ: Princeton University Press, p.14; p 41.

13. Koshoo, T.N. (1995) "Census of India's Biodiversity: task ahead. Curr. Sci. 69:14-17.

14. Kotwal, P.C. and Banerjee, S. (1998) Biodiversity conservation in forests and protected areas: Practical problems and prospects. In: Biodiversity Conservation in managed forests and protected areas (eds. P.C. Kotwal and S.Banerjee), AGRO BOTANICA, Bikaner. pp. 1-10.

15. Ministry of Environment and Forest (MoEF) (1998) Draft Status Report.

16. Ministry of Environment and Forest (MoEF) (1998) Implementation of article 6 of the Convention on Biological Diversity in India, National Report (interim).

17. Nayar, M.P. and Sastri, A.R.K. (1990) Red Data Book of Indian Plants. Vol 1, Botanical Survey of India, Calcutta.

18. NRC (1993) Managing Global Genetic Resources. Washington, DC: National Academy Press. Also, see Cleveland et al., 1994.

19. Paroda, R.S., Rai, M., Gautam, P.L., Kochhar, S. and Singh, A.K. (1999) National Action Plan on Agrobiodiversity in India. National Academy of Agricultural Sciences, Indian Council of Agricultural Research and Indian Society of Plant Genetic Resources, New Delhi: 156.

20. Prescott Allen and Allan Prescott (1992) "Conservation Biological Diversity in Agricultural/ Forestry Systems". Bioscience 42 (5): 354-62.

21. Raven, P.H. (1987) "The scope of the plant conservation problems worldwide" In: D. Bramwell, D. Hamann, V. Haywood and H. Synge (eds.) Botanic Garden and the World Conservation Straregy. Academic Press, London. pp. 19-29.

22. Ray, G.C. (1988) "Ecological diversity in coastal zones of oceans" In: EO Wilson and FM Peter (eds) Biodiversity. National Academy Press. Washington DC. pp. 36-50.

23. Rege, J.E.O. (1994) "International Livestock Center Preserves Africa's Declining Wealth of Animal Biodiversity". Diversity 10 (3): 21-25

24. Rex, M.A., Stuart, C.T., Hessler, R.R., Allen, J.A., Sanders, H.L. and Wilson, G.D.F. (1993) "Global scale latitudinal patterns of species diversity in the deep-sea benthos" Nature 365: 636-639.

25. Shiva, V. (1991) "The Green Revolution in the Punjab", The Ecologist. 21(2): 57-60.

26. Singh, A.K. (2002) Role of Indian Agricultural Heritage in Conservation and Enhancement of Plant Genetic Resources. Nene, YL and Choudhary, S L (eds.) 2002. Agricultural Heritage of India, Asian Agri-History Foundation, Secunderabad, India pp. 22-40.

27. Stork, N. (1993) "How many species are there?" Biodiversity and Conservation 2: 215-232.

28. Stork, N. and Eggleton, P. (1992) Invertebrates as Determinants and Indicators of Soil Quality". American Journal of Alternative Agriculture 7(½): 39.

29. Toniolo and Uhl (1995) "Interaction between Agriculture and Natural Habitats." Draft Paper, World Bank Environment Department, Washington, DC.

30. UNEP (1995) Global Biodiversity Assessment. Cambridge University Press, Cambridge.

31. Wilkes 1983, or Frankel and Soule, 1981 (cited in draft by Faeth, P., ed. 1993. Agricultural Policy and Sustainability: Case Studies from India, Chile, the Philippines and the United States. Washington, DC.

32. Wilson, E.O. (1988) "The Current State of Biological Diversity". In: E.O. Wilson (ed)) Biodiversity Washington DC: National Academy Press, p. 15.

33. Zeven, A.C. and Zhukovsky, P.M. (1975) Dictionary of cultivated plants and their centres of diversity. PUDOC, Wageningen. p. 219.

UNIT 9 ENERGY

Structure

9.1 INTRODUCTION

You are familiar with the term energy. Sometimes you may feel tired and say, "I don't have the energy to do anything." In the newspaper you may have often read about various sources of energy, solar energy, hydropower etc. Technically, energy is a term used to describe or measure the amount of work done for any activity. Suppose you have to lift a bucket (10 litres) of water from a 10 metre deep well or from the ground floor of a house to its first floor. To lift the water, you have to do work, and energy is required to do this work. Similarly, suppose you have to boil one litre of milk. What will you do? You will heat the milk until it boils. How will you heat it? By using cooking gas or kerosene oil, firewood or electrical heater, etc. This means that all of them have the capacity to heat milk. They are called as **energy sources.**

You are familiar with electrical energy, which is used for providing heat and light as well as running motors and pumps. Heat, light and electrical energy are various **forms of energy**. Without going into too many technical details about energy, in this unit we focus on the various issues involved in the management of energy as a resource, particularly with reference to agriculture.

We draw your attention to the energy needs of the agricultural sector and how these can be fulfilled without polluting the environment. In this context, the renewable energy resources have an important role to play. In rural areas, the issue of energy is not purely a technological issue. It has a socio-economic dimension that you should be aware of. Finally, we consider strategies of conserving and managing energy. In the next unit, we consider the issues and challenges we face in the management of off-farm inputs.

Objectives

After studying this unit, you should be able to:

- describe the energy needs of the agricultural sector;
- discuss the renewable energy resources viz., solar energy, biomass energy, bio-fuels, wind energy;
- explain how best renewable sources of energy can be used in agriculture; and
- discuss various strategies for energy conservation and methods to achieve higher efficiency in energy use in agriculture.

9.2 THE ENERGY SCENARIO IN AGRICULTURE

Agriculture is basically a process of conversion of energy. In this process, solar energy is converted to chemical energy, as plants make their food in the presence of sunlight. Plants use the solar energy to convert it into chlorophyll, the green substance in leaves that gives them their colour, in a process called **photosynthesis**. Modern agriculture enhances production of biomass by increasing photosynthesis through better plant types, use of irrigation water, fertilizer, pesticides and other growth promoters.

Agriculture is both a producer as well as a consumer of energy. Some energy inputs in agriculture are commercial like animal power, diesel, fertilizer, irrigation water, seeds, etc. while some are provided free of cost by nature like solar energy for photosynthesis, rain water, microbial activities in soil, etc. Let us study both these aspects of agriculture in relation to energy.

9.2.1 Agriculture as a Consumer of Energy

Crop production (from preparing the land, sowing seeds, managing crops to harvesting the produce and post harvest operations), livestock management, fisheries, poultry, and many other agricultural systems need energy for their various processes/practices and productivity.

Traditionally, human beings and animals have been the main sources of energy in agriculture in South Asian countries. If you remember your school physics, you might find the information given in Table 9.1 interesting. *Otherwise, you may skip it.*

Energy requirement in the agricultural sector depends upon the size of cultivated area, level of technology, cropping pattern, water availability etc.

Units of Power and Energy

The S.I. unit of power is watt whereas S.I. unit of energy is joule.

Since S.I. unit of time is second, we may say

1 joule = 1 watt × 1 second. The familiar unit of electrical energy is kWh (kilowatt-hour).

Hence,

1 kWh = 1000 W × 3600 seconds = 3600,000 joules = 3600 kJ or 3.6 MJ
1 kJ(Kilojoule)=10^3 J,
1 MJ(Megajoule)=10^6 J

Table 9.1: Energy norms for various inputs

Input	Unit	Energy (MJ)
Adult men	Man-hour	1.96
Adult women	Woman-hour	1.57
Children	Child-hour	0.98
Medium Bullocks	Pair-h	10.10
Buffalo	Pair-h	15.15
Mule	Animal –h	4.04
Camel/horse	Animal-h	10.10
Diesel	Litre/ Kg	56.30 /63.27
Petrol	Litre	48.23
Kerosene	Litre	41.30
Coal	Kg	32.7
Fuel wood (dry)	Kg	20.0
Saw dust	Kg	18.0
Dung/dung cakes	Kg	18.0
Rice straw	Kg	12.5
Fertilizer N	Kg	60.0
Fertilizer P_2O_5	Kg	11.1
Fertilizer K_2O	Kg	6.7

Different agricultural operations require energy. As examples, let us see how much energy is required for rice transplanting, wheat harvesting and soybean cultivation and how it can be met by human power or machine power:

Examples of Energy Requirements

Rice transplanting: For covering one hectare rice planting (including nursery raising, uprooting, washing and transport), we require 212 man hours (≡15.82 kWh). Energy required for a rice transplanter of 3.73 kW will be 67 man hours and nine hours of machine operation (Total 38.57 kWh). This shows that energy required by machines is 2.44 times more as compared to human beings.

Wheat harvesting: For harvesting one hectare cropped area, manual method requires 125 man hours, which is equivalent to 9.33 kWh. If the same job is done by machines, e.g., a 26.11 kW tractor operated with vertical conveyor reaper, it would require 42 man hours and 3.226 of machine hours equivalent to 84.22 kWh and 3.13 kWh for human labour to operate the machines. The total energy consumed in the second method is 9.3 times more than the manual one.

Seed bed preparation and sowing of soybean in black soil: For one hectare area ploughing (once) will require 40 hours of a pair of bullocks equivalent to 29.84 kWh and harrowing (twice) will require 16 hours of a pair of bullocks equivalent to 11.94 kWh. Seeding will require 5 hours of the bullock pair, equivalent to 3.73 kWh. The total energy consumed will be 45.51 kWh. The same operation when done by a 26.11 kW tractor will consume 6.75 hours equivalent to 306.79 kWh of energy. The machine energy is 6.7 times more than the animate energy.

The above three examples clearly show that the work output per unit energy is more in animate energy as compared to commercial energy. However, the increased cropping intensity, production and productivity of land require more and quick input of energy which cannot be met alone by animate energy. The use of tractors, pumping motors have also become necessary and all sources of energy have become complementary to each other.

The energy requirements do not end with agricultural operations. The transport of produce is a major issue in most South Asian countries. Animal and human beings are extensively used in rural transport system in the developing countries. Bulk of the harvested produce is transported as head loads from field to threshing floor and then to storage areas or trucks or bullock carts etc. as it is convenient and economic. The firewood from field to house and small quantities of fruits, vegetables, grains etc. are transported as head loads or by animal driven carts etc. for short distances under field conditions and *kachcha* roads.

Fig.9.1: Energy needs in rural transport

wever the use of commercial energy is increasing as shown for India in Table 9.2.

Table 9.2: Energy used in Indian Agriculture

nergy source	1970-71	1975-76	1980-81	1985-86	1990-91	1992-93
.. Diesel energy						
ı agriculture)00' t)	153.5	527.6	1034.5	1339.7	2113.9	2186.4
or crop roduction (000' t)	61.4	211.0	413.8	535.9	845.6	874.6
ligh speed Diesel, g/ha	0.37	1.23	2.39	3.0	4.55	4.72
IJ/ha	23	78	148	190	288	299
. Electrical energy						
lectricity, GWh	4460	9592	14489	23422	50321	63328
Wh/ha	27	56	84	131	271	342
IJ/ha	322	668	1002	1563	3233	4080
otal mechanical nergy, MJ/ha	345	746	1150	1753	3521	4379
. Animate energy						1059*
nimal energy, IJ/ha	1606	1485	1404	1293	1101	1059
luman energy, IJ/ha	1331	1363	1401	1348	1409	1434
otal energy in griculture, MJ/ha	3282	3594	3955	4394	6031	6872
hare of ommercial over otal energy,%	11	21	29	40	58	64

te : 1. *Estimated
2. Capacity: Diesel, 63.27 MJ/Kg: electricity, 11.93 MJ/KWH.
3. Bullocks pair, 10.10 MJ; human, 1.84 MJ (male, 70% and female, 30%).
4. 40% of the total diesel used in rural sectors assumed for crop production and remaining for transport and other agro-industrial activities.

ırce : "Data Book on Mechanization and Agro-Processing Since Independence" by Dr. G. Singh, **Director, CIAE, Bhopal - 462038, Dec 1997.**

ble 9.2 shows the trend of increasing use of commercial energy in the form of ctrical and diesel energy. The share of animate energy is declining. Why? This may due to the problems associated with using animate sources of energy.

Expenditure on the purchase, upkeep and maintenance of animals, irrespective of work.

Less annual utilization of animal energy. For example, the current annual utilization in different parts of India ranges between 350-1250 hours as against the ideal utilization of 2400 hours.

Under-utilization of the potential.

High unit cost of energy as compared to commercial energy.

ıe question you may like to raise is: **How can we increase the efficiency of the imate sources of energy?**

iis is because the use of animate sources of energy will continue in agriculture in uth Asian countries and it is necessary to improve the efficiency of animate sources energy.

Improving the efficiency of animate sources

Efficiency of human energy can be improved by using efficient and matching equipment for various operations done by human beings. The existing equipment should be improved or redesigned keeping ergonomic considerations in view, by scheduling rest under various modes of weather conditions to get maximum output.

The animate energy efficiency can be improved by the following measures:

- By improved breeds of animals and their health care to suit climatic conditions of the area.
- By increasing draft availability of animals by use of improved yokes and harness and designing equipments based on mechanics of animal traction.
- By increasing their annual utilization by developing equipments for those periods when they are not being utilized presently.
- By using them for stationary operations like grinding, oil extraction, chaff cutting, water lifting etc. and by designing matching equipments.
- By utilizing milch and pack animals for draft purposes.

Energy management in agriculture requires an understanding of not only the needs but also how agriculture itself is a source of energy. But before you learn about this aspect of agriculture, you may like to attempt an exercise.

SAQ 1

Although the energy consumed in machine operations in agriculture is more as compared to animate energy, explain why there is a growing preference for mechanized agriculture in developing countries.

9.2.2 Agriculture as Producer of Energy

Though agriculture requires energy inputs both commercial and natural, its output energy is generally more than inputs. We get back energy in the form of food, fibre, fodder and crop residues. There are other benefits as well, e.g., we get oxygen from plants during photosynthesis. The stored energy in food (cereals, pulses, fruits, vegetables, milk, eggs, fish, flowers, sugar etc.) is many times more than that used as energy inputs.

There are many crops, which can be exploited for bio fuels – like ethanol or diesel. Such crops are also called **energy crops**. Jatropha and Karanj seeds can be used for extracting bio-diesel, which can be blended with petroleum diesel. The time is not far when we will have to depend upon these type of energy sources. Our governments should promote these schemes of bio-fuels by giving several incentives to farmers to grow such crops in wastelands.

You can get a quantitative idea of energy produced by various sources from Table 9.3.

Essentially, in the plants and trees around us, we have an energy producing biochemical factory that can help us meet our energy needs and leave a surplus too. We discuss this aspect in detail in Sec. 9.3.3 on biomass.

So far we have given you a brief overview of the energy scenario in agriculture. The challenge is to meet the energy needs through environment-friendly methods and improve the efficiency of energy use. Agriculture itself is a source of biomass, which can be used to provide energy.

Table 9.3: Energy of various outputs

Output	Energy (MJ) per kg	Output	Energy (MJ) per kg
Cereals (dry)	14.7	**Fruits**	
Pulses	14.7	High value Grapes, Tamarind	11.8
Oilseeds	25.0	Low value Guava, Mango, Apple, Peach	1.9
Sugarcane (cleaned)	5.3	Fibre crops: Cotton, Jute	11.8
Vegetables		Fodder crops: Berseem, Oats, Maize, Millet	18.0
High food value-Potato, Tapioca	5.6	Cotton seed	25.0
Medium food value-Colocasia	3.6	Milk (Buffalo)	4.9
Low food value-Carrot, Radish, Onion	1.6	Milk (Cow, Goat)	2.8
Fruit or seed vegetables; Beans, Ladyfinger	1.9	Eggs	7.5
Gourd family Cucumber, Papaya, Tomato	0.8	Meat Poultry	4.5
Leafy vegetables: Cabbage, Spinach, Mustard leaves	1.2	Meat Mutton	4.9

The next issue we take up is: What are the resources that can provide us energy without adversely impacting the environment? This is where the renewable energy resources have an important role to play.

9.3 RENEWABLE ENERGY RESOURCES

We begin with the question: What is the difference between **renewable** and **non-renewable resources** of energy?

You know that most of the energy we use today is being obtained from coal and petroleum. We also have nuclear power plants. But these energy sources are limited as only finite quantities of coal, petroleum and gas exist underground or in oceans. The present reserves of coal and petroleum, if consumed at the current rate, may be exhausted after a certain period.

Nature would take thousands of years to produce them. Thus, as far as human life times are concerned, once exhausted, they will not be available for use. This is why these are called **non- renewable sources of energy.**

On the other hand, there are some sources of energy, which can be used repeatedly without exhausting them, such as, energy from the sun, energy from a water- fall, wind energy, tidal energy. Biomass energy and energy from plants can be obtained by growing plants. Hence, we call such resources of energy as **renewable resources,** i.e.; those that are continuously restored by nature. The challenge today is how to tap these energy resources efficiently and economically.

Renewable energy and farming are a winning combination. Solar, wind and biomass energy can be harvested forever, providing farmers with a long-term source of energy and income. Renewable energy can be used on the farm to replace other fuels. It can also be sold as a "cash crop".

We now discuss each of these sources.

9.3.1 Solar Energy

Sun is a unique source of energy. It also indirectly controls other sources of energy like wind, tidal, hydro-energy, biomass energy etc. The sun radiates continuously and the earth receives 4.4×10^{15} kWh of solar energy every day. This means that solar energy falling on the earth per day is sufficient to meet the energy needs of the world for 15 years. In comparison, the total energy available in the form of coal, petroleum and other reserves is equivalent to just 27 days of solar energy.

Today, solar energy is accepted world wide as the energy of future society. It is said that by 2020, solar electricity will be cheaper than conventional electricity. Developed countries are planning to produce 20% of their energy through renewable sources by 2020, because the existing oil reserves will last only for 50 more years. It is also projected that the cost of production of conventional electricity will increase further while the cost of producing solar electricity will decrease.

Unfortunately, as of now, we are not able to tap even a small fraction of this vast energy. Scientists and technologists are working hard to develop various appliances and conversion devices to utilize this vast and freely available energy. Many devices and appliances like solar cookers, solar geysers, solar stills, solar photovoltaic cells etc. are in use, but all of them put together still utilize a very small fraction of solar energy.

The major advantage of solar energy is that it is clean and unlimited. Capturing the sun's energy for lighting, heating, providing hot water and electricity can be a convenient way to save money. On the farm, solar energy can be efficiently used for drying crops, powering a water pump or heating buildings. The use of solar energy in agriculture helps in saving money, increasing self-reliance, and reducing pollution. Green houses are quite common.

Solar energy can be basically converted through two pathways:

- Solar energy to thermal energy through *solar thermal devices.*
- Solar energy to electrical energy through *solar photovoltaic devices.*

Solar Thermal Devices

More than 3 lakh solar cookers have been sold in India. The cost of ISI approved solar cookers is in the range of Rs. 900-1100. To promote the use of solar cookers state governments are giving subsidy and soft loans. The Bureau of Indian Standards in consultation with Ministry of Non-conventional Energy Sources of India has set up national level testing centres for solar cookers.

Solar thermal devices convert solar energy into thermal energy. This is generally achieved using a black metallic surface, which acts as a heat absorber. This surface is enclosed in an airtight box, which is covered by insulating materials from all other sides except the one, which is used to receive the sunlight. The top cover is normally made of transparent glass sheet. Some of these devices are: **Solar cooker, solar water heating systems, solar dryers** and **solar still.** We briefly describe them below:

Solar Cooker: The box type solar cooker (Fig. 9.2) is capable of cooking various types of food like rice, vegetables, pulses, chicken, fish, etc. It can also be used for steaming, roasting or boiling, etc. It works as an airtight box with double glass covers. A reflector is also used over it, which boosts the incoming sunlight. The temperature rises depending upon duration and intensity of sunlight. These cookers have special vessels in which food is kept. Some cookers have space for four such vessels, in which rice, pulses, vegetable etc. can be cooked at the same time. Due to their simplicity and easy operation, these cookers have become popular even in urban areas.

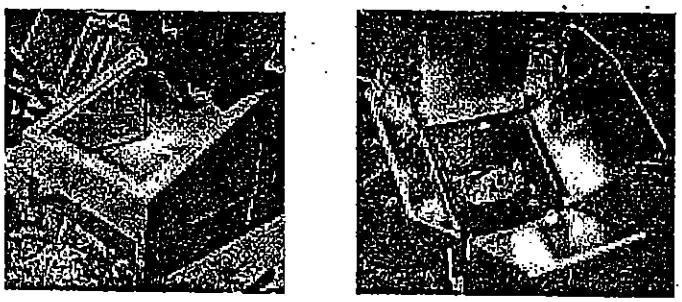


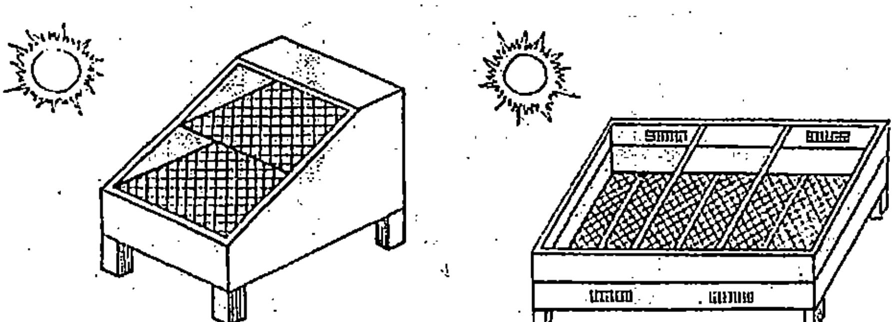
Fig.9.2: Solar cookers

Solar Water Heating Systems: Solar water heaters (Fig. 9.3) also have flat plate collectors with built-in water channels attached to the absorber sheet. With black paint or coating on flat plates and tubes, water can be heated up to 60 to 90°C. With special coating, the temperature can be raised up to 100°C. These solar water-heating systems are being used for domestic, commercial and industrial applications. For domestic heating, a temperature of 60°C is sufficient. For hospitals, hotels, milk dairies, textile mills etc, a little higher temperature is used. These water-heating systems are commercially available from 100 litres per day for domestic uses to even 20,000 litres per day capacity for huge establishments.

On a farm, solar water heaters can provide hot water (low- to medium-temperature) for cleaning of cattle pens. Dairy operations can use solar heated water to clean equipment and to warm and stimulate cows' udders. For homes or farms with electric or propane water heaters, solar collectors can save hundreds of rupees per year.

Fig.9.3: Solar water heating systems

Solar dryers: Solar dryers (Fig. 9.4) are very useful for agricultural processing and drying of produce. Various types of solar dryers are available for drying vegetables, fruits, grains, fish, etc. These are also being used in some industries. There are reports that these are very successful in the seasoning of wooden panels and timber.



Cabinet Solar Dryer *Flat Solar Dryer*

Fig.9.4: Solar dryers

The basic principle is that the plates absorb heat and then ambient air is blown over the heated surface, which gets heated, and then it passes over the material to be dried. There are some direct dryers also where the subject material gets solar heat and gets dried like surface drying. The only difference is that heat losses that occur in open surface drying are reduced.

Crop and Grain Drying: Using the sun to dry crops and grain is one of the primitive applications of solar energy. Solar drying equipment can dry crops faster and more evenly than leaving them in the field after harvest, with the added advantage of avoiding damage by birds, pests, and weather. A typical solar dryer consists of an enclosure or shed, screened drying trays or racks, and a solar collector. Natural convection or a fan moves hot air through the crops to dry them. If a farm has a crop dryer already in place, it may make sense to install a low-cost solar heater to supplement a propane or oil heater. The farmer would save on fuel costs while still being able to dry crops in cloudy weather.

The sun's heat can also be used to warm homes and livestock buildings. In confinement operations, a steady supply of fresh air is critical to maintain animal health, but this can result in substantial heating bills. "Active" solar heating systems, which use heat boxes and fans, can warm the air and save fuel. "Passive" solar designs, where the building is designed to take advantage of the sun automatically, are often the most cost-effective.

Greenhouse Heating: Commercial greenhouses often rely on the sun for lighting, but on gas or oil heaters to maintain constant temperatures. A solar greenhouse uses building materials to collect and store solar energy as heat (Fig. 9.5). Insulation retains the heat for use during the night and on cloudy days. To capture maximum sunlight, a solar greenhouse generally faces south in the northern hemisphere, while its northern side is well insulated, with few or no windows. A gas or oil heater may be used as a backup.

Fig.9.5: The sun is a reliable source of heat, light and power for greenhouses

Solar Still: A solar still (Fig. 9.6) can produce 4-6 litres of distilled water for every square meter of basin area during day sunshine of 8-10 hours. The efficiency depends on various factors like ambient temperature, quality of glazing, and temperature of basin water. Fibreglass body basin type stills are commercially available in India with an approximate cost of (Indian) Rs. 2500 per sq.m. of basin area. Concrete-based solar stills will be cheaper. It is estimated that 30-40 sq.m. of land is required for a 100 litres per day water still system.

The solar distilled water can be used for batteries, laboratories and industries. In brackish water areas it can also be used as drinking water.

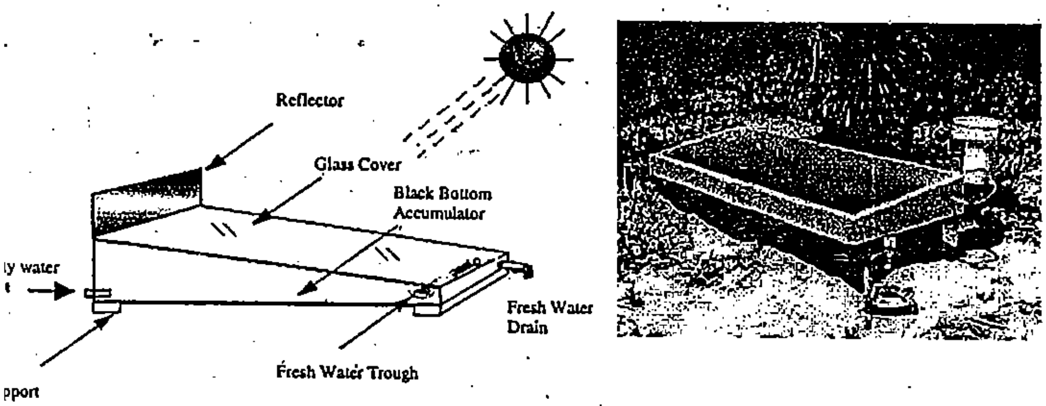


Fig.9.6: Solar Still

Solar Photovoltaic Devices

You may have heard of solar photovoltaic (SPV) technology, which uses photovoltaic cells.

Photovoltaic cells can convert solar energy into electrical energy in an environment friendly manner. You may like to know: **What is a solar photovoltaic cell?**

Solar photovoltaic cells are most commonly made from semi-conductor materials like silicon, the same material which is used for making computer chips. A solar cell is built like a sandwich, with two layers of silicon separated by a thin layer of a transparent insulating material. All the three layers work together to convert the sunlight into electricity. When sunlight falls on the upper surface of the solar cell, it produces a small electrical charge. As in a battery, negative charge is accumulated on the upper layer and positive charge on the bottom layer. If a wire is connected between the two, the charge or current flows, which can be used to power a small bulb, or charge a battery or run a calculator.

A single solar cell can provide only a small current. But if a large number of solar cells are connected together on a multi-cell panel, higher amounts of currents can be produced.

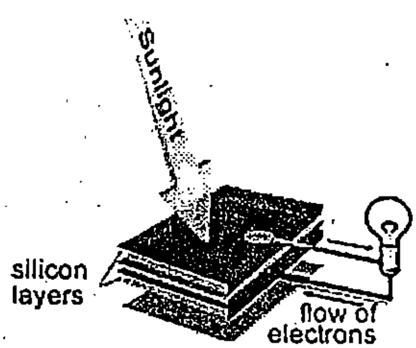


Fig.9.7: Solar photovoltaic cell

The energy converted by an SPV system can either be used instantaneously or can also be stored in batteries for use in night or in times of need.

Various types of silicon based photovoltaic cells, modules, solar panels and complete PV systems for a variety of applications have been developed in India. Some of the devices based on photovoltaic system are: *solar lantern, street lights, domestic lights, community centre light and power system, solar water pumps* and *solar power plants*. We briefly describe them below.

Fig. 9.8: Solar Lanterns

Solar lantern: We do not need light during daytime when we have ample sunlight. A PV system also converts solar energy during daytime when we do not need it. We can store that energy in a battery. Solar lantern (Fig. 9.8) is the smallest gadget, which converts solar energy during daytime into electrical energy and stores it in a battery. In other words, it charges the battery during daytime. The battery in turn gives electrical power to a small low voltage lamp during night. These days CFLs (Compact Fluorescent Lamps) are available which consume less energy and provide more light. But as compared to a simple bulb, a CFL will require an inverter circuit and ballast (Choke).

Streetlights: Solar photovoltaic-based street light system (Fig. 9.9) is very useful in remote areas. It also saves on cabling .A PV system for streetlights does not require cables from one pole to another. Each pole is equipped with a PV panel, a battery, an inverter, a ballast circuit and a tube-light or CFL. For automatic operation that does not require human intervention, a timer can be included in the circuit, which will switch on or switch off the lights at preset timings.

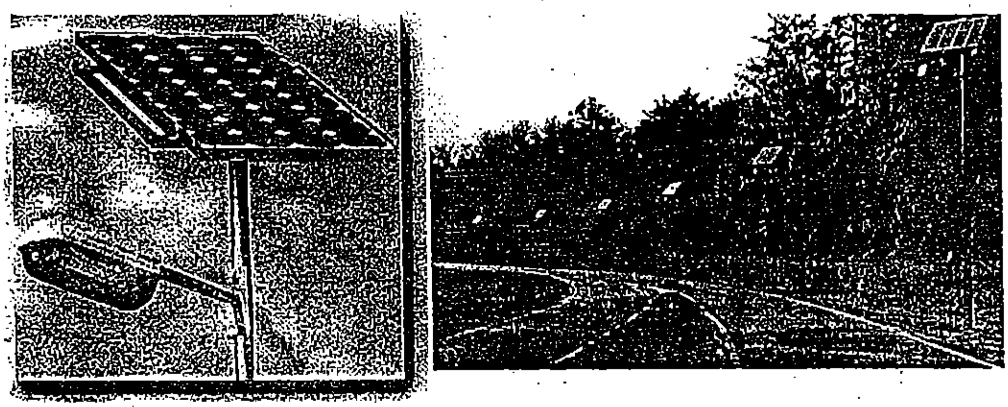


Fig.9.9: Solar street lighting system

Domestic lights: The basic principle is the same as for streetlights. The PV system is placed on the roof of the house. In some typical houses the roofs are made slanting facing towards sun and PV systems are fitted on these roofs. The electrical wires are connected from the PV system to the battery, which is kept in the house. Various circuits are distributed from this battery and an inverter which supplies electrical power during night or in need.

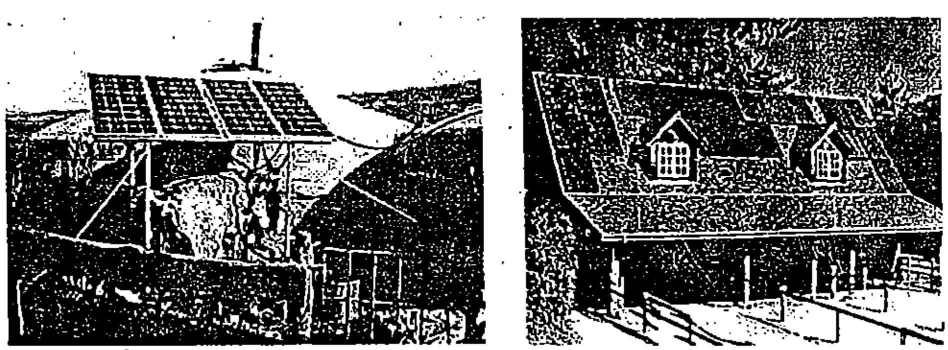


Fig.9.10: Domestic solar lighting

One of the simplest ways to use solar energy is to design or renovate buildings and barns to use natural daylight, instead of electric lights. Dairy operations using "long

ay" lighting to increase production can save money with skylights and other sun-
ghting options.

ommunity centre light and power system: In remote villages where electrical
ower lines are not installed or difficult to install, a PV system can provide light and
ower to run small electrical gadgets like TV or radio. The medium power solar
hotovoltaic system (300-1000 W) with battery and inverter circuits provide
ectricity at 220 Volts AC. Villagers can save money on the cost of community based
V/ radio and other common devices.

olar water pumps: Water lifting pumps can also be operated using solar power
Fig. 9.11). Since these can be operated during daytime, DC motors of matching
apacity can be used directly. The photocell current is directly consumed by the motor
ithout any intermediate converter. However, when AC motors are used, an inverter
s necessary. Small capacity 360 W PV pump sets are available. These pumps can
ump 20-30 m^3 of water on a sunny day from a depth of 4-5 metres.

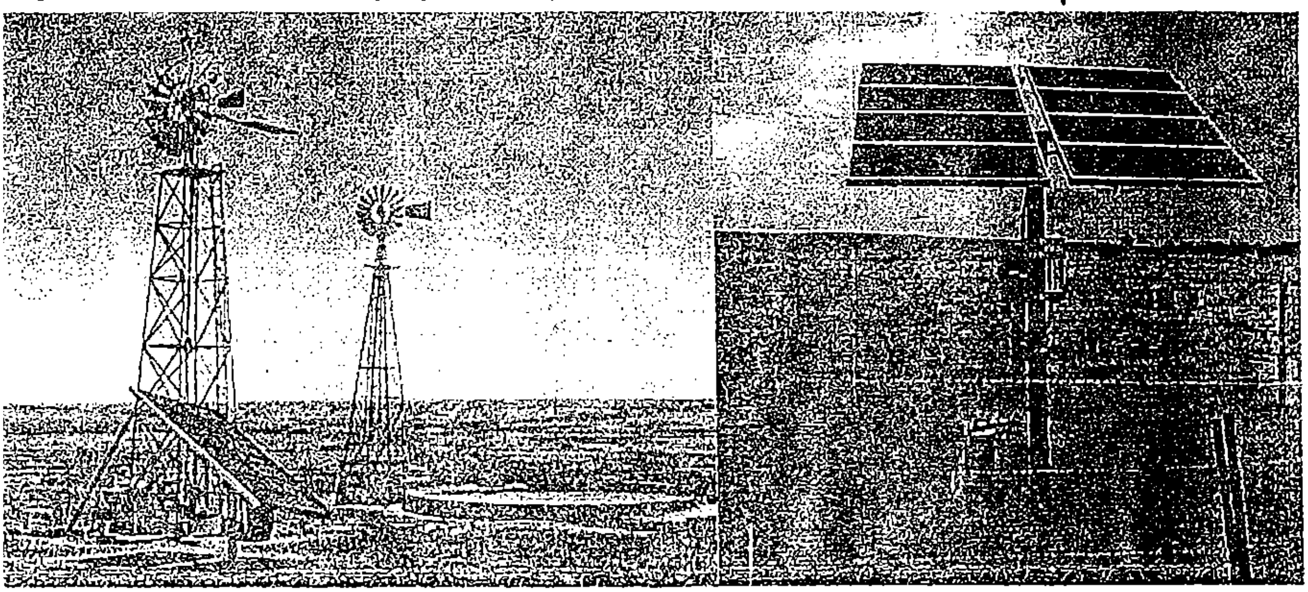


Fig.9.11: Solar water pumps

For higher head pumping, positive displacement pumps can be used, but simple PV panels cannot be used for running them. A small battery is also required to run these pumps.

As the photovoltaic system produces DC power, the use of DC motors is preferred for solar water pumps.

PV based power plants: Village based 2-10 KW capacity power plants (Fig.9.12) based on photovoltaic panels / array of panels are commercially available.

In addition to the main panels, it requires a battery bank housed in a small shed, power-controlling unit, and power distribution lines. The load may be used for lighting, running TV and other low power gadgets. The time may not be far when such power plants will become a common thing (portable generators) in remote /rural areas of South Asian countries.

In spite of the high capital cost, photovoltaic (PV) panels are often a cheaper option than new electric lines for providing power to remote locations. And, because they require no fuel and have no moving parts, they are more convenient to operate and maintain than diesel or gasoline generators. In some areas, the distance from a power source at which PV becomes more economical than new transformers and electric line is surprisingly short – often as little as 50 feet. With the increasing cost of fossil fuel-based electricity and transmission lines and the declining costs of solar-based power plants, the acceptable option will be to go for solar-based power.

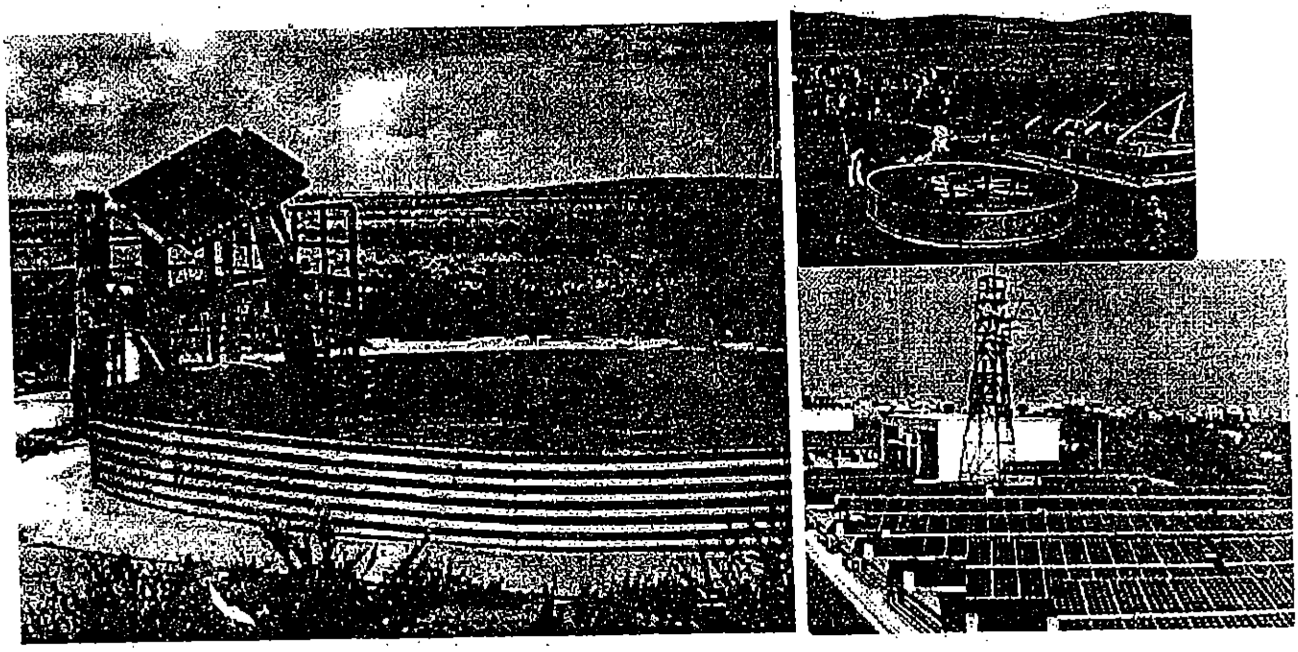


Fig.9.12: Solar powered plants

PV systems are a highly reliable and low maintenance option for electric fences, lights and water pumps. Although current prices for solar panels make them too expensive for most crop irrigation systems, photovoltaic panels are economical for remote livestock water supply, pond aeration, and small irrigation systems. In addition, the cost of PV is projected to decline significantly over time, which will make more applications cost effective.

You may like to stop now and consolidate this information about solar energy.

SAQ 2

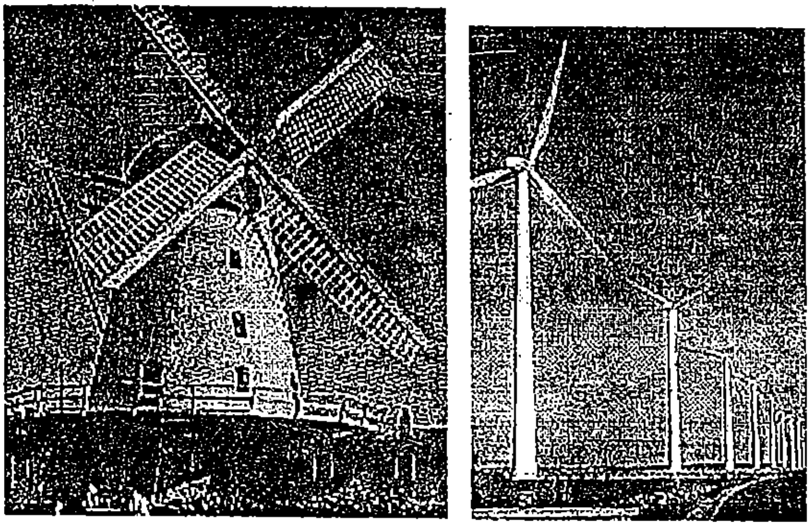
a) What do you understand by solar thermal devices? Which of these are appropriate for agricultural operations, and why?
b) In what ways can the SPV devices be used to meet the energy needs of remote and rural areas?

9.3.2 Wind Energy

Energy from wind is free like solar energy. It is also free from pollution of burning fuels. What is more, it is an inexhaustible source of energy. You may know that it was used for sailing of ships in earlier times. The issues involved in the efficient harnessing of wind energy today are:

- Locating a suitable site where sufficient wind velocity is available for most of the time;
- Selection of the most efficient wind mill for that wind velocity and utilization of the wind power directly, and
- Storage of peak time energy to be utilized as and when needed.

You may have come across pictures of windmills used to produce energy from wind (Fig. 9.13). Windmills are ideal for open locations having minimum ground resistance to wind flow. Windmill power can be directly used for water pumping, grain grinding, fodder chopping etc. It can be converted into electricity using a common automobile alternator. The electricity produced can either be used at the same time or can be stored in batteries.



(a) (b)

Fig.9.13: a) An ancient windmill; b) windmills used nowadays

Wind speed is a very important factor in harnessing of wind energy. Wind generated power accounts for 4500 MW of installed capacity worldwide. It is also increasingly being used in the developing countries. For example, India has about 1100 MW installed capacity for wind energy generation.

Windmill – Power Plants

Wind farms, which constitute a cluster of grid-connected wind electric generators of 250 kW – 500 kW each, have been found to be a quite feasible method of power generation. The wind power generators should be installed at those locations where the average annual wind speed is at least 18 km/h. This amounts to annual energy content of 2000 kWh/sq.m. Wind farms require large open areas (8-10 ha/MW) making the availability of land in windy areas extremely important. However, only 5-10 per cent of land is used for installation of mills and other equipment. The remaining area can be used for crop growing, cattle grazing, etc.

Cost of production

The average capital cost of a wind farm works out to be between (Indian) Rs. 3.5 to 4.0 crores per MW, which is fairly comparable to the capital cost of a conventional power plant. In a conventional plant, we require some fuel like coal, petroleum whereas in wind power the wind is freely obtained from the nature. Also there is zero pollution and zero carbon emission in a wind power plant.

SAQ 3

a) What are the advantages and limitations of using wind energy?
b) In what ways can wind energy be used to meet the energy needs of agriculture?

9.3.3 Bio-Energy

Energy from biomass is broadly termed as bio-energy. Bio-energy is renewable and produced from biological sources. The food we eat has bio-energy; the milk we drink is bio-energy. Besides the main food crops, there are energy plantation crops, which are used for extracting energy in the form of solid and liquid fuels. Ethanol, a partial

Biomass is a term used for the total quantity of living organisms in a given area, e.g., crops, crop residues, animal residues, forests, etc. It is expressed in terms of living or dry weight per unit area.

substitute of petrol is being extracted from crops like sweet sorghum and cassava. Today we are talking of bio-diesel to be produced from crops like jatropha.

Large-scale production of bio-energy would initially require the use of agricultural and forest residues, and eventually dedicated energy crop plantations. The cost-effectiveness in any particular investment situation is likely to depend on site-specific opportunities. The long-term effects of bio-energy exploitation, through dedicated plantations, on soil quality, fertility and biodiversity may be adverse.

Therefore, a balance needs to be struck between the advantages and disadvantages of bio-energy, and this is reflected in both optimistic and pessimistic views regarding the uncertainties about how bio-energy systems can provide cost-effective local and global benefits. These uncertainties have restricted the development and commercialisation of modern biomass technologies.

Among the important bio-energy sources are:

Fuel wood, organic residues, dung cakes: For direct burning through improved ovens (*chulhas*).

Biogas plants: For generation of biogas- a clean fuel gas and manure from organic residues like animal waste, domestic waste, crop residues etc.

Biomass-based gasifier systems: For production of thermal and electric power.

Biomass-based fuels: For producing bio-ethanol and bio-diesel.

We now discuss some of these sources.

Biogas Plants

A typical family biogas plant requires cattle dung from about 4-5 adult cows or buffalos (about 50 Kg of wet dung). The fresh dung contains about 18% solids and almost the same volume of water is mixed with fresh dung. Slurry so formed is fed into a digester normally underground. The slurry in the digester undergoes anaerobic fermentation in the presence of methanogenic bacteria, which are present in the cattle excreta. Sometimes used digested slurry is mixed initially to boost the fermentation process. The digester, which is 12-15 feet deep below the ground, gets filled up with the daily feed in about 50-60 days depending upon the temperature. For higher temperatures lower retention time is recommended and vice-versa.

The gas produced in the digester bubbles out and is collected in a floating gasholder. When the gas is produced the holder moves up. The gasholder has outlet connections for gas through valves. When the gas is consumed the holder moves down. The upward and downward movement of gasholder also serves as stirrer for the slurry. The gas pipelines from gasholder to the kitchen are laid down in such a way that the moisture in the biogas is condensed and collected in a trap, which can be cleared from time to time.

The utility of biogas has led to its application to other feed- stocks. Today we have dedicated bio-methanation plants for distillery effluents, industrial wastes rich in organic matter, urban solid waste, fruits and vegetable wastes, kitchen wastes etc. These plants not only produce biogas but also give bio-digested slurry or sludge, which is a substitute of fertilizer.

The clean gas can be used for cooking and lighting. Moreover, the digested slurry coming from biogas plants is very good quality manure. Today biogas is being produced from not only cow dung, but also other wastes like municipal solid waste, distillery waste, crop residues etc. The product, biogas, mainly constitutes methane (60-65%) and carbon dioxide (30-35%). After digestion the remaining slurry can be used as organic manure. The biogas is a clean fuel and gives blue flame if properly burnt with air (oxygen).

Biogas plants in India: A Case Study

In 1939, scientists of Indian Agricultural Research Institute showed that biogas (methane) could be produced from cattle dung using a simple digester and gasholder. It was called the Gobar Gas Plant. In 1951-53, Khadi Village Industries Commission (KVIC) developed its own model (KVIC Model) which was slightly different from IARI model. During the last 40 years about 30 designs of biogas plants have been developed in India to suit the specific requirements of feedstock, water availability, cost reduction and climatic conditions. A major breakthrough took place during the Janata Government's regime in 1977 when a drum-less biogas plant was introduced. It was further improved by various agencies involved in the biogas work. A Deenbandhu model was introduced by AFPRO, which became very popular and cost effective.

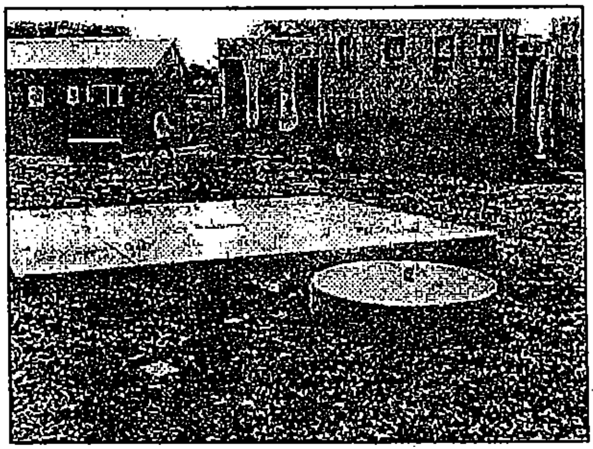


Fig.9.14: A biogas plant

Gasification of biomass – Gasifiers

The gasification technology, which involves a series of interlinked thermo-chemical processes like drying, pyrolysis, oxidation and reduction etc., offers a good scope for use in stationary and mobile operations. The basic advantage of a gasifier is its simplicity in construction and operation. The producer gas produced by a gasifier can operate normal diesel engines after some modification in compression ratio, fuel injection time etc. Up to 70% of diesel can be substituted without any loss of power and efficiency. The gasification technology is full of potential for energizing water pumping sets, rural electrification, thermal applications etc.

Fig.9.15: A gasifier.

Gasifier-based power generation systems have been in successful operation in the range of 5 KW to 100 KW at various places in India.

So far we have discussed applications of renewable energy resources in agriculture and other sectors of the economy. A natural question that may have occurred to you is: **Why have we not adopted these technologies, especially in rural areas?** This is where we need to examine the socio-economic dimensions of the energy problem. However, before we move on, we would like you to attempt an exercise.

SAQ 4

a) List various ways in which bio-energy can be produced from biomass.
b) How can biomass energy be used to meet the energy needs in rural areas?

9.4 SOCIO-ECONOMIC ASPECTS OF ENERGY IN RURAL AREAS

We now discuss some of the major socio-economic aspects of the energy question in the rural context.

Energy has a key role in economic and social development

Without appropriate energy services there can be no true economic development, yet around 2 billion people world-wide do not have access to modern forms of energy. Aid in support of national efforts includes a variety of rural energy programmes to improve energy provision, often through rural electrification. Increased access to energy services can help reduce poverty, but much of the effort thus far has focussed primarily on household energy use, with less attention being paid to energy services for rural industries and agriculture.

Energy has a major impact on the global and local environment

The needs of sustainable development and the use of clean energy technologies are well recognised. Actions at national and international levels to tackle the problems of air quality and climate change are being developed, and these will require new directions for both energy policy and technology and the nature of investment decisions in energy supply and end-use systems.

Insufficient modern energy is available for agriculture and this affects food security

In agriculture, a wide range of modern and traditional energy forms are used directly on the farm, e.g., as tractor or machinery fuel, and in water pumping, irrigation and crop drying, and indirectly for fertilizers and pesticides. Other energy inputs are required for post harvest processing in food production, packaging, storage, transport and cooking. Direct energy use in agriculture accounts for only a relatively small proportion of total final energy demand in national energy accounts. In developing countries it is between 4-8%.

Energy for agricultural practices in many developing countries continues to be based to a large extent on human and animal energy, and on traditional wood-fuels. Empirical evidence suggests that the potential gains in agricultural productivity through the deployment of modern energy services are not being fully realized in developing countries. This reduces both the quantity of food and quality of food produced. Rural people are sometimes forced to eat either uncooked food or food that can easily be cooked but which may not give full nourishment.

Lack of rural energy development programmes

Many energy policies and interventions in developing countries are designed for the needs of industry, transport and urban infrastructures, whilst agricultural energy requirements are frequently overlooked. Although agriculture contributes significantly to economic and social development, often accounting for around 30% of developing country GDP, energy provision in agriculture has not received the attention that the sector deserves. Energy for agriculture needs to have a higher priority in rural policy and technology assessment work in developing countries than has been the case hitherto.

An energy transition is needed in rural areas

Given the spread of technology and general economic development, it can be expected that traditional energy technologies will co-exist, with a gradual improvement and ıtroduction of new technologies accompanying the rural development process. There ; also the prospect of technological 'leapfrogging', which could give developing ountries the chance to commercialise new technologies relatively quickly. But there ; a need for more urgent action, due to the low rate of economic improvement in ıany rural areas and the drift of rural populations to peri-urban and urban areas in eveloping countries. Agriculture can have a major role in supporting sustainable ıral livelihoods through the increased provision of locally sourced bio-energy. Such n approach can assist more broadly in rural development as well as improving food ecurity.

ı challenge and an opportunity

ın integrated approach, which exploits the synergies and dual role of agriculture as an nergy user and an energy supplier, needs to be developed. The links that energy and griculture can make between sustainable rural livelihoods, local environmental rotection and global environmental benefits are important issues to address. In order ɔ mobilize the synergies and develop the energy function of agriculture:

- the role of agriculture in providing both a source of renewable energy which contributes to rural economic development, and a substitute for fossil-fuels should be recognised and exploited in future energy policy formation and technology development;

- The potential of bio-energy and renewable energy sources should be recognised in general to assist both in the provision of energy services in the rural areas of developing countries and in the transition to more sustainable energy systems world-wide.

The solution to the problem of availability of energy depends not only on generating nore energy but also conserving and managing energy. What measures can we adopt or energy conservation and better management of energy? This is the issue we are ıow going to discuss.

).5 ENERGY CONSERVATION AND MANAGEMENT

There is a saying "Energy saved is energy produced." Similarly, we can say, "Energy conserved is energy produced." The difference between the two statements is that when we say energy saved we mean we do not use energy when it is not required. For example, if nobody is in a room, lights and fans can be switched off.

However, energy conservation more strictly means we use energy efficiently and save energy using efficient devices, which do the same amount of work for less input of energy. We give below some examples of energy conservation in the context of agriculture in India.

Gur or khandsari production

Much of the sugarcane produced in India is processed into *gur* or *khandsari*, i.e., (*unrefined* sugar) in small-scale enterprises.

Improved crushing machines and fuel-efficient furnaces can save a substantial amount of energy. The use of a screw expeller and a fuel-efficient furnace in a *khandsari* mill has reduced the average cost of production per ton of sugar to the extent of about 20%.

Agro-based industries

Co-generation of electricity and process heat from some fuels has been used in many industries (dairy based industries). The heat produced from the engine or turbine is used in the various processes where heat is required. More than 50% of fuel energy can be recovered in the form of heat from cooling water and exhaust gases.

Energy conservation through improved stoves

The energy used for cooking accounts for over 70% of the total energy consumption in the agriculture sector of India. Biomass fuels like wood, crop residues and dry animal dung cakes have been traditionally used for cooking and heating in winter months.

Improved *chulhas*(stoves) are one of the most important energy conservation technologies from India that can be used in the entire SAARC region. The improved *chulha* technology is the latest version of smokeless *chulhas* which besides being smokeless accounts for higher thermal efficiency. The Ministry of Non-Conventional Energy Sources (MNES) of India has developed about 40 models of improved *chulhas* for different feedstocks and applications. These include fixed as well as portable models.

Energy conservation in irrigation pumping systems

The increased number of tube wells and pumping sets is a direct indicator of increased use of energy in this system. When the majority of these pumping sets were installed, due importance was not given to proper selection, installation and operation. As a result of which they are not operating at the desired level of efficiency and causing a huge waste of energy.

If we take the example of Punjab in India, which is cent per cent irrigated today, the average annual consumption of electrical energy per pump set is 5000 kWh (units). The average number of pump sets is around 6 lakhs, consuming about 3000 million kWh. Even if the overall efficiency is increased by 15%, we can save 450 million units of electricity.

There are many other areas in agriculture sector, which consume some energy. Efforts are to be made them efficient so that energy can be saved. Any amount of energy saved is energy conserved.

In this unit, we have acquainted you with various aspects of the issue of energy, with particular reference to agriculture. We now summarise the contents of the unit.

9.6 SUMMARY

- Technically speaking, energy is the capacity to do work. The unit of electrical energy commonly used is kWh.
- Agriculture is both a producer and consumer of energy. The entire range of agricultural operations from preparing the land to sowing and harvesting produce as well as post harvest processing and transport require energy.
- Traditionally, in South Asian countries, human beings and animals have been the main source of energy.
- The conventional sources of energy such as coal, petroleum are finite and likely to end in the near future. Moreover, these also cause pollution. Therefore, there have

been efforts to tap renewable sources of energy, such as solar energy, wind energy and biomass.

Solar thermal devices convert solar energy into heat and solar photovoltaic devices convert solar energy into electrical energy. Most commonly used solar energy devices in agriculture are solar water heaters, solar dryers, greenhouses, SPV panels and solar water pumps.

Windmills can be used for grinding grain, pumping water and chopping fodder as well as for generating electricity.

Biomass energy is easily available in rural areas. Biomass can be converted into usable energy through biogas plants and gasifiers. Bio-fuels are nowadays being used in conjunction with petrol and diesel.

Energy has a key role in socio-economic development. Insufficient energy supply to agriculture affects food production and food security. Fulfilling rural energy needs is a challenge today.

Along with generation of energy, energy conservation and management is needed to improve efficiency of energy use in agriculture.

.7 TERMINAL QUESTIONS

Prepare a report on the energy scenario in agriculture in your region covering the following aspects:

- Energy requirements,
- Sources of energy being used,
- Feasibility of using renewable energy resources.

Why should we encourage the use of renewable energy resources? What are the challenges faced in using these resources in South Asian countries?

Develop a plan for the efficient use of energy in agriculture in your region for energy conservation and management.

UNIT 10 OFF-FARM INPUTS

Structure

10.1 INTRODUCTION

For successful farming, various inputs are required to be applied in the soil and the crops. Small and marginal farmers usually use the on-farm produce and wastes as inputs but for successful commercial farming, major inputs are brought from outside the farm and are called **off-farm inputs.** These inputs are usually energy intensive and produced mainly in the urban region.

The major off-farm inputs are **fertilizers, pesticides, oils,** and **farm machinery.** In the last unit of this block, we discuss the issues and challenges pertaining to the use of these off-farm inputs.

In this block you have developed an understanding of the major environmental concerns pertaining to the use of natural resources in agriculture. In the next block, we discuss ways of meeting the challenges and devising strategies for eco-friendly agriculture.

Objectives

After studying this unit, you should be able to:

- describe different types of fertilizers and their functions in the soil and crops;
- analyse the environmental impact of fertilizer use;
- describe different types of pesticides, and the hazards involved in application of pesticides; and
- discuss the functions and environmental impact of different types of agricultural machineries.

10.2 FERTILIZERS AND CHEMICALS

We are faced today with the challenge of increasing agricultural productivity as land is limited and the population is increasing steadily. An intensive use of land and judicious use of irrigation, fertilizers, high-yielding seeds, pesticides and better agronomic practices seems to be one of the ways out. For example, in India, where the average fertilizer application is as low as 92 kg/ha, one tonne of nitrogen can substitute for 20 to 25 hectares of land under unmanured wheat or paddy. An additional production of one million tonnes of N would mean creation of the equivalent of 20 million hectares of unmanured wheat land.

Thus, a balanced use of fertilizers allows for greater productivity from the same area of land. Fertilizer use substitutes labour and improves its output. For instance, the overhead labour costs on land, tillage, irrigation, weed control and seeding will not vary much whether one produces 10 quintals or 50 quintals yield per hectare. Thus, by the use of fertilizers, the same field can produce 50 quintals per hectare by using approximately the same amount of labour. This is one way of improving the productivity of man hours used in agriculture in South Asian Countries.

The rapid increase in production brought about by the high-yielding varieties could not have been possible without the use of heavy doses of fertilizers. The main superiority of the high-yielding varieties lies in higher response per unit nutrient as compared with local varieties. Moreover, the high-yielding varieties can stand heavier doses of fertilizer without lodging. Thus, more fertilizer means more production.

Fertilizers also increase the efficiency of irrigation water and in fact irrigation without fertilizers is like a resource wasted. On a most conservative estimate, it is evident that if adequate fertilizer is available for the entire irrigated area, food production can be easily trebled as compared to the present level. Thus, the easiest solution of the food problem in these countries lies in the balanced use of fertilizers.

However, the indiscriminate use of fertilisers and their negative impact on the environment has led to many misconceptions about their use.

Some wrong notions about fertilizer use

As far as the use of fertilizers is concerned, a major issue today is that it may spoil the farmer's land, which is so very precious to him and which is his heritage from generations.

What we need to remember is that the balanced and scientific use of fertilizers containing nitrogen (N), phosphorus (P) and potassium (K) will not create any problems but any long-term use of nitrogen or any other single fertilizer alone can cause imbalance of nutrients. Thus, it is very essential to make use of modern tools such as frequent soil testing and keep checking the nutrient status of soil.

Long-term experiments conducted in many parts of India as well as other countries have clearly shown that with balanced fertilization not only continuous high production is maintained but soil fertility is also improved. However, a wrong selection of fertilizers, without the knowledge of the soil test values, can create other fertility problems. For instance, in a highly acid soil or low pH, continuous use of ammonium sulphate may cause reduction of pH and thus may affect availability of many nutrients. Likewise, indiscriminate use of high doses of phosphates can reduce availability of zinc in soils which have marginal supply of the nutrient. It hardly needs to be emphasized that fertilizer application requires sound knowledge in order to derive maximum benefit.

The second misconception about fertilizers is that these can be used only for irrigated soils and their use is dangerous for unirrigated soils, particularly low rainfall areas.

As far as unirrigated areas are concerned, if the crop is sown in proper moisture, the fertilizer applied acts as an insurance against drought. The dose of fertilizer and the method of application has to be carefully selected depending primarily on the rainfall pattern and seasonally available soil moisture conditions. The foliar application of fertilizers is the surest way of making the best use of fertilizers under unirrigated conditions.

The third notion about fertilizers is that they are expensive. No doubt, fertilizers in developing countries cost much more than in many advanced countries, but the investment on fertilizers produces the best dividends. The dividends increase as the price of the produce increases.

10.2.1 Types of Plant Nutrients and their Sources

Plants require 16 essential nutrients to grow of which carbon, hydrogen and oxygen are taken from the air and soil water, while the other 13 are supplied by the soil. On the basis of the amounts in which these 13 elements are taken up by the crop plants, they are classified as follows:

Primary nutrients (N, P, and K): These nutrients are taken up by the crop plants in the largest amount and are the nutrients most commonly applied almost each crop season unless organic farming is practiced. The materials containing one or more of these three nutrients are known as fertilizers. Some fertilizers do contain some secondary and micronutrients also.

Secondary nutrients (Ca, Mg, and S): The nutrients Calcium (Ca), Magnesium (Mg) and Sulphur (S) are taken up in the next largest amounts next only to N and K, but their uptake is not as high.

Micro-nutrients: There are several micro-nutrients with different functions.

The important functions and deficiency symptoms of essential plant nutrients are given in Table 10.1.

Table 10.1: Plant nutrients, their functions and deficiency symptoms

Type of Nutrient	Functions in Plants	Deficiency Symptoms
Primary Nutrients		
Nitrogen	Synthesis of amino acids, proteins, chlorophyll, nucleic acids, coenzymes	Light-green coloured leaves, lower leaves turn yellow and die in severe deficiency
Phosphorus	Metabolic transfer processes, ATP, ADP, photosynthesis, and respiration; component of phospholipids	Purplish leaves, especially on the margins
Potassium	Involved in sugar and starch formation; lipid metabolism and nitrogen fixation; neutralize organic acids	Marginal burning of leaves, curling of leaves
Secondary nutrients		
Calcium	Component of cell walls; cell growth and cell division; cofactor for some enzymes.	Failure in the development of terminal bud, dead spots in the mid rib of some plants. In corn, tip of the new leaves may be covered with a sticky, gelatinous material that causes them to adhere to one another
Magnesium	Components of chlorophyll, hence essential for food synthesis in plants	Light green leaves and yellowing of leaves similar to N. In rapeseed the leaves are cupped inward

Micronutrients		
Zinc	Formation of auxins and chloroplasts; carbohydrate metabolism; stabilizing and structural orientation of membrane proteins	Stunted growth, pale to white colouration of young leaves white colouration of young leaves-white bud and white streaks in leaves of corn; brownish red (rusty) discolouration of leaves in rice known popularly as "Khaira" disease in rice. Corn, beans, citrus and rice are indicator plants for zinc deficiency
Manganese	Photosynthesis-evolution of oxygen, oxidation-reduction processes, decarboxylation and hydrolysis reactions	Intravenous discolouration green veins against a pale backgrounds; whitening and abscission of leaves, grey speck of oats, marsh spots of peas
Iron	Structural component of cytochromes, perrichrome, and haemoglobin and thus involved in oxidation – reduction reactions in respiration and photosynthesis	Yellowing or whitening of young leaves. In severe deficiency in rice nurseries, or direct-seeded rice or sorghum fields the entire plants may turn pale or white. Pale yellow inter-veinal chlorosis in stem
Copper	Constituent of chlorophyll, catalyst for respiration, carbohydrate, and protein metabolism	Stunted growth, terminal leaf buds die, leaf tips become white, and leaves are narrowed and twisted
Boron	Involved in germination and pollen tube growth; fruiting, cell division, nitrogen metabolism	Terminal buds die, rosette formation, flower or fruit shedding
Molybdenum	Essential component of nitrate reductase and nitrogenase, thus important in N fixation by legumes	Resembles N-deficiency symptom, 'whip tail' disease of cauliflower
Chlorine	Involved in the evolution of oxygen in photosystem II of photosynthesis, raising cell osmotic pressure	Chlorotic leaves, some leaf necrosis.

We also list the sources of primary, secondary and micronutrients (Table 10.2).

Table 10.2: Some commonly available sources of plant nutrients

Nutrient	Material	Content (%)
Nitrogen (N)	Ammonium sulphate	21
	Ammonium nitrate sulphate	30
	Ammonium chloride*	25-26
	Anhydrous ammonia	82
	Calcium ammonium nitrate (Ammonium nitrate with lime)	20.5
	Calcium cynamide	22
	Sodium nitrate	16
	Urea	45-46
	Urea sulphate	30-40

	Urea-ammonium nitrate (solution)	28-32
	Ammonium sulphate	23.7
	Ammonium phosphate sulphate	15.5
Nitrogen Phosphate (NP)	Ammoniated ordinary super phosphate	4
	Monoammonium phosphate	11
	Diammonium phosphate	18-21
	Ammonium phosphate sulphur	13-16
	Ammonium polyphosphate solution	10-11
	Urea-ammonium phosphate	21-38
	Urea-phosphate	17
	*66% Chloride	
Phosphate (P)	Ordinary super phosphate	13.9
	Concentrated super phosphate	1.5
Potassium (K)	Potassium sulphate	17.6
	Potassium magnesium sulphate	22.0
Calcium (Ca)	Agril. limestone	80-95 CaCO3
	Basic slag & delomite	20-45 CaO
	Gypsum	40 CaO
	Single superphosphate	25-30 CaO
	Rock phosphate	40-48 CaO
Magnesium (Mg)	Magnesite	40 NgO
	Magnesium sulphate (Magsulf)	16 MgO
	Devimicroshakti	2 Mg
	Multiplex	10 MgO
	Aries Chelamag	5 Mg
	Dolomite	5-20 MgO
	LCFC slag	7 MgO
Sulphur (S)	Ammonium sulphate	24
	Single super-phosphate	12
	Potassium sulphate	18
	Ammonium phosphate sulphate	15
	Gypsum or calcium sulphate	18
	Iron pyrites	22-24
	Elemental sulphur	85-100
	Magnesium sulphate	13
	All sulphate salts of micronutrients	13-19
Boron (B)	Borax (deca)	11.3
	Borax (penta)	15.0
	Boric acid	17.5
	SOLUBOR	20.5
	Boronated gypsum	1.5-3.0
Copper (Cu)	Copper sulphate	24
	Aries chelacor (Chelated)	6
	Chelekta 25 (Chelated)	12
	Devimicroshakti	5
	Multiplex	8
Iron (Fe)	Ferrous sulphate	19
	Amity clawfer	12
	Chelekta 10	12
	Devimicroshakti	5
	Chelated iron	12

langanese (Mn)	Manganese sulphate	30.5
	Aries Mn-chel	11
	Chelekta-20 (Chelated)	12
	Devimicroshakti	5
	Multiplex chelated	12
lolybdenum (Mo)	Ammonium mollybdate	54
	Devimicroshakti	5
	Multiplex nitrofix	
inc (Zn)	Zinc sulphate	21
	Zinc spray	4
	Amity clawzin (Chelated)	12
	Aries chelamia	12
	Chelekta-5	12
	Devimicroshakti (WSP)	113
	Multiplex (Chelated)	12
	Zimin-F (Chelated)	12
hlorine (Cl)	Potassium Chloride	48
	NPK Complexes	variable

.ll nitrogenous fertilizers are produced from ammonia gas. Over 90 million mega rams (Mg) of nitrogen are commercially fixed each year world wide for use as ertilizers.

ertilizer and Crops

. study conducted by FAO shows that there is a highly significant relationship etween fertilizer consumption and crop yields in different countries of the world. A rong parallelism between the fertilizer consumption and crop production has been bserved in India as well (see Table 10.3).

'able 10.3: Responses (kg grain/kg N) of different varieties of rice and wheat to nitrogen

	Dose kg N/hectare	High-yielding variety	Local best variety
Rice	40	19.22	17.90
	80	16.53	13.54
	120	12.98	9.20
	160	11.73	7.89
Wheat	20	24.10	13.30
	40	20.20	10.40
	80	12.30	4.70
	100	8.40	1.80

'ield response

\ farmer is often disappointed in the response of the crop to the fertilizer because 1ere are several factors other than soil fertility that limit production. Some of them an be removed or overcome but others have to be accepted as a part of the ncertainties associated with farming. Some important factors, which affect the rofitability of fertilizers, are:

- tillage practices,
- drainage,
- weed control,
- insect and disease control,
- variety,

- climate,
- irrigation
- soil pH,
- plant density,
- planting date,
- lodging, and
- dose, method and time of fertilizer application.

The most important factor determining the profitability is the price of the produce. The high-yielding varieties and high prices of the produce have boosted the application of fertilizers in developing countries in the last few years.

You may now like to concretise what you have studied in this section. Attempt the following SAQ.

SAQ 1

Classify fertilizers according to their nutrient content. What are the functions of N P K and what are their sources?

10.2.2 Pollution due to Fertilizers

Fertilizers, no doubt, are important in intensive agriculture. When applied to soil, they meet the nutrient needs of the crop. The fertilizer use efficiency (FUE) depends on the type of management practices adopted. However, the crop does not take up the entire quantity of applied fertilizer. Some quantity is retained by the soil, which can be washed down by erosion or drainage water into water sources or can also be lost into atmosphere in the form of gas. Upto a certain level, all fertilizers are safe but when they exceed a certain limit, they pollute the atmosphere, water sources and soil. The major nutrients that are supplied through fertilizers are nitrogen, phosphorus and potassium and we briefly describe how they pollute the environment.

Nitrogen and **phosphorus** can contribute to both surface and ground water pollution.

Nitrogen is mostly taken up by crops either in the form of ammonia or nitrate. Nitrates are taken up by most crops except paddy, which takes nitrogen in the form of ammonia. Nitrate itself is not toxic. In fact, it has its own medicinal importance in treating kidney stones. Nitrate becomes a problem only when it is converted into nitrite. Nitrates are soluble in water; hence some quantity of nitrates is lost in runoff water leading to pollution of surface water sources like lakes, ponds, tanks etc. In India, farmers have a practice of letting off water from one rice field to another field during flood irrigation. This leads to the loss of applied nitrogen. Thus, the plants do not use a significant amount of nitrogen. The lost nitrogen pollutes both surface and ground water resources.

Phosphorus losses may take place basically through soil erosion by water as it moves down into the soil. Since the soil solution is generally low in phosphorus, its downward movement is also insignificant. The loss of this nutrient by soil erosion can be controlled by different crop rotations.

Nutrient loss of **potassium** mostly occurs through soil erosion and leaching. Control measures like proper crop rotation, avoiding fallow, soil and water conservation measures easily reduce potassium losses and the pollution created by it.

Surface water pollution usually occurs during rainfall. The surface runoff carries sediment, pathogens, chemicals absorbed in sediments, dissolved chemicals (such as nutrients and pesticides), heavy metals, and easily oxidizable organics into adjacent water ways. Dissolved chemicals may also percolate through the soil to ground water, and be discharged in sub-surface flows.

Nutrient pollution of ground water involves sub-surface transport to water bearing zones. The transport and fate of nitrogen in the sub-surface is dependent upon the form in which nitrogen enters and various biological conversions, which may take place. There are two forms of nitrogen that result in ground water pollution: ammonium ions and nitrates. Ammonium ions can be introduced directly from fertilizer applications, or they can be generated within the upper layers of soil from the ammonification process, i.e., the conversion of organic nitrogen to ammoniac nitrogen.

Denitrification or the reduction of NO_3 to N_2O or N_2 is the only mechanism by which NO_3 concentration in the percolating (and oxidized) irrigation water can be decreased. It has been seen that the agricultural residues of nitrogen and phosphorus enter into the surface and ground waters from run off and leaching losses and from movement of sediments into surface waters. The total amount of the nitrogen and phosphorus that can be lost from agricultural lands depends upon a number of factors. For instance, for the cropland, these include

- application rates,
- soil properties,
- terrain,
- soil erosion,
- crop management practices, and
- amount of rainfall.

Soil sediments enter into water from all agricultural segments, and these act as a transport agent of plant nutrients, heavy metals and pesticides. Any practice that increases or reduces sediment transport affects the pollutant transport accordingly.

It is important to note that the potential environmental effects of pollutants from agriculture often cannot be assessed separately. Various other sources of pollutants lie within the common environmental receptors like streams, rivers, lakes etc. Consequently, synergistic effects occur and associated environmental implications may result. By volume, sediment is the major pollutant in surface water, and it is also the transport agent for other residues. Sediment obstructs the drainage and irrigation canals, fills the reservoirs and lakes, and creates turbidity. Therefore, it is an economic issue to clear the canals and reservoirs that have deposition of sediments.

The surface and ground waters show increased salinity from irrigation practices. However, there is no danger to human health from increased salinity in surface waters. Its control also is primarily an economic issue since it involves industrial water treatment costs. High salinity levels can result in unpleasant taste and hardness, and loss of aesthetic quality. Salt build up in ground water can reduce crop yields, and crop production can become economically infeasible in areas of toxic salt levels.

Increased levels of nitrogen compounds and phosphates in surface waters may lead to excessive algae growth which then increases the dissolved oxygen in water. The resultant stagnation in shallow water can cause increased mosquito population and their consequent threat to health, a decrease in fish populations and other aquatic life, an overall decrease in animal and human water use and taste and odours. If there is a movement of ground water containing high concentrations of nitrates into well waters, then there is a major direct threat to humans from nitrates. In this context, it is important to note that the US public health service has set 10 mg of nitrate expressed as N per litre as the upper safety limit. But many wells as well as water from some surface sources exceed these limits.

You may like to stop for a while to recapitulate what you have studied in this section.

SAQ 2

a) What is the role of sediments in surface and ground water pollution?
b) How do nitrogen residues from agriculture pollute the environment?

10.2.3 Chemicals: Diesel, Petrol and Natural Gas

Oils play an important role in agriculture as direct off-farm inputs for irrigation, running HSD pump sets, HSD engines and tractors as well as in agro-processing industries. Diesel, petrol and natural gas are used to fulfil energy requirements of various stages of production in agriculture.

Fig.10.1: Diesel, petrol and natural gas are used to run agricultural machinery

The total power (energy) available for Indian agriculture through various sources is given in the Table 10.4.

Table 10.4: Sources of energy in agriculture

Sources	Human	Animal	Oil engines Tractors	Electric engines	Total
Total H.P. (in crores)	1.40	3.78	0.93	0.26	6.37
Percentage of total	22.0	59.0	0.15	4	100

It is important to know about the fuel characteristics as all these fuels pollute air and efforts are on to find a mix of fuels or a fuel that causes minimum pollution.

Fuel quality: A good fuel contains a combination of good volatility, high antiknock value and chemical purity.

Volatility of the fuel: The vaporising of fuel at a given temperature is called ***volatility***. It is measured by means of the distillation test on the fuel. It indicates the operative characteristics of the fuel inside the engine. Petrol which shows lower initial and final boiling points compared to other fuels, vaporises at a lower temperature.

Octane number: It is the standard yardstick for measuring knock characteristics of fuels. The percentage by value of iso-octane (C_8H_{18}) in a mixture of iso-octane and normal heptane (C_7H_{16}) is called the octane number. The higher the octane number, the better is the fuel.

You have learnt in Unit 9 that these fuels are non-renewable sources of energy. It is desirable to minimise their use in agriculture and build up a renewable energy resource based farm economy.

10.3 PESTICIDES

The term pesticide literally means "killer of pests". **A pesticide is any substance used for controlling, preventing, destroying, repelling, or mitigating any pest.** Thus, many chemicals such as attractants, repellents, chemo-sterilants, hormonal agents, etc., are also designated as pesticides, although from a strictly technical viewpoint they may not be directly involved in killing the pest. Recently, terms like agrochemicals or bio-regulators have been proposed to describe pesticides. Many kinds of pesticides are in use today, though they can generally be classified into a few categories.

The agricultural sector uses around 250 pesticides of which 100 are insecticides. In India, insecticides constitute above 80% of total consumption of pesticides, though it is still very low (570 g per hectare) compared to the developed countries. For example, in USA, it is 2.3 kg/ha (4-6 times more than India) and in Japan it is 10 kg/ha (20 times more than India). Although pesticide consumption in South Asian countries is less as compared to Western countries and has not reached alarming levels, yet, the residual effects are already being seen in vegetables, fruits etc.

Pesticides though applied for pest control also harm the non-targeted groups. Their residues build up in food items and ultimately reach human beings. Many beneficial organisms living in soil like nitrogen fixing bacteria, algae, earthworms, etc. are also affected by application of pesticides. Apart from this, pesticide residues persist in soils for several years and organisms develop resistance to them. Thus, the toxic persistent organic pollutants (POPs) are of great environmental concern. As they move up the food chain, there is an increase in their concentration, i.e., they have high BCF (bio concentration factor) values.

Pesticide use is also associated with pesticide resistance, health damage and loss of biodiversity. Due to wider use of stronger pesticides, an ever-increasing number of species of insects (over 900 now against 182 in 1965), pathogens and weeds are becoming resistant to these chemicals.

10.3.1 Types of Pesticides

Pesticides may be classified in several ways, according to their

- method of entry
- functions,
- mode of action,
- target pathogens,
- chemical structures.

Some chemicals are legally classed as insecticides but these do not necessarily kill the pest.

Method of entry: Pesticides can enter into the body of the target organism through various channels, and are categorised as stomach poisons, contact poisons, and inhalation poisons or fumigants. This kind of classification has some limitations since, at present, there are many compounds which can act both as stomach and contact poisons, and others which can act in all categories;

Functions: The broad classification of pesticides according to their functions is given in Table 10.5.

Table 10.5: Pesticide grouping according to their broad functions

Pesticides	Functions
Attractants	Attract insects
Chemo-sterilants	Sterilize insects, birds or rodents and prevent reproduction
Insect growth regulators	Stimulate or retard growth of insects, interrupt normal development
Pheromones	Released by one individual and affect the physiology or behaviour of another individual of the same species (e.g., females emit it to call males for copulation).
Repellents	Repel insects, mites and ticks, or vertebrate pests such as dogs, rabbits, birds, deer; prevent damage by rendering the commodity unattractive, unpalatable or offensive.

Mode of action: Pesticides may be classified in two ways — by selectivity and by site of interaction with pests:

- ***by selectivity*** – the degree to which a pesticide discriminates between target and non-target organisms.

  selective : affects a very narrow range of species other than the target pest.

  non-selective : kills a very wide range of plants, insects, fungi etc.

- ***by site of interaction with pest***

  systemic : the pesticide is absorbed by the pest/plant and moves around within the pest/plant system to reach parts of the pest/plant remote from the point of application.

  contact : directly affect the parts of the plant, insect, to which they are applied. They cause localized damage to the plant or animal tissue on contact.

Target pathogen: The classification of the pesticides also depends on the pathogens they kill as shown in the Table 10.6:

Table 10.6: Pesticide classification as per target pathogens

Pesticide Class	Acts on
Acaricide/Miticide	Mites
Algicide	Algae
Avicide	Birds
Bactericide	Bacteria
Fungicide	Fungi
Herbicide	Weeds
Insecticide	Insects
Molluscicide	Snails and slugs
Nematicide	Nematodes
Ovicides	Eggs
Piscicide	Fish
Predicide	Predators
Rodenticide	Rodents
Silvicide	Tress and brush
Termiticide	Termites

:hemical structures: Pesticides are classified according to their chemical nature and ıave been given in Table 10.7 with a few examples.

Table 10.7: Classification of pesticides according to chemical structure

;roup	Examples
)rganochlorines	DDT group such as DDT, DDD, (TDE), methoxychlor, HCH; texaphene; cyclodienes such as aldrin, dieldrin, heptachlor, heptachlor epoxide, isodrin, endrin, chlordane, mirex
	1. Phosphates such as dichloros, monocrotophos;
	2. Phosphorothionates such as parathion, methyl parathion;
	3. Fenitrothion, diazinon, chlorpyrifos;
	4. Phosphorothiolates such as profenophos; phosphorotiolothioates such as a malathion, dimethoate, prothiophos, azinphos-methyl;
	5. Phosphonates, Phosphonothionates and phosphonothiolothionates such as trichlorfon, EPN, fonofos;
	6. Phosphoroamidates such as monitor, acephate, salithion;
Carbamates	1. Aryl carbamates such as carbaryl, propoxur, carbosulfan, aminocarb, BPMC; 2. Oxime carbamates such as aldicarb, methomyl; 3. N, N-dimethyl carbamates such as pirimicarb;
Pyrethroids	Such as allethrin, tetramethrin, cypermethrin, deltamethrin, fenvalerate, fluvalinate, etofenprox;
Nitrogenous	1.Nicotine; neonicotinoids such as imidacloprid;
Inorganics	Chlordimeform, Sodium fluoride;
GAB Aergics	Avermectins;
Respiratory inhibitors	Electron transport inhibitors such asrotenone, fenazaquin, pyridaben, phosphine; uncouplers such as dinitrophenols;
Insect growth regulators	juvenile hormone mimies (juvenoids) such as methoprene, pyriproxyfen; ecdysone regulators such as tebufenozide; benzoylphenyl ureas such as dimilin;
Chemosterilants	Alkylating agents such as apholate, thiotepa, metepa; antimetabolites such as 5-fluorouracil; antibiotics such as cycloheximide; colchicines; triphenyltin; urea, thiourea; s-triazine compounds;
Attractants	Methyl eugenol; pheromones such as grandlure;
Synergists	Piperonyl butoxide, sesamex;
Fumigants	Hydrogen cyanide, phosphine (from aluminium phosphide); methyl bromide, ethylene dibromide;
Nematicides	Methyl bromide, ethylene dibromide;

Miticides	1. Diarylcarbionols such as dicofol; 2. organic sulphur compounds such as chlorfenson; 3. phenolics such as binapacryl; 4. organotin compounds such as cyhexatin; 5. antibioticssuch as avermectins, milbemycins;
Molluscicides	Metaldehyde, clonitralid;
Avicides	4-Aminopyridine;
Rodenticides	Red squill, phosphorus, barium carbonate, zinc phosphide, anti coagulants such as warfarin;

For effective control of pests in the crop environment, the following general guidelines must be followed:

- Correct identification of pest species,
- Assessment of level of pest infestation,
- Selection of appropriate pesticide for pest species present,
- Application at correct time (Pre-emergence or post-emergence),
- Application of correct dose,
- Adequate treatment of the area,
- Consideration of weather factor (no rain forecast or no strong wind),
- Consideration of age of some pests (e.g., weeds are easier to control when they are young),
- Consideration of ground cover and soil type (organic soil and clay soil absorb pesticides)

We will now discuss the impact of pesticides on the environment. But before studying further, you may like to consolidate your understanding of pesticides.

SAQ 3

a) Define the term pests in relation to agriculture. Give examples.

b) Classify pesticides according to their

i) Mode of action, and
ii) Hosts involved.

10.3.2 Environmental Impact of Pesticides

Pesticide usage has aided in increasing agricultural productivity but has also proved detrimental to health and environment.

There are several types of potential hazards associated with the use of pesticides. People exposed to some highly toxic compounds may suffer short-term or long-term health problems. Excessive residues in the environment may contaminate water supplies and lead to lower water quality. They may contaminate our food through excessive residues on sprayed crops. Pesticides may cause injury to the non-target organisms such as bees, birds, other wildlife, and natural enemies of insects. Improperly applied pesticides may cause damage to treated surfaces, or through drift to surfaces adjacent to treated areas. Some pesticides may be phytotoxic, that is, injurious to crops and ornamental plants.

sum, pesticides result in

- The destruction of non-target organisms;
- Deposition of residues that magnify in food chains and eventually injure predatory animals at the top, including human beings; and
- Direct health effects on pesticide users.

ost pesticides adversely affect the environment including air, soil, water and a large ımber of living organisms. The major concern related to pesticide usage on natural .vironment arises from the fact that pesticides can be transferred from their original ıplication sites to other locations. There are numerous transport mechanisms that can ad to surface and ground water pollution, soil pollution and air pollution.

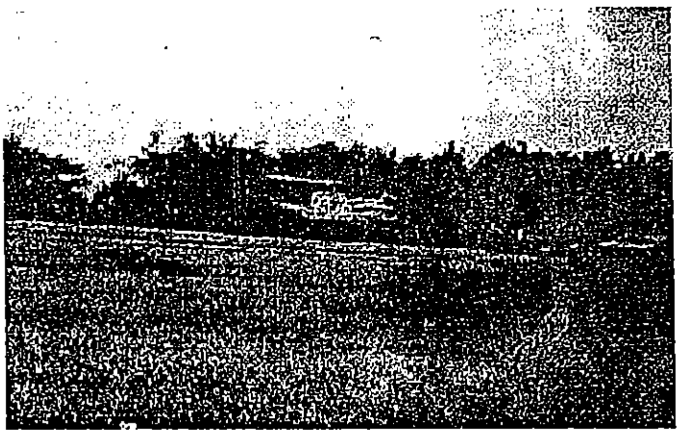


Fig.10.2: Aerial spray of pesticides

lot all the pesticide that is sprayed in a given location actually remains in that area. It estimated that as much as 55% of the applied pesticide may leave the treated area ue to spray drift, volatilization, leaching, run-off, and soil erosion. Some of this drift ıay move to adjacent areas and contaminate residences, water bodies, other crops, orest trees, and wildlife.

esticides when applied to soil may be utilized or lost by different ways. Adsorption f pesticides by soil microorganisms like nitrification bacteria, soil fungi and ctinomycetes affects the processes of nitrification, ramification, decomposition of rganic matter etc. Insecticides and fungicides affect these processes more than erbicides. The negative effects of pesticides on soil microorganisms are temporary nd after a few days or a few weeks, populations of organisms generally recover. But are should be taken to apply the pesticides only at recommended levels.

'esticides like trifluralin, PCNB, DDT, dieldrin, etc. are volatile, i.e., they vaporize nd pollute the air.

'esticides have been detected in ground water in many parts of the world. They re known to percolate with irrigation water and pollute ground water. These hemicals, even though present in minute quantities (in parts per billion) can pose a erious threat to living organisms in the long run. In ground water contamination, the ollutant percolates through a top layer of soil, and then penetrates through a protective layer (the unsaturated zone) eventually reaching groundwater either in its riginal form or as a breakdown product.

This process is usually slow and time consuming during which the pollutant may ındergo various physical, chemical and biological modifications. It is very likely that he pollutants, which are being detected in groundwater today, originated from carelessness and indifference to environmental sanitation many years ago.

Several pesticides have been detected in soil and in groundwater. It has been shown that the spread of pollutants in the area occurs by horizontal migration of the organic contaminants deep in the aquifer. Surface water pollution occurs due to runoffs from agricultural fields when it rains.

Once in aquatic systems, pesticides are either broken down to simpler, less toxic compounds, or remain in the medium. They can also move back into the atmosphere by volatilisation and condensation, in which case they recycle back to water bodies by fallout due to wind, rain, snow, and dust storms. The effects of pesticide pollution on aquatic systems depend on the chemical characteristic of the compound, its stability and persistence in water, its water solubility, its potential for uptake and bio concentration into aquatic organisms, and the physical characteristics of the ecosystem, such as size, form, and location.

Pesticides and non target groups

Non-target organisms include human beings, plants and animals in or near a treated area that are not intended to be controlled by pesticide application. Human exposure to pesticides may be accidental, work-related, due to food contamination, improper use in the home, and through contact with non-food items.

There are several ways by which pesticides can enter the body. It can be through the skin (dermal); through the mouth (oral); through the lungs (respiratory); and through the eyes (ocular). Breathing or swallowing pesticides, and spilling or splashing pesticides into the eyes or onto the skin may cause injury. Some pesticides are very toxic and can cause poisoning at low doses, while others, of low toxicity, require substantial amounts to cause injury.

In this context, we should also learn to distinguish between **toxicity** and **hazard**.

Toxicity is the innate capacity of a substance to cause injury to living organisms and is characterized in terms of acute, chronic, local, or systemic effects. **Hazard** is a function of toxicity. It involves the likelihood of injury or danger that may arise from the degree of exposure to the chemical under defined circumstances.

Therefore, hazard to human beings must be considered strictly in relation to the chemical's usage. Some highly toxic compounds may be considered safe if their usage involves little or no exposure of the applicator or the people in the vicinity. For example, highly toxic rodenticides are considered safe if used properly, because of little likelihood that people may come in contact with them.

Exposure also depends on the rate of contamination and time. Thus, actual exposure is the absolute amount of pesticide landing directly on the skin and therefore available for absorption, or present in the air and available for inhalation and ingestion in a given time. Long exposure causes more damage and the pesticide may get deposited in the body fat for a long time.

Pesticides on the skin may cause irritation, dermatitis, or more severe injury upon prolonged exposure. When absorbed through the skin they enter the blood stream and are transported to various organs in the body where they can cause internal poisoning. Pesticides that are more soluble in oil or formulated in petroleum solvents are more readily absorbed than those that are water-soluble.

Oral ingestion may occur by accidentally drinking a pesticide, by splashing spray material into the mouth, or by eating contaminated food or beverage. Smoking while using pesticide may also cause ingestion.

sticide dusts or vapours may be inhaled during mixing and loading, during aerosol raying, and during spray applications in general. Upon entering the lungs, they are ickly absorbed and transported to all parts of the body. For this reason, respirators ould always be worn while mixing and loading pesticides, and during their plication.

Fig.10.3: Proper method of spraying pesticides

rious damage can result from pesticides entering the eyes. Both the pesticides and organic solvents used to dissolve it can cause serious damage. Besides eye injury elf, the eyes provide another route of pesticide entry into other parts of the body via blood stream. Pesticide applications from aircraft are more hazardous than ground plications.

late, a number of insecticides of chlorinated hydrocarbon like DDT, Aldrin, ptachlor, dieldrin have been banned for agricultural use. However, the damage they ve already caused to the ecosystem by way of eliminating other animals is ormous. Heptachlor which was used for fire ant control, killed many raccoons, bits, and opossums. The use of heptachlor in seed dressing resulted in the death of ne 1300 foxes in England. Dieldrin caused high mortality of fox squirrels, odchucks, and shrews, and practically eliminated ground squirrels, cottontails, and iskrats from treated areas. Many badgers were also affected after feeding on ntaminated wood pigeons that had eaten treated seed. Endrin, another cyclodiene ecticide, proved to be even more toxic to large herbivores. There are no records of ld animals killed from organo phosphorus or carbamate insecticides, although some ecticides of both groups are quite toxic to wild mammals.

rm machinery is a major off-farm input that we discuss in the next section. wever, we would first like you to attempt an exercise.

.Q 4

scuss the short term and long term impact of pesticides on human health.

10.4 FARM MACHINERY

It is commonly believed that farm mechanisation through improved agricultural implements tended to decrease labour employment per hectare. However, as it helped to perform the time-bound operations in time, it made multiple cropping feasible, which, in turn, increased the labour employment. In this way, loss of labour employment due to mechanization was offset by the diversification of cropping. The negative effect of farm mechanization on labour employment could almost be neutralized.

A variety of machines are used in various agricultural operations, which we now briefly describe.

10.4.1 Agricultural Operations and Farm Implements

Various agricultural operations and the implements used for them can be classified as follows:

1. **Primary cultivation** involves working the undisturbed soil to loosen it to the required depth and/or to bury trash and to control weeds. Making major soil erosion earth works and land levelling may also be considered under this category. The major implements used for primary cultivation are **country plough, mould board plough, disc, chisel and rotary plough.**

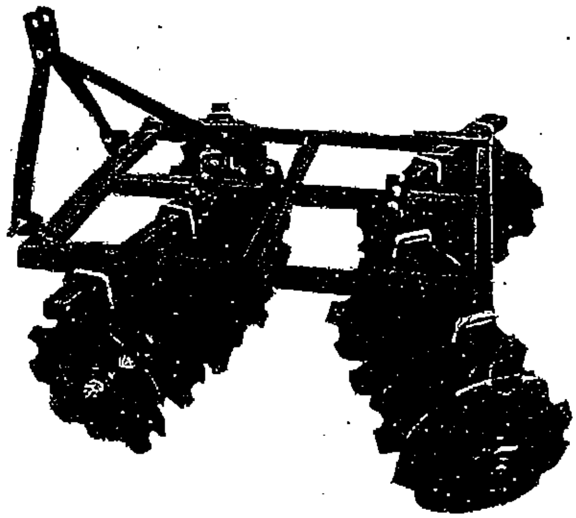
(a) (b)

Fig.10.4: Some implements used for primary cultivation: a) traditional mouldboard plough; b) rotary plough

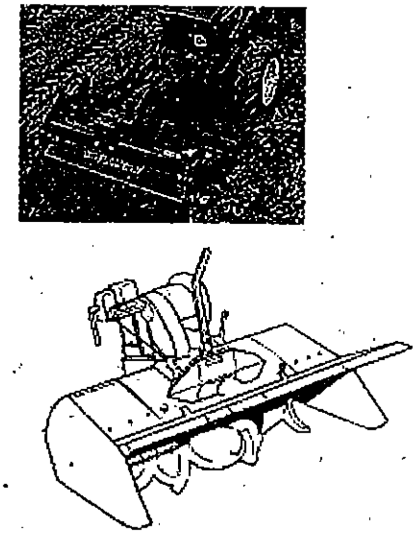
2. **Secondary cultivation** requires working of the loose ended soil into the required clod size and distribution and providing the correct degree of compaction to give good soil contact with the seed or plant with correct permeability to air and water. Machines used in secondary cultivation are **disc harrow, cultivators, light harrows, rotary cultivators** (powered, non-powered).

3. **Planting and transplanting** involve the planting of the seed and seedlings at the correct depth and spacing in the soil. **Seeders and seed drills** are used for this purpose.

4. **Crop upkeep operation** includes protection of crops from pests and providing timely nutrition. **Plant protection equipments** include the **seed treating drum** which is required for treating the seed with appropriate fungicides. The drum is mounted on a shaft and placed on a stand for convenient operation by hand. **Sprayers and dusters** (manually operated as well as electrically powered) are used for chemical control of weeds and other pests such as insect, fungus, and diseases.



(a)



(b)

Fig.10.5: a) Disc harrow; b) Rotary cultivator

Root zone granular fertilizer applicator is used for **providing the correct balance of plant nutrients in the soil.**

Weeding or **controlling of weeds** to avoid significant competition with the crop is done by **mechanical weeders.**

Fig.10.6: Weeding equipments

5. **Harvesting** refers to the collection of the required part of the crop for subsequent use e.g., grass cutting, uprooting root crops or grain crops. Harvesters are quite common on big farms.

6. **Processing** of the raw crop to convert into storable, usable or saleable item is done through **threshers** on a mechanised farm.

Fig.10.7: a) Harvesting combines; b) threshers

7. **Transport** of material to the required place has to be done at various stages in the process, e.g.,

   - Machines to the field,
   - Crop to farmstead,
   - Produce to market,
   - Production inputs, (seeds, fertilizers and insecticides) to fields.

There are many types and sizes of farm implements available, which have been designed to perform the tasks listed above more easily, quickly and cheaply than can be done manually. Many of these designs have been developed over considerable periods of time to suit particular human, soil and crop conditions.

Contribution of selected farm equipments to agriculture productivity is shown in Table 10.8.

Table 10.8: Increase in productivity due to use of selected farm equipments

Equipment Used	Increase in Productivity (%)
Seed cum fertilizer drill	10-15
Plant protection equipment	10-20
Harvesting and threshing equipment	5-10
Irrigation pumps	10-30

Apart from machines used for operations on and off the field, devices used for irrigation also fall under this category. These are given in Table 10.9 below.

Table 10.9: Water lifting devices by different powers

Human-powered devices	Animal powered devices	Wind powered devices	Water powered devices	Mechanically powered devices or pumps
A. Swing basket B. Counterpoise Lift C. Archimedean Screw D. Paddle wheel	A. Rope and bucket lift B. Self-emptying bucket lift C. Two-bucket lift D. Persian wheel E. Chain pump	A. Wind mills	A. Water wheel B. Hydraulic ram or hydram	A. Displacement pump 1. Reciprocating pump 2. Rotary pump B. Centrifugal pump C. Turbine pump 1. Deep well Turbine pump 2. Submersible pump D. Propeller pump 1. Axial flow 2. Mixed flow E. Airlift pump F. Reciprocating pump.

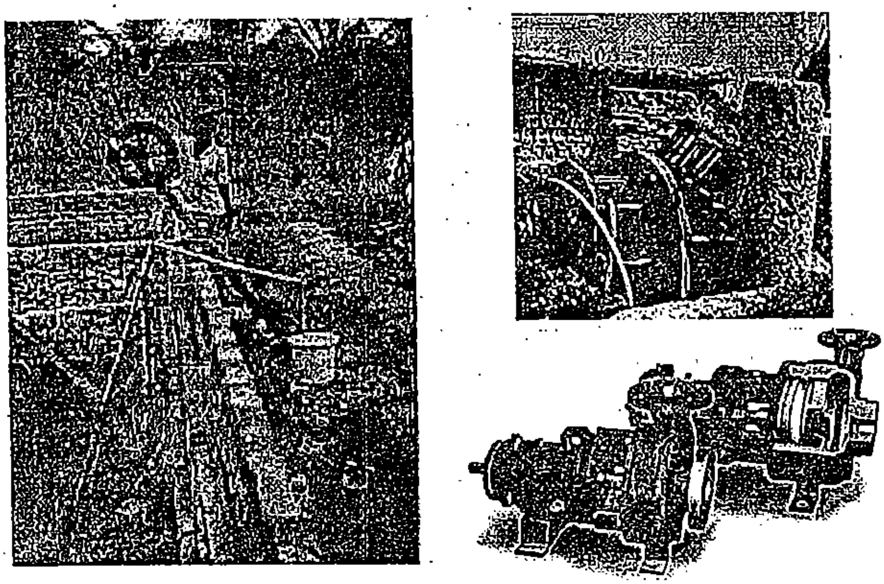


Fig.10.8: Some common water lifting devices

Design considerations

You have seen that agricultural implements, in general, are important for carrying out various operations on the land. A farmer spends two thirds to three quarters of his working time with such implements. The existing farm implements require continuous use of only a few muscles. This tires a farmer quickly. So farm implements should be designed in such a way that a farmer uses as many of his muscles as possible to diminish the load on any single muscle.

Damage to health by the use of unsuitable implements generally becomes apparent only after their sole and excessive use over long periods. The constant use of digging hoes and spades can lead to permanent abnormal curvature of the spine. Similarly, implements with very short handles causes pressure on the chest and vertebral column.

Generally implements consist of a working part and a controlling handle firmly joined together by some connective device. Efficiency of an implement depends on the material, handle, its grip, length and balance. Hence, these factors must be taken into consideration while designing and selecting any implement.

10.4.2 Farm Machinery and the Environment

Tillage machinery and tillage practices can either increase or reduce the problem of soil erosion by air. Machines that tend to pulverize the soil or to diminish the vegetative cover increase soil blowing. To be most effective in preventing soil erosion the tillage equipment should do a god job of creating a cloddy surface and at the same time avoid burying the crop residue. The equipment should create a rough, cloddy, and residue covered surface.

Deep ploughing to depths of 30 to 45 cm has become a common practice in the Western countries to improve the wind resistance of sandy soils. Following the sorting action of the wind, many field surfaces have become extremely sandy. Where they are underlain with fine textured material, immediate benefits are associated with burying the surface material that can be eroded, and bringing silt and clay to the surface. Studies on the methods of controlling wind erosion indicate that certain tools nearly meet specific wind erosion control requirements more than others. Residues, for example, are usually best handled with implements having sweep-type furrow openers. Both bullock drawn and tractor-drawn cultivators, equipped with sweep furrow openers, are suitable for this.

The next best implement is a properly angled one-way disc plough, which leaves the material in a partially standing position. The mould board plough does not meet the requirements for preserving residues on the surface. However, if residues are meagre or absent, the plough, under favourable soil surface conditions, produces a rough, cloddy, wind resistant soil surface.

Disk harrow and other vertical disk type tools are not suitable for creating cloddy surfaces and retaining residue on the surface. Their dual function is to reduce the size of clods and bury plant residues. The greatest surface roughness can be created by a lister; hence this tool is particularly suitable where residue covers are poor. Subsurface tillage implements equipped with straight or V-shaped blades or rods undercut land with the minimum disturbance of surface residues. They may maintain 8 to 90 per cent of the residue on the surface after a single operation. However, these implements do not bring many clods to the surface to prevent soil blowing.

We end this section with an exercise for you.

SAQ 5

Classify different agricultural implements according to their functions.

10.5 OFF-FARM INPUTS AND AIR QUALITY

The use of agricultural technologies affects air quality and air pollution can exert undesirable effects upon agricultural crops and animals. Air is polluted in agricultural activities due to tillage operations, pollutants from open burning, wind erosion and agricultural vehicles used in fields. Harvesting, grain handling and pesticide applications also result in air pollution.

During the tilling operation, dust particles from loosening and pulverization of the soil are introduced into the atmosphere. Open burning of crop residues as well as debris from land clearing operations, represents a potentially significant source of air pollutants from agricultural activities. Ground level open burning is affected by many variables, including wind, ambient temperature, composition and moisture content of the debris burned, as well as compactness of the pile. In general, it can be said that the relatively low temperatures associated with open burning increase the emission of particles, carbon mono-oxide, and hydrocarbons and suppresses the emissions of nitrogen oxides. Particulate emissions represent the primary type of air pollutant resulting from wind erosion. Factors influencing particulate emissions from wind erosion include soil type, precipitation patterns, exposed area and wind speed.

Vehicles used for agricultural operations include diesel-operated pumps, tractors, trucks, etc. The types of air pollutants emitted from such vehicles include carbon monoxide, hydrocarbons, and nitrogen oxides. Harvesting and grain handling can produce large quantities of particulate and hydrocarbon emissions. Further, substantial quantities of pesticides can become air-borne during and following the aerial spraying operations. The key mechanisms for pesticide introduction into the atmosphere include aerial drift and evaporation (volatilisation) from soil and soil and plant surface. Volatilisation is a major pathway of loss of pesticides from soil, and loss is greater from moist soils than from dry soils. The relative amounts of a given pesticide entering the air and surviving to some downwind site depend on the nature of the source (e.g., the type of application in agricultural operations), its physical properties and chemical reactivity, its form once it enters the air, and that which exists throughout the process. One concern pertaining to air borne pesticide residues is related to potential human health effects, particularly for agricultural workers.

Air pollution effects on crops

In order to understand the effects of air pollutants on agricultural crops, it is necessary to consider the basic structure of plant leaves and the functioning of the various components of a plant leaf. The major plant processes that occur include photosynthesis, transpiration and respiration. Several components of the leaf structure are involved in the photosynthesis process. The leaf veins are involved in moisture and nutrient transport to the leaves from the soil and root system of the plant. The effects of air pollutants on crops must be considered, in terms of environmental factors including temperature extremes, excess water, water deficiency, nutrient deficiency and bacterial or viral disorders.

High temperatures may cause chlorosis, which is reflected by yellowing of the leaves, while low temperatures may also cause chlorosis or necrosis. Excessive water can damage veins of the leaves and lead to plasmolysis, while a water deficient condition is reflected by necrosis. Nutrient deficiencies to plants can cause chlorosis or necrosis, while bacterial and viral disorders may be manifested by plasmolysis. In brief, it can be said that many factors influence the visible response of a given species of plant to a particular pollutant. Among the more important are the age and variety of the plant itself, the concentration of the pollutant, the length of exposure, the vigour of the plant and growing conditions before, during and after exposure. Thus, the environmental factors can act as potentiators for the specific air pollutants in terms of effect, or they can cause some typical symptoms, specific to the type of the pollutant.

Air pollution effect on animals

Under both acute as well as chronic conditions, air pollutants can affect the animals significantly. In terms of chronic effects, the air pollutants, which have received the utmost attention, include fluorides, arsenic and lead. Air borne fluorides have caused more worldwide damage to domestic as well as farm animals than any other air pollutants. The animals most affected by fluorides include cattle and sheep. The symptoms of fluorosis in cattle are a function of whether there is an acute exposure or a chronic exposure. In general, the acute symptoms may include lameness, stiffness, lack of appetite and thirst, diarrhoea, muscular weakness and possibly death. The chronic symptoms may include skeletal changes, lethargy, emaciation, poor health, and possibly a poor reproductive efficiency.

Fluorosis can result from drinking water with high fluoride contents, which may affect the human being as well as animals. However, it is possible that in some cases diseases and symptoms as indicated above can occur from factors other than exposure to atmospheric fluorides. Some other examples of air pollutants, which have exhibited effects on domestic animals, include ammonia, carbon monoxide, hydrogen sulphide, sulphur dioxide and nitrogen oxides. There is some evidence that ammonia can have harmful effects on poultry, carbon monoxide can affect quite a number of animals and dusts can also affect rabbits, hydrogen sulphide can affect poultry, sulfur dioxide can affect cattle and sheep and nitrogen oxides may also affect quite a number of farm animals.

We now summarize the contents of this unit.

10.6 SUMMARY

- **Fertilizers, pesticides, chemicals, machinery** and **implements** constitute various off-farm inputs. The use of these inputs has lead to a manifold increase in agricultural productivity but has also had harmful impact on the environment.

- Plant nutrients are classified as **primary, secondary** and **micro-nutrients** and a large number of chemical fertilizers are used today to supply these nutrients.
- The indiscriminate, unbalanced use of **fertilizers** particularly nitrogen has resulted in soil pollution, and surface and ground water pollution.
- **Diesel, petrol, kerosene** are chief fuels used for various agricultural operations and adversely impact the air quality.
- Pesticides can be classified in many ways, e.g., according to the **mode of action, target population, function** and **chemical structures**. The overuse and misuse of pesticides in modern agriculture has resulted in severe ecological damage of water sources, soil and air.
- **Pollution due to pesticide** affects non-target populations, viz., human beings, animals and healthy crops and is a matter of grave concern.
- **Farm machinery** used in various agricultural operations is a major off-farm input. Machine-based operations like tillage result in air and water pollution.
- Off-farm inputs such as the use of chemical energy, tillage and pesticides cause **air pollution** and adversely affect air quality.

10.7 TERMINAL QUESTIONS

1. What are off-farm inputs in agriculture, and why are they called off-farm inputs?
2. Discuss the impact of the overuse or misuse of pesticides on different non-target organisms.
3. Do agricultural implements affect the environment adversely? Justify your answer.
4. Describe the various ways in which off-farm inputs affect air quality.

SAFLI

South Asia Foundation
Learning Initiative

Towards Participatory Management

Department of Environmental Science
Allama Iqbal Open University Islamabad

D-ESD-03(31A)

PGD-ESD - 03

Uttar Pradesh
Rajarshi Tandon Open University

Agriculture and Environment

Block

3

STRATEGIES FOR ECO-FRIENDLY AGRICULTURE

BLOCK 3 STRATEGIES FOR ECO-FRIENDLY AGRICULTURE

UNIT 11 INTEGRATED RESOURCE MANAGEMENT

Structure

11.1 INTRODUCTION

You have studied so far that resource intensive agricultural strategies along with increasing area under cultivation have resulted in enhanced production, leading to surplus stocks for exports. However, the increasing productivity has been accompanied by a build up of several environmental problems like-deterioration of the quality of soil and water, loss of biodiversity, and escalating levels of air pollution. It is worrisome because these problems have shown a magnifying trend since the past few years. It is pertinent to point out here that soil/land, water, air, biodiversity and energy are the primary resources for agriculture.

Presently, on one hand the demands of growing population compel to keep the agri-production graph upwards, but on the other hand, the repercussions of the foregoing practices are turning out to be costly and unsustainable. The goal is clear, but the path is to be chosen. Collective opinions of the think-tanks in governments, agri-scientists, farmers and the sections of the society who comprehend and feel concerned with these issues, are all for adopting environmentally compatible practices and sound management of resources. The growing need for a productive and sustainable agriculture calls for a new view of agricultural development that:

- builds upon the risk-reducing, resource conserving aspect of traditional farming,
- draws on advances of modern biology and technology, and
- can combine ecological principles and practical knowledge to create self-renewing agricultural production systems.

Several options for guidance, and use are available. These include a large storehouse of new, established and traditional knowledge, the local experiences, innumerable variations in practices, and a wide array of modern technologies. Today, we need an integrated mix of options that are ecocompatible, have the potential to fulfill the social demands and are suitable for various agrogeoclimatic conditions and agri-resources. These can equip us to take on complex agriculture-environmental challenges. Since integrated management is area based and targeted for community of farmers rather than individuals, enlisting people's participation is a major challenge. This has been a real lesson learnt from the models of watershed management.

Objectives

After studying this unit, you should be able to:

- state the importance of managing agri-resources in an integrated manner;
- prepare strategy(ies) for integrated resource management for a specific area/region;
- list some ecofriendly and economically profitable ways of managing the agri-resources like soil, water, energy, nutrients, and biodiversity; and
- comprehend the importance of considering the various dimensions of a resource in order to manage it in an environmentally compatible and sustainable manner.

11.2 SOIL, WATER AND ENERGY MANAGEMENT

You have learnt in Unit 6 that soil is one of our most important natural resources. It constitutes the medium for plants to grow and provides food for plants, which in turn furnish food for humans and animals. It also serves as a storage place for most of the water that the plants use.

Soil and water – the two vital resources for agriculture are so closely interlinked in nature, that any effect or change in either of them has a bearing on the other. For this very reason they are being taken up collectively in this section.

In Units 6 and 7, you have studied about various agroenvironmental issues and challenges pertaining to land and water. This unit further builds up on the ways of addressing or managing them. Making the best use of land, tackling salt-laden soils and water, soil erosion, scarce water availability to crops, and use and management of water resources are the prominent areas in agriculture that require immediate attention. In view of the vast agro-geographic diversity across the nations and the world, there is no one way of addressing these concerns and problems. But if we consider these as challenges, and take them up with a holistic, interdisciplinary and conservation outlook, not only can effective ways of management be devised but also the environmental problems could be put on a reverse gear. Making this as the cardinal principle, let us look at some of the effective and promising ways of handling the various soil and water related management challenges.

11.2.1 Making the Best Use of Land

This implies that any area of land be used according to its capability for sustained and economic productivity. The capability of different lands for sustaining crops differ depending on land characteristics like slope, soil type, soil depth and commonly associated problems like erosion and waterlogging. In some lands the characteristics could be such that they may not be suitable for crop production. Such areas may be ideally used for nonagricultural purposes like brick-making, developing human habitation, pastures or forests. It is necessary to have a balance of different land uses as per the needs of the society. The different uses could be guided by the land capability classification: *This classification is also very useful for planning and selecting the right measures for conservation of soil and water resources.* The important physical data needed for this purpose includes soil type, depth, texture, land slope, and erosion conditions. Information about these and other properties are collected through soil surveys that are at times combined with aerial photography. There is no universal method of land capability classification, but several methods are developed in different parts of the world, suiting the local conditions. One of the earliest and widely used methods is the system developed by the United States Department of Agriculture. This system has 8 classes of which classes 1-4 are suited for agricultural purposes.

Description of Class I lands

Lands in Class I have few limitations that restrict their use. Lands in this category are very good lands, which can be cultivated safely. They are nearly level, have deep and workable soils and are subject to slight water or wind erosion. They are well drained and not subject to damaging overflows. The lands are well suited for intensive cropping.

1.2.2 Land Grading

ny land used for agriculture requires an even surface for crop production. Land ·ading refers to levelling the land to make it suitable for agricultural purposes. Not ıly that, this also helps in efficient use, and conservation of the various agri- sources in the long run.

ınd grading is often done by equipments operated with either animal power or with echanical power. This process removes humps and depressions so that water could ɔw evenly on the land surface. Low spots could cause concentration of water or aterlogging which affects the crop growth.

ınd levelling need not necessarily mean to bring the surface to perfect level. Many a ne a moderate grade or slight slope is created for surface drainage. Depending on e topography of the agricultural land, land levelling requires moving a lot of soil, metimes over large distances.

ınd grading in irrigated-agriculture helps in uniform application of water, better ater regulation and saving in irrigation time. Under rainfed conditions, land grading lps in soil and water conservation. Both in irrigated and rainfed conditions, land ading provides the much-needed surface drainage, thus proving a valuable anagement tool.

ıQ 1

Identify a set of criteria for deciding about the best use that a piece of land can be put to.

What features/characteristics of a land/soil would you consider to use it for agricultural purposes?

What are the benefits of land grading in agriculture?

.2.3 Salt-laden Soils and Water

gh concentration of certain salts when present in the soil cause soil and water anagement problems and ultimately affect the crop growth.

High concentration of soluble salts increases solute suction and thus reduce the availability of soil water to plants. Salts like sodium carbonate, and soluble borates are toxic to plants. They are also harmful indirectly, as for example, the rise in soil pH by sodium carbonate makes nutrients like phosphates, manganese, and zinc unavailable to plants. High concentration of exchangeable sodium adversely affects the soil structure that results in reduced permeability, aeration, infiltration rate, and soil workability.

ost of the salt affected soils are found in the arid and subarid regions of the world. ɔme soils have salts as original deposits. In irrigated agriculture, even though to start th the water may be of satisfactory quality, salt build-up in the root profile variably occurs over a period of time. This is because during crop growth water aporates leaving behind the salts in the root zone. High water table in some ricultural lands bring the salts to or nearer the soils surface. The groundwater too in me agricultural lands contains large amounts of salts and the use of such waters for igation, accelerates salt build-up in the soil profiles. Salt could also be brought in rough subsurface inflows of water. In irrigated areas, particularly if the irrigated ater contains considerable amount of salts, its concentration in soils should be ınually assessed and it should be ensured that the salts accumulated in the root zone e not beyond the permissible limits for the crop. The excessive salts in soil solution ın be removed by leaching and subsequent drainage. And the salts held by clay as changeable salts have to be exchanged before they could be removed by leaching.

Salts are found in two forms in the soil – one, in the soil solution in a soluble form; and two linked with the clay particles in exchangeable form.

eclamation of Salt-affected Soils

ou have learnt in Unit 6 that salt-affected soils are categorized as **saline**, **sodic** and **line-sodic**. There are specific reclamation measures for each of these categories.

- Saline soils - soils affected by neutral Na salts, mainly NaCl and $NaSO_4$ that are soluble.
- Alkali soils - also known as sodic soils, these are affected by Na salts capable of alkaline hydrolysis, including $NaHCO_3$, Na_2CO_3 and $NaSiO_3$, and these are exchangeable.
- Saline-alkali soils - contains a combination of soluble and exchangeable salts as mentioned above, are present in soils in such amounts that interfere with the growth of most plants.

Saline soils

- For saline soils with **efforescence of salts at the surface** two things are recommended.
  - Scraping of the surface salt.
  - Flushing with water to wash away the excess salts.
- Soils with high concentration of soluble salts to great depth, and with deep water table, can be treated by
  - Impounding rain water, or using irrigation water to leach out the injurious salts to a safe limit inside the soil.
  - Employing surface and subsurface drainage for flushing out excessive salts.
- Soils with high concentration of soluble salts up to great depth but with high water table can be reclaimed by
  - Lowering the water table either by pumping or subsurface drainage.
  - Subsurface drainage.

Sodic soils

Reclamation of these soils is achieved by:

- treating with alkali amendments like gypsum, sulfur, and others;
- adding organic materials like farm yard manure, crop residue, and green manuring;
- leaching out the products of reaction after amendments are added; and
- deep ploughing for breaking any hard pan for improving drainage.

Table 11.1: List of tolerant and semi tolerant plants for salt-laden soils.

Tolerant plants	Semi tolerant plants
Wheat, Barley, Oat, Sugarbeet, Datepalm, and Cotton.	Maize, Sorghum, Pearl-millet, Rice, Safflower, Sugarcane, Cotton, Onion, Potato, Mango, and Pomegranate.

Saline-sodic soils

These are comparatively easier to reclaim than the alkali soils. In certain cases these can be reclaimed by leaching alone. Sometimes amendments are needed before leaching.

After reclamation of salt-affected soils it is necessary to prevent their resalinization. This is achieved by maintaining a salt balance, drainage and controlling the depth of the water table.

Another way of driving economic benefits, as well as improving the salt-laden soils for agricultural purposes is to grow the select salt-tolerant and semi tolerant plants (See Table 11.1) in such lands.

SAQ 2

a) What are the causes of soils and water resources being impregnated with salts?

b) List the different categories of salt-laden soils. On what basis is any salt-laden soil-type assigned a particular category?

11.2.4 Soil Erosion

Though soil erosion is a natural process, but an accelerated soil erosion due to various human activities is a major management concern for our agriculture. A large proportion of our agricultural lands whether in plains, hill slopes, or along rivers, are continuously exposed to the action of atmosphere. Wind and water in motion are the two main agencies which act on the top fertile soil layers, dislodge the soil particles and transport them from one place to another. Soil from the top layers usually has more nutrients, more organic matter, and less clay and is easier to till than the layers below. So if the top layer is lost to erosion, plants do not grow as well, and consequently the crop production gets lowered. Erosion is also important for the overall environment. The eroded soil particles from fields enter streams and lakes and other water bodies and harm the aquatic life and lower the water quality. It is essential to prevent and control this problem.

- **Planning for Erosion Management**

While planning for controlling soil erosion, the factors affecting erosion and the agencies causing erosion need to be understood. The major factors that affect soil erosion are climate, soil type, vegetation, topography, and cultivation practices. In addition their impact in a particular area should also be determind before taking up or designing the remedial measures. For instance, in rain-caused erosion based on the rain parameters like erosivity, rain-drops characteristics, intensity, duration of rainfall, and amount of soil loss, suitable cropping and conservation practices can be adopted for an effective management of this problem.

- **Wind erosion control measures in plains**

Proper land use and moisture conservation practices are key to preventing and containing this problem. And if the problem has set in and persists two things are needed. ***One,*** employing **measures to reduce surface wind velocities**, which make erosion a havoc especially in the arid and semiarid areas. The salient measures include:

i) Vegetation-based measures;
ii) Tillage practices; and
iii) Structural or mechanical methods.

We shall take up these points in detail, after introducing the point number *two*, that is, all such **measures that improve the soil characteristics.**

We come back to the three measures (mentioned under *point one*) *for reducing surface wind velocities.*

i) Vegetation-based measures – These measures can be: temporary, or permanent. *Temporary measures* refer to the *crop management practices* to provide a cover to the soil. Close growing crops provide a good protection. The roots of the harvested crops hold the soil in place, while the stalks or the stubbles of the crop that are left in the field, help tremendously in reducing the impact of the wind currents on soil. *Permanent measures* consists of planting trees, shrubs and grasses for protecting the lands from wind erosion. Even the sand dunes can be stabilised by establishing grass and subsequently shrubs and trees. The vegetation – shrubs, trees, and grasses, planted in the form of belts, are technically known as *shelter belts.*

Constructing *wind-breaks* that are barriers either mechanical or vegetation-based include structures/areas like building, orchards and farmsteads, are quite helpful in controlling wind erosion. Shelter beds are longer barriers than wind breaks, and provide additional advantages. They provide fuel wood, reduce evaporation, protect orchards from hot and cold winds and make spraying of trees for insect control more effective. They may affect crop yields in the adjoining fields by their shade, root competition and also by harbouring bird population.

For their best outcome, these should be located at right angle to the direction of the wind against which they are designed to protect the area. If the prevailing

Features considered for design and construction of wind breaks or shelter beds:

- direction,
- location,
- species selection,
- shape,
- protection measures, and
- casuality replacement.

Some common plant species used for shelter beds in India.

Trees

- Babul (*Acacia arabica*)
- Neem (*Azadirachta indica*)
- Cashewnut (*Anacardium occidentale*)
- Casuarina (*Casuarina equisetifolia*)
- Eucalyptus (*Eucalyptus spp.*)

Shrubs

- Sisal (*Agave americana*)
- Railway creeper (*Ipomoea carnea*)
- Common sesban (*Sesbania aegyptiaca*)
- Spotted Gliricidia (*Gliricidia maculata*)

Grasses

- Dubgrass (*Cynodon dactylon*)
- Blue panic (*Panicum antidotale*)
- Thin napier (*Pennisetum polystachon*)

winds are from more than one direction, secondary breaks can be put at right angles to these directions. Spacing between successive belts depends upon the area protected by individual belts. For the best outcome, and for protecting the entire area, these belts be located successively. The species to be planted for shelter belts should be selected taking into consideration their adaptability to the local climate and soil conditions and needs, rate of growth, ease of establishment, economic value of the produce, and the possibility of serving the dual role of wood production and shelter bed. The overall best results are obtained when mixed plantations consisting of grasses, shrubs, and trees are raised. A typical shelter-bed should have the shape of a conical roof as viewed in cross-section (see Fig. 11.1). The tall trees in the centre be flanked by short trees, conifers, tall shrubs, and grasses with low shrubs on outside. Shelter bed plantations should be protected from cattle and wild fire. It is important to replace for any casualties.

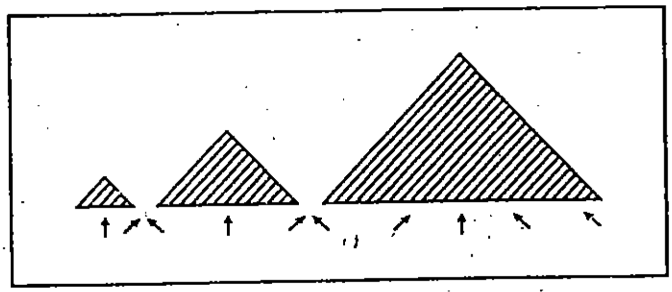


Fig.11.1: Cross section of different lengths of shelter-beds. Note the areas protected by each one of them. (Source: Murthy V.V.N., 1985)

ii) Tillage practices – Some tillage practices, help temporarily in controlling wind erosion. These include strip cropping, primary and secondary tillage, and use of crop residues. Strip cropping (Fig. 11.2) refers to the practice of growing crops in strips alternating with strips of grass in between them. The grass strips stop the flow of water and filter out sediments. Primary and secondary tillage aims to develop a rough, cloddy surface to resist wind erosion. A system of ridges and furrows, to the normal direction of prevailing winds, reduce the wind velocities and help in soil deposition. Crop residues left on the soil surface reduce wind velocities and trap eroding soil. Crop residues in combination with ridges and furrows are more effective in controlling wind erosion.

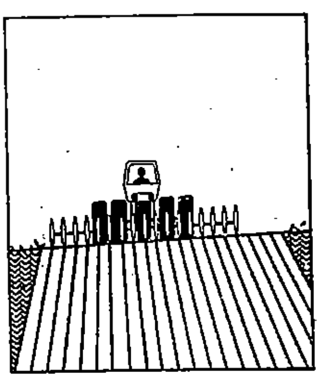


Fig.11.2: Diagrammatic representation of strip cropping

iii) Structural or mechanical methods – Barriers like fences, walls and stone packings also serve as wind breaks. These type of structures are used for protecting farmsteads and are not economical for protecting large cropped areas. Terraces and bunds are useful mechanical barriers.

Now let us discuss the measures to improve soil characteristics. The principal way of controlling wind erosion using soil factors includes *conservation of moisture to improve growth of vegetation, and conditioning the surface soil to improve aggregation.* All moisture conservation measures either biological or engineering, have an indirect effect on reducing wind erosion. Mulching has been found to be efficaceous for this purpose. The condition of the top soil influences wind erosion to a large extent. This problem is considerably reduced if the topsoil consists of large clods or non erosive soil aggregates. Crop management practices like tillage, crop rotations, and addition of organic manures should be increasingly employed, to maintain good soil structure, which in turn helps in the development of nonerosive soil aggregates.

- **Stream bank erosion control measures**

Stream bank erosion is mostly caused by the flowing water in rivers and streams traversing through hilly regions and the plains. This erosion destroys the productive crop lands situated on the river margins. The problem of erosion is compounded by flood flows. Stream bank erosion control measures include both direct and indirect measures.

Direct measures include: i) Stabilization of stream bank by vegetation; ii) Protection of stream banks and slopes by paving with stones or masonry. Indirect protection measures are not constructed directly on the banks, but are constructed in front of them. These measures reduce the erosive force of the current either by diverting the current away from the banks or by inducing deposition of silts in front of the banks. This is achieved by *installing retards* or by *construction of spurs*. At some places along the stream bank the runoff from the adjacent areas enter the stream and in the process *gullies and ravines* are formed on the stream bank. If this is left unchecked the erosion is accelerated by the stream also. In such cases various gully control measures like *constructing diversion drains*, and the *check dams* are helpful in controlling such erosion.

Ravines are a form of extensive gully erosion. These not only damage the land resources but at the same time contribute large amounts of sediment load to the river systems.

- **Conservation measures for hill slopes**

Hilly areas are very important and special for our agriculture because a large portion of productive agricultural lands are situated here and they provide unique niches for special crops to grow. The best use and conservation of these special agricultural lands are of great importance – socio-economically as well as ecologically. These areas because of their undulating topography are the foci of soil erosion. And once the problem of soil erosion begins, it does not let the vegetation to establish easily. Due to lack of vegetation cover, soil erosion is accelerated further, transporting large quantities of silt to the valley or the stream below. In addition to this, the uncontrolled runoff carrying the fertile soil from the sloping areas causes extensive damage to the adjoining agricultural lands. Also the rainwater does not get sufficient time to be absorbed by the soil, and is thus wasted as runoff. When hill slopes are put under cultivation, erosion becomes more severe due to soil-working that is required for agriculture. Shifting agriculture is an example of the same. This involves removal of the natural protective cover of vegetation resulting in accelerated erosion. The problems due to shifting agriculture and management needs to be looked from the socioeconomic aspects of people residing in the hilly areas.

This system of farming is practiced widely in some hilly areas. It is a system of farming the land under which forests are cut and burnt to raise crops. After a few years of cropping the area is abandoned, because the yields decline due to impoverishment of soils.

Contour trenching – it implies excavating trenches along the contour or along a uniform level. These are useful both on hill slopes as well as on degraded and bare waste lands for soil and moisture conservation by making it suitable for afforestation or agriculture. These trenches (see Fig. 11.3) break the slope lengths, reduce the velocity of surface runoff and consequently retard its scouring action and carrying capacity. The water retained in trenches help in conserving moisture and thus providing advantageous sites for sowing and planting.

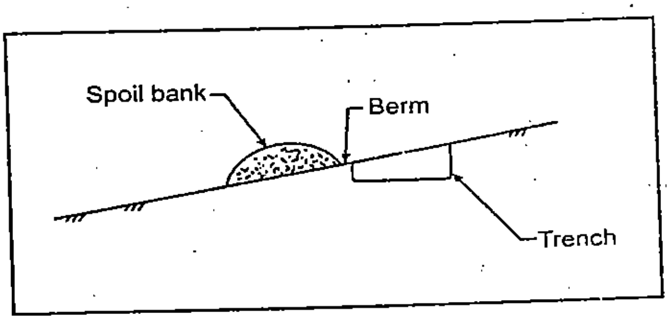


Fig.11.3: Cross section of a contour trench

Bench Terracing – is done by constructing a series of platforms along the contours cut into hill slope in a step-like formation. These platforms are separated at regular intervals by vertical drops or by steep sides, and protected by vegetation and sometimes by packed-stone retaining walls. The bench terraces convert the long unintercepted slope into several small strips and make protected platforms which are suitable for farming purposes. In many hilly areas this is an intensive practice, whereby the entire slope areas are turned to terraces which are extensively used for agriculture. After developing requisite facilities for irrigation with bench terraces, even rice has been profitably grown in such areas. Proper and regular maintenance of bench terraces is very important. Also it is important to note that the shoulder bund should be planted with permanent vegetation, and ploughing the toe of the bund should be avoided. The out-of-shape slope of terraces should be stabilised and protected by establishing deep-rooted and soil-binding, and spreading type of grasses.

Stone terraces – also known as stone wall terraces. They are small embankments constructed with stones across the hill slopes (Fig. 11.4). These can be adopted on any slope where stones are available in plenty at the place/spot. By intercepting surface runoff, these stone terraces help in retarding the soil loss and conserving soil moisture. At the same time the formation of the stone terraces helps in removing the stones that lie scattered on the field and otherwise hinder agricultural operations like ploughing, and interculture. Suitable vegetation may be planted to stabilize these bunds.

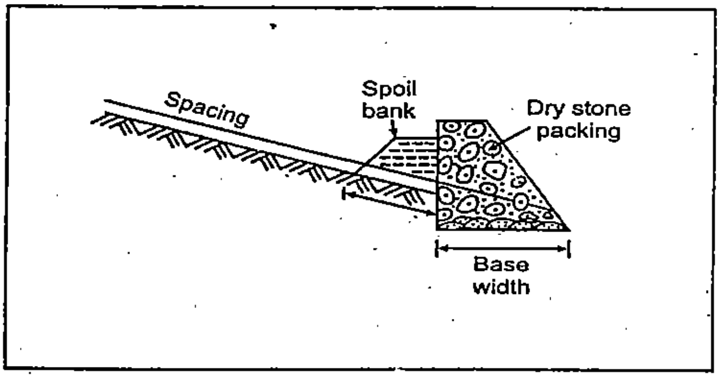


Fig.11.4: Stone terrace as seen in cross section

Cropping practices - Along with contour trenching, bench and stone terracing, cropping practices like: i) strip cropping (also see Fig. 11.2), ii) intercropping, and iii) crop rotation also prove very useful in controlling soil erosion in agricultural lands situated over the hill slopes. Crop rotation for an area can be chosen such that during the rainy period, there is a vegetative cover over the soil surface. A vegetative cover controls splash erosion by intercepting the rain drops, and absorbing their energy. Legumes when included in crop rotation help in maintaining soil fertility. Crops like groundnut, chickpea, soyabean, green gram are commonly used in crop rotation. Including certain green manuring crops in rotation help in adding organic matter to soil. It needs to be understood that crop rotations be developed to suit particular soil and climatic conditions and hence they differ from place to place.

SAQ 3

a) Cite some additional temporary/permanent measures for controlling wind-caused erosion of agricultural lands.

b) What determines the selection of crops for rotation?

11.2.5 Dry Farming

This is a system of soil and crop management for the regions having low and uncertain rainfall, which occurs in large area of our country. The term '*rainfed farming*' is increasingly being used instead of 'dry farming' in order to include areas of high rainfall but no irrigation facilities. Each such area has its own peculiar rainfall, soil conditions, and cropping practices. Because of these variations, technology of crop production in these areas is location specific and its application is regional in nature.

.ll the soil and water conservation measures dealt earlier in the unit, are applicable to ry farming as well. The most important factor in dry farming is conservation of ioisture for proper and timely utilization by crops. In order to select suitable dry irming practices in an area, a thorough study of climatic conditions, adaptable crops, ature of soil, and topography of the area is essential. The recommended practices iay be broadly grouped as: i) crop management; and ii) land management practices.

Crop management practices – This includes: selection of crops, tillage practices, sowing methods, control of plant population, weed control, and application of fertilizers and manures.

- Selection of crops involves the type of crop, its particular strain that is suitable for dry farming conditions, drought resistance, and short duration crops.
- Along the traditional methods of tillage, a number of modified tillage operations are available for the improvement of soil-water-plant relations. Reduction of soil erosion and runoff helps in moisture conservation, which helps in reduction of time and cost of tillage operations. *Minimum tillage* is one such form, it entails preparation of seed bed with minimum soil disturbance, opening the land just to plant seed, and making use of chemical herbicides to control weeds. *Strip or zone tillage* is another form whereby seed bed for planting is prepared by cultivating the soil in narrow strips, and some untilled/tilled area is left in between. These strips known as crop rows are managed for their proper soil structure, aeration, and soil temperature as per the requirements of the crop. The area in between the crop rows is known as water management zone and is meant for water detention and its infilteration in soil, and erosion prevention.

  The tillage operations in these two zones in the agricultural land are to be devised in spatially differential manner such that maximum crop production is obtained side-by-side the limited resource water is stored for future use, and the erosion problem is also controlled. *Mulch tillage* is yet another modification of tillage for dry farming conditions. In this the tillage operations involve leaving substantial amount of vegetative matter like leaves, stalks on the soil surface as a protective cover. Usually the residual material of the previous crop is left as mulch - *stubble mulching*. It helps in reducing the beating action of rain drops, reduce splash erosion, reduce sheet erosion by reducing surface flow, facilitate infiltration through open soil structures, and help in controlling soil temperature. The mulches also help in protecting soil against wind erosion.

- Seeding methods are also important as they have direct bearing on germination and initial establishment of crop. These methods are worked out depending on the crops and soil conditions. Time of sowing is important in areas where precipitation commences reliably with good possibility of follow-up rainfall. Seeds are sown shortly ahead of rain.
- Regulation of plant population, and
- Weed control are important, so that limited moisture available in soil is used efficiently by the crops.
- Application of fertilizers, done at appropriate time helps in increasing crop yields. Organic manures are found to be useful in enhancing nutrient value of soils side-by-side improving the physical conditions of soil.

ii) *Land management practices* – These include the soil erosion control and water conservation practices discussed above. In addition, the land management practices that are particularly useful for dry land agriculture are: water harvesting and runoff recycling; tide ridging; subsoiling; and watershed based soil and water conservation.

- Interplot *water harvesting*, and surface runoff from upper areas in a farm are collected in a pond made in lower part of the field. This method is useful in very low rainfall conditions. In case of enough rainfall is expected in the area, a crop like maize requiring good drainage can be planted at the receiving end.

- *Tied ridging* consists of covering the land surface with closely spaced ridges in two directions at right angles so that a series of rectangular basins are formed. An implement known as *basin listing* is often used for making the basins. The purpose of such basins is to retain the rain water till it infilterates into the soil. Its success lies in its careful design and construction. The system can be successful on level ground, or when the amount of water which can be stored in the basins, plus the amount infilterating during the storm, is more than the worst storm likely to occur. Failure of a ridge, particularly on sloping land can cause a series of failures of other ridges. To say it in short, tied ridging has been found to be successful on permeable soils rather than on shallow soils. To counter the likely damage due to failure of the ridges, a backup of the system with terraces and ground bunds is very effective.

- The practice of *subsoiling* consists of deep ploughing or chiselling using special equipment known as chisel plough or subsoiler. The objectives in subsoiling are: breakthrough and shatter plough soles or other impermeable layers in the soil profile; loosen soil layers to considerable depths to permit deep leaching of salts accumulated in the upper layers; bring the clod forming subsoil to the surface for wind erosion control; and to deepen the effective plough zone depths for crop growth. Subsoiling has to be done after a few years as its effect does not last long.

- Watershed-based soil and water conservation - In arid and semi arid areas, water is a limiting factor, and is sometimes available only through rainfall. It is therefore important that rainfall management in relation to conservation and utilization be planned on a watershed basis. For this, all the land treatment measures like contour cultivation, bunding, bed and furrow system are executed on individual plot basis. The runoff from the areas is conveyed through grassed waterways to prevent erosion. Water at a convenient place is collected in farm ponds to be subsequently used for irrigation. Figure 11.5 shows one such layout of beds, collection system in small agricultural watershed. All the above mentioned practices are location-specific and the package of practices to suit the particular area taking into consideration the climate, soil, and crops needs to be developed.

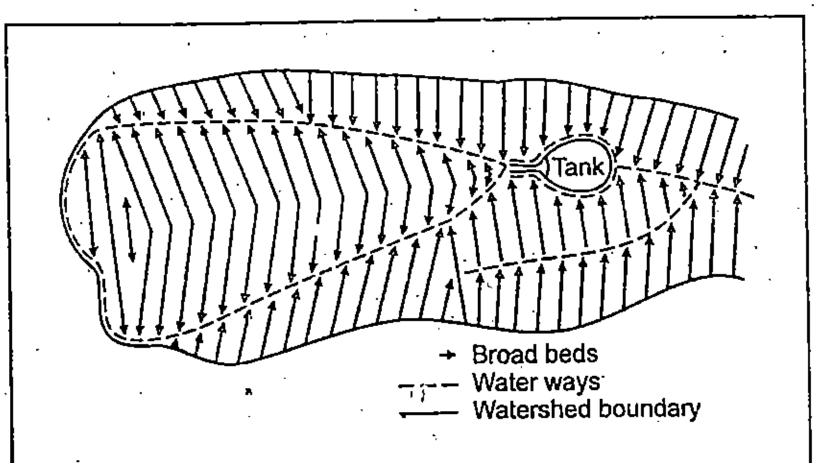


Fig.11.5: Layout of beds and collection system for soil and water conservation purposes.

11.2.6 Managing Water Resources

While soil is the medium for crop growth in terrestrial agriculture, water mediates the dynamics of crop production. Implying thereby the need of sound management and use of this critical resource for the success of an agriculture venture.

i. Building and Conserving Water Resources

If we put together the water available from the various water resources in our country, it can irrigate nearly 50 percent of our cultivated area. And for meeting the remaining water requirement for agriculture we have to depend on rainfall. And as you know rainfall is erratic at times. That's why the agriculture in India is described as a gamble on monsoon. In such a scenario, the proper utilization of rainwater and moisture conservation are very important. The rainfall is not only erratic but is also non-uniform throughout the region. In areas with high rainfall the problem is to dispose off excess rainfall to save crops from damage. And in areas with low rainfall such as in arid and semi-arid areas, efficient methods are needed to catch and store whatever rain water falls.

Ground Water Management – Ground water forms a substantial part of our total water resources, and is a major source of water for irrigation purposes. This is renewable water source as it gets replenished by the natural process of recharge. Ground water utilization is to be properly planned so as to achieve a balance between replenishment and extraction in order to maintain a perennial supply.

Farm ponds are used for storing water during rainy season and using the same for irrigation subsequently.

Farm Ponds Management – In rainfed agriculture, renovating, constructing, and maintaining ponds in farms and in the catchment areas besides storing the scare resource water, also have a retarding effect on the flood flows downstream. Depending on the source of water and their location in respect to the land surface, farm ponds are grouped into four types:

i) dugout ponds;
ii) surface ponds;
iii) spring or creek fed ponds; and
iv) off-stream storage ponds.

The design on construction of farm ponds require a thorough knowledge of the site conditions and requirements. Factors like loss of water through seepage and evaporation, growth of weeds, cost of bringing water from the pond to the place of use, are some important considerations that determine the viability of this option. Protection and maintenance of farm ponds are important too. The farm ponds, need to be protected from cattle trespass, especially for protecting the lining materials if used in its construction. Construction and stabilising embankments around the periphery prevents rapid inflow of sediments into the pond. The watershed area of the pond also needs to be protected from soil erosion with appropriate soil conservation measures. Regular maintenance of pond and ancillary structures is essential.

A watershed is an area from which runoff, resulting mainly from precipitation, flows past a single point into a large stream, a river, lake or an ocean. The terms watershed, catchment area or drainage basin are used in the same sense. A watershed may be a few hectares as in the case of small ponds or hundreds of square kilometers as in case of rivers. All watersheds can be divided into smaller sub watersheds.

Watershed management – Watershed management or protection implies the proper use of all land and water resources of a watershed for optimum production, and with minimum hazard to natural resources. The watershed management programme could have some or all of the following objectives:

- to control damaging runoff;
- to manage and utilize runoff for useful purposes;
- to control erosion and consequent sediments production;
- to moderate floods in downstream areas;
- to enhance recharge of groundwater; and
- to develop forest and fodder resources in the watershed site, thus optimizing the use of land resources.

Aerial photography for collating information about topography, land forms, vegetation and cultural features of the land surface, is a valuable tool. For watersheds on larger scale, satellite images using remote sensing techniques provide the needed accurate information on many important characteristics of agriculture, topography, water resources, land use, soil types, cropping patterns, pollution and many other aspects.

Experiences have shown that development of watersheds on larger scales such as those involving river basins, could be economically and ecologically profitable, if they are used for multiple, and integrated purposes. These could include purposes like irrigation, power, and flood control.

- Irrigation

Irrigation refers to the artificial application of stored surface or underground water for fulfilling the moisture needs of crops. Irrigation is important not only in preventing crop failures in dry conditions but in producing higher yields during normal years. Skilled irrigation, that is, right timing and dosage of moisture have been found to double or treble yields, bringing in greater economic returns to the farmers and the nation.

Various major, medium, or minor irrigation projects/schemes, tapping largely the surface water resources, have benefitted our agriculture. The major irrigation projects are the ones that supply water over large areas through a network of main canals and distributories, e.g., the dams and canal systems. The areas served by such irrigation projects are known as command areas, and they need to be developed for making efficient use of the water resources. This includes shaping and levelling land, construction of field drains, and use of suitable application systems. Lining of field course is needed to prevent seepage losses. Likewise efficient water management is equally important in areas commanded by small reservoirs, ponds and tube wells through the medium irrigation schemes. Minor or microirrigation schemes are discussed under the heading 'Application of irrigation water'.

Groundwater, i.e., the water stored in several independent hydrologic basins inside the ground serves as the additional water source for irrigation. It has been traditionally used for irrigation in our country over centuries with the help of manual or mechanical means. The quality of groundwater, and its withdrawal in safe limits, are the important considerations for making it a perennial water resource. This valuable water resource that is renewable, could be used over a large number of years, if the withdrawn levels are allowed to be replaced by equal recharge from rains. Certain artificial recharge methods like construction of ponds, serving as percolation ponds can ensure the replenishment of the underground water.

Deficit or excessive amount of water adversely affects crop growth and their yields.

Planning is an essential component for the optimum, efficient, and environmentally safe usage of irrigation water. The amount of water to be applied, the timing of application, and the means of application, are to the extent of water available and one's economic resources to fulfill the crop demands. It is therefore necessary to be conversant with the water requirement of crop(s) in particular climate conditions, the right schedule of irrigation, the suitable farm irrigation distribution system, and soil parameters like water evaporation, runoff, percolation, retention and releasing capacity, and the drainage conditions.

The rate of water use, type of crop, stage of its growth, climatic parameters like temperature, wind velocity and humidity are to be considered to gauge the water demands of crops.

Farm distribution systems convey water to a number of fields from the source or the point of supply. The system should be such that it conveys water to each field equally, with minimum losses, and without causing any erosion. The types of channels used for conveyance of water is very important. These may be surface channels, or underground pipelines. Lining of earthen channels reduces seepage losses, reduces danger of breaks, and checks the growing of weeds. Underground pipeline distribution systems save considerable land area and have no weed problems, but they are expensive to construct.

Good drainage conditions are necessary to prevent soils from salinity, and water logging in irrigated agricultural lands.

Application of irrigation water: Efficient utilisation of irrigation water involves several practices like conveying water from the source to the field without seepage losses, following the right method of irrigation consistent with the topography, applying water to the crop at right time and in proper amounts. The common irrigation practices involve application of water over, below, and above the surface of soil. The terms surface, subsurface, and overhead or sprinker are used to describe these three methods of irrigation respectively. *Drip* or *sprinkler method* is a highly efficient subsurface, microirrigation method that is fast gaining acceptance and popularity of farmers especially in the acute water shortage areas in the country. India has about 3.5 lakh hectares covered under drip irrigation. It is reported to save between 40 to 60 percent of water usage and effect an increase in yield between 60 to 100 percent.

Drip irrigation water in small amounts is applied uniformly to crop plants, through perforations known as emitters in the distribution lines that are placed under the soil and near the roots of the plants. These pipes are usually made of plastic, and are left in place for the duration of the growing season of the crop. Fertilizers are also applied in solution form along the water.

The main disadvantage of this microirrigation system is high installation costs, and the outlet or emitter blockage problem. Another method whereby water is applied above the ground surface, somewhat resembling rainfall is known as *sprinkler irrigation*. The rain-like spray is obtained by the flow of water under pressure through small orifices or nozzles referred to as sprinklers. A pump is used for developing the right pressure. In some situations when the source of water is high enough above the area to be irrigated, the required pressure may be developed by gravity alone. It is otherwise an effective method, but is affected by atmospheric conditions like high temperatures that cause evaporation losses, high winds that distort the application, thus making distribution uneven, and the high operation costs. Its use at night when wind velocities are low can minimise the problem.

By far the *surface irrigation methods* are the most commonly and widely used.

Irrigation water is one of the most costly inputs a farmer is using. In industry one tonne of water can produce a tonne of processed goods but in agriculture a few thousand tonnes of water is required for producing one tonne of food. It is less than one percent of the total water received by crops which is harvested in the final produce. This perspective makes a strong case for the need of increasing the water usage efficiency of agriculture.

Evaluation of irrigation efficiency – In irrigation water management, it is necessary to evaluate the irrigation practices from the time, tracking the water that leaves the source till it is utilized by the plants. The concept of efficiency which is an input-output relationship is applied to irrigation practices. The objective of this analysis is to identify the areas where improvement is necessary in order to achieve higher efficiency of irrigation water use.

Enhancing efficiency and efficacy of irrigation –Foremost in the list is:

- adopting such practices that have soil and water conservation as the core principle. The common examples being cropping rotation suitable to the land and its capacity, crop and fallow in rotation, maintenance of grassways, farming on contour, strip cropping, construction of terrace system and its maintenance, use of cover crops for bare soil surfaces, mulch tillage, checking and collecting surface runoff or rain water for percolating in the ground, and fertilization and liming.

- Second measure is prevention of overgrazing by cattle for retaining a healthy vegetation cover governs the soil structure, and moisture levels.

- Third is application of biotechnology for mass production of less water requiring crops, and early maturing crops.

- Fourthly, collective or collaborative farming whereby a group of farmers with small land holdings share the common water source and the running costs for irrigation operations. Use of modern tools and technologies such as information technology can ensure equity, and sense water consumption by each of the farm of the group. The recently developing contract farming approaches can also help farmers to adopt modern and more efficient agricultural methods including irrigation because of the know-how and monetary investments by the contract party.

- Fifth, utilisation of surface and underground water in an integrated manner, for getting optimum benefits of irrigation on a long term basis.

11.2.7 Drainage

Drainage problems are widespread both in the rainfed and irrigated areas. Construction of roads, railways and canals have blocked the natural surface drainage in several places aggravating the drainage problem. Continued irrigation over a

The surplus water in the root zone is detrimental to crop production as it restricts soil aeration, affects soil temperatures, hinders with tillage operations and brings the water table containing salts and other harmful substances, nearer to the soil surface resulting in water-logging. It is estimated that nearly 8 million hectares of land in our country is affected by salinity and waterlogging.

number of years, without adequate drainage facilities is resulting in large tracts of irrigated areas becoming unproductive. Drainage is necessary not only for removal of excess water but also for removing excessive salts from the root zone. Depending on the drainage problem, provisions for surface and subsurface drainage are made.

Surface drainage – It is required both in rainfed and irrigated areas. Surface drainage problems occur in flat or nearly flat areas, uneven land surfaces with depressions or ridges preventing natural runoff and in areas without any outlet. The common methods involve land shaping and construction or improvement of irrigation channels for enhancing their drainage efficiencies. In sloping areas, surface drainage is to be accomplished without causing soil erosion. Methods like open ditches have been found to be effective.

Subsurface drainage – refers to the removal of excess water present below the ground surface. Agricultural lands affected by high water table generally need subsurface drainage. While surface drainage removes the excess rain water before it enters the root zone, subsurface drainage lowers the water table and provides a better environment to the root zone. In many places subsurface drainage problems are due to natural causes, and in a large number of instances this is a manmade problem, one example is the waterlogging occurring in the canal command area of the irrigation projects. In planning subsurface drainage systems, information about ground water subsurface depths, its fluctuations and quality are needed. For this purpose, observation wells are made to study these parameters. The underlying principle of various subsurface drainage methods is that the drainage water moves under the influence of gravity to suitable outlets. The methods commonly applied for effective drainage are the following:

i) *Tile drains* including perforated pipes – these consists of short length pipes, about 30-90 cm installed at particular depth from the land surface. The pipes are invariably made of concrete or burnt clay. After digging the trench to the desired depth, the pipes are held end-to-end without any jointing. They are covered with an envelope material in certain cases and the soil is backfilled. Water enters the tile drains through the openings available between the pipes. A network of tile lines laid with a grade or slant removes the subsurface water. Perforated pipes are like tile drains except that they are continuous and water enters the pipes through openings provided on the pipe. Pipes made of PVC are most commonly used for the purpose.

ii) *Mole drains* – are cylindrical channels formed at a desirable depth below the soil surface. There is no lining material and the inherent stability of the soil at the depth gives stability to the mole drains. Water enters throughout the mole drains and is guided to the outlet.

iii) *Drainage wells* – also known as vertical drainage, these are usually made in areas underlying an aquifier, so that if the water is pumped out, the water table gets lowered. This pumped out water if of satisfactory quality is used for irrigation purposes. Thus a water balance in the soil could be achieved by this method keeping the water table at the desired level.

iv) *Deep open drains*– These drains are also used for subsurface drainage (Fig. 11.6). They however, use land area that could have been cultivated. These also need regular maintenance.

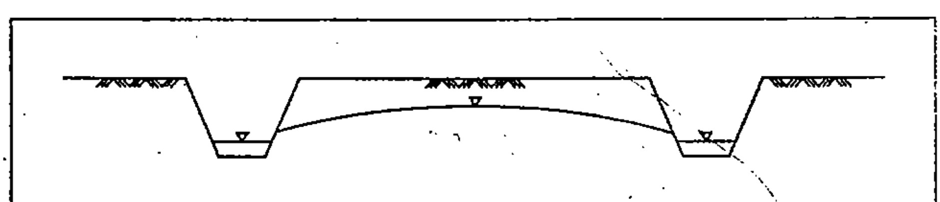
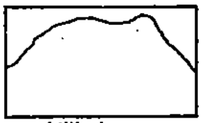
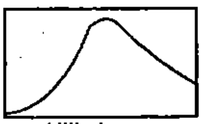
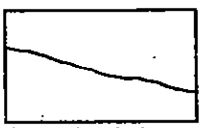
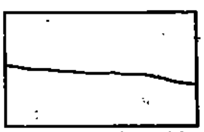
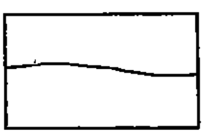
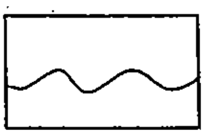
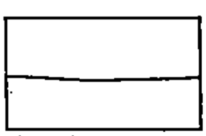


Fig.11.6: Deep drains of subsurface drainage and water table control.

) *Combination of tile and open drains* - In many areas affected by acute drainage problems, a combination of surface and subsurface drainage becomes necessary. A combination of tile and open drainage helps to combat this problem. The need for maintenance of the open drains, and the cost of installing the tile system inside the ground is to be kept in mind while adopting this combination system.

ith this we end our discussion on management of water resources. In Table 11.2, we ımmarise various land management practices suitable for different kinds of land with ırying water management problems.

able 11.2: Land management practices to address water management problems in a given topographical class.

I. Topographical class	II. Water management problems	III. Land management problems
 Hill slopes	Water retention	Afforestation; Contour trenching
 Hill slopes	Water retention and disposal	Bench terraces
 Steep land slopes	Water retention and disposal	Contour and graded bunding
 Sloping agricultural lands	Water retention and disposal	Contour cultivation
 Irrigated areas	Irrigation water management	Land levelling; Irrigation system design
 Sand dunes	Irrigation water management	Land levelling; Irrigation system design
 Flat irrigated areas	Disposal of water	Drainage
 Stream banks	Disposal of water	Stream bank protection
 Gullied lands	Storage and water disposal	Farm ponds; Gully protection

11.2.8 Energy Management

Agriculture is a means of converting and storing solar energy into various bio-products for human use. Food, feed, fibre, and fuel are the major categories of the bio-products grown as crops. All kinds of crops whether grown from small to large scale, or by simple to intensive processes, require an input of energy, in order to capture and convert the solar energy into a useful form. And with the harvest of each crop energy gets removed or lost from the agroecosystems, in the form of harvested materials. To restore the productive capacity of agroecosystem for yet another cycle of crop growth, a fresh input of energy is essential. This cycle goes on crop-after-crop.

The increasing food needs of the growing population has been challenging agriculture to produce enough to fulfill their requirements. The new tools, techniques and ways of modern agriculture have made it possible to take on these challenges successfully. Viewing this from an energy perspective these increases in crop yields have been achieved largely by using enormous amounts of fossil fuel energy in the form of fertilizers and pesticides, in irrigation, and as fuel for running agri-machinery. This input is even higher to restore and cultivate the degraded land, that has become necessary, for growing more food. From analyses of such energy inputs in agriculture, it is clear that the net returns from agriculture are not commensurate with the inputs. In addition these are affecting the salubrity of the environment, and are not sustainable in the long run. That is we actually invest more energy than we get back as energy in food and various other bioproducts. Also the environment is getting degraded due to the practices adopted. The enormous costs of environmental restoration and the adverse effects on human health and other life forms are ill-affordable especially by developing nations. To sustain agriculture in the future, we need to bring about fundamental changes in how we view and use energy in this sector. For this we need to understand how energy is used in food production? How much of it is actually required and at what stage of crop growth? What are the leakage points while energy flows through various means to the crops? How energy-usage could be made efficient? Are there any renewable, environment-friendly alternatives to the ones in use? And a number of important social issues are to be considered towards sustainable energy use.

Energy consumption in agriculture – Both energy and power are required for agricultural operations like land preparation, sowing, irrigation, intercultural operations, harvest, and post-harvest processing. While human and animal labour provide the power, commercial energy on the other hand through petrol, diesel, kerosene, electricity, and fertilizers run the various operations. The shares of human and animal labour vary widely, with an increasing tendency of the former shifting this role to animals or machines. Thus, there is a crucial role of animal power and mechanisation in Indian agriculture.

Agricultural energy planning – In view of the social needs and environmental concerns the key elements to be considered during energy planning are: minimizing the dependence on chemical fertilizers; use of alternative fuels to replace the fossil fuel usage; improving practices towards conservation and increased efficiencies; and renewing current practices and developing fresh outlook towards consumption and use of agricultural produce.

Salient energy-issues and management approaches:

- Fossil fuels and other alternatives – In view of the heavy drain on fossil fuel supplies, biomass (crop residues and industrial wastes like bagasse, fuel wood) could be used as substitute fuels. To some extent biomass has always been used for fuel, but to use it in the amounts needed to spare fossil fuels, requires a careful analysis. One constraint, operating against the increased use of biomass for fuel is the amount of land required to grow it. Not only that, the priority and economic aspects of using land for meeting the fuel needs or producing food has to be determined.

Biomass in the form of wood has long been a major source of fuel. But the supplies of firewood are diminishing rapidly, as more and more forest land is being cleared for agricultural production. As a result, the total amount of wood biomass available per person has declined 10% during the last decade or so. If biomass usage is increased, we must consider the effect this would have on available quantities of arable land for food/fibre production. Furthermore, the removal of trees and crop residues is known to decrease soil fertility, and facilitate soil erosion. The conclusion based on this perspective is that the biomass resources are limited in their usefulness as fossil fuel substitutes. Nevertheless, biomass particularly the wood still is largely used in rural India. The introduction of thermal-efficient devises have cut down considerably the amount of wood used.

Solar energy has shown great potential in agriculture. This can be harnessed in decentralized manner reducing the cost of transmission and distribution which account for more than 50% cost of providing electricity. Solar energy has been successfully used for running engines for water pumping and in drying systems.

Solar energy can very well meet with the thermal energy consumption needs of agriculture. Drying of food grains, tea leaves, fruits and vegetables, chillies and other spices, tobacco, and drying seasoning of timber are the common examples where it could be used alone or along with the conventional forms of fuels like kerosene, LPG, and diesel.

Biogas is another alternative fuel with lot of potential. Biogas generation is a simple and cheap method of decentralised energy production over a wide range of agricultural and climatic conditions. Many organic materials are converted by anaerobic digestion to methane and carbon dioxide. The slurry obtained from digestion contains most of the nutrients including N.P.K. and there is no loss of fertilizer value. Thus biogas can be used as a dual purpose fuel for meeting the energy needs of communities, and increasing the fertility of soil. Recently biogas has also been used as a fuel for running agricultural machinery. It can be used for pumping water. Petrol engines can be run 100% on biogas except that little petrol is consumed for starting up. Diesel engines can be slightly modified for using biogas, replacing diesel by gas to about 80%. The dual fuel engines can be used for running an irrigation pump, chaffcutter, thrasher and many other equipments. Even electricity can be generated from biogas. The cost involved is low. In generation of gas, about 10% of gobar is consumed, and it has been found that the thermal efficiency of the gas is more than that of the whole dung. The other advantage of biogas generation is production of manure. Community biogas plants are very cost-effective, and labour-efficient.

It has been found that tractors having larger power consume less diesel per hectare of operation compared to smaller powered tractors. The latter could be used for carrying out everyday farm operations or when smaller machinery is used. A diesel engine may yield best fuel economy when it is working on high load. It is also important to well match the implements, and allow the energy to work at a more fuel efficient loading and speed. If at any stage the exhaust shows more black smoke than natural, it means the engine is over loaded as it is unable to burn all the fuel supplied, and is discharging unburnt fuel through exhaust gases which is both wasteful and expensive. Also for a good fuel economy proper engine maintenance is essential.

Wind energy can be very efficiently harnessed for pumping water in the coastal, hilly, desert, and any such areas having good amount of wind. A typical windmill starts lifting water at 12 kmph wind speed and yield about 30-35 cubic meter of water per day. Energy consumption from conventional sources, in lifting water for irrigation and other agricultural operations can be conserved by the use of these alternative fuels for energy.

Energy Conservation practices and attitudes can help tremendously in making agriculture a sustainable venture. For this there is a need to analyse each and any conservation opportunity. Energy conservation does not imply cutting down energy consumption, but implies efficient utilisation of the available energy. Another dimension of conservation is integrated use of conventional and nonconventional fuels, as mentioned above. This would not only help conserve the fuels of former category as they are nonrenewable considering the life span of humans, but also minimise the harmful environmental repercussions of their usage. Some energy conservation opportunities and measures are bulleted below:

- Energy plantations, conversion of crop residues and other biomass,
- Use of a fallowing system,
- Cultivating the land as per its carrying capacity,
- Reduced tillage, minimum tillage, and zero tillage,
- Selecting and using implements that have a low draft,

- Appropriate weed control measures, and
- Enhancing efficiency of agricultural machinery. For example, in case of tractor by selecting its right size, appropriate fuel, engine speed, and the level of load, promoting custom services in use of tractors, power tillers for small and marginal farmers.

- Use of low pressure irrigation is another energy saving oppurtunity. This along with efficient water use and distribution, optimise the cost of irrigation per unit area. Recently low level applicators like minijets, microsprinklers and drippers have become popular. Energy consumption by irrigation installations is greatly affected by pump efficiency and this depends on how well the flow and head requirement match the performance of the pump.As fuel cost increases, selection of the type of energy used to run the irrigation pumps is becoming more critical. The best of the various options to power irrigation pump are: electricity, diesel, petrol, LPG, and solar photovoltaic cells. Careful placement of dams around the farm is an energy saver. Firstly, water pumped from dams needs much less horsepower than water pumped from bores, although evaporation losses can be greater. Windmills or solar-based systems which operate intermittently when the conditions are suitable can be used to pump bore water into dams with no fuel cost. If the dams could be sited up a slope, so that the adjacent areas can be either flood or sprinkler irrigated using gravity pressure from the dam.

- Fertilisers, and their application that are high energy-invested products and energy-driven processes respectively, their right and efficient use can bring tremendous savings in energy and costs. Fertilisers are usually applied to crops at least once a year by a manure spreader.

- Methods of applying fertiliser which do not require a separate operation are now available. Soluble nutrients can be applied through a spray unit and if compatible with the spray mixture, can be applied with routine sprays. Soluble nutrients are also available for distribution through irrigation systems and the use of this method is gaining favour. Systems with droppers and microjets are designed to supply water just near the roots of the crops. Including the soluble fertilisers along with water enhance their better utilization by the crops. The amount of fertilizers required when it is applied in this manner is tremendously less as compared to the amount required to fertilize the entire field. Artificial fertilizers, such as nitrogenous fertilizers, are energy intensive and therefore these are to be used to the minimum.

- Attention should be given to biofertilizers, rather an integrated use of fertilizers, and organic manures. This aspect will be discussed in detail in Section 11.3.

- A large amount of energy can be conserved during the spraying operations by: using concentrated sprays to reduce the volume of spray mixtures that would have required considerable energy inputs; use of ultra low volume sprays could reduce energy requirements significantly; planning more efficient and less frequent spraying through monitoring pest and disease populations with bait traps and weather data; and combining compatible materials in a spray mixture, that could provide a timely multipurpose application, thus reducing the spraying costs.

Developing a right *energy management approach* is necessary for energy conservation in agriculture. For this one needs to assess the total energy consumption on the farm. This assessment is based on the total annual energy requirements and costs in relation to per unit of production. Based on this information, by adopting appropriate energy reducing measures as discussed above, higher production is achieved with lower energy consumption.

ıe very important and practical aspect of energy conservation could be – a *change in nsumption patterns*, i.e., to *consume less animal proteins*.This diet modification ›uld reduce energy expenditures and increase food supplies because less edible ıins would be fed to livestock to produce costly animal proteins. The average yield ›m 10 kg of plant proteins fed to animals is only 1 kg of animal proteins. Viewing s relationship on a large scale, say a hundred million tonnes of grains that are fed to estock, are consumed directly as human food, about 400 million more people could sustained on this grains-stock for one year. Bringing in such a change is a slow ›cess, because people all over are accustomed to their social and religious beliefs ı conditioning, as well as have developed personal preferences for food over the ırs. Nevertheless, it is an important dimension of feeding the ever increasing ıber of people in an energy efficient manner.

Q 4

What considerations are important for deciding about dry farming practices of an area?

Name the water sources that are tapped for meeting with the moisture requirements in an agricultural area familiar to you.

List, and write the main features of the common types of irrigation.

Differentiate between surface and subsurface drainage in a farm situation.

List the various energy conservation oppurtunities during crop production.

.3 NUTRIENT MANAGEMENT

agricultural systems whether crop-, or animal-based, involve removal or loss of rients from the land through their harvested produce. Grazing animals remove less n crops, for although their intake can be high, most of the nutrients are returned to land through their faeces and urine. The removal in crops depends on the total ld, the part of the crop that is removed in the harvest, and the particular crop that is ›wn. Table 11.3 gives some such typical amounts.

ble 11.3: Nutrient removal in some harvested crops (figures in kilogram per hectare).

	Dry matter yield ($t\ ha^{-1}$)	N	P	K	S	Ca	Mg
/heat grain	5	100	20	28	8	3	8
/heat straw	5	35	4	40	5	18	5
laize grain	5	100	20	30	5	10	8
laize straw	5	50	10	60	8	10	10
ice grain	5	90	20	25	8	5	1
ice straw	5	20	5	50	5	15	8
yegrass ay	10	160	30	180	12	40	12

te: The values in the table, which are from various sources, give only the order of magnitude because rient removal varies with the crop variety, and depends on the amount of the nutrients supplied.

ıtrients are also lost by erosion, surface-run-off, leaching, gaseous loss, and by rning of vegetation. If there is no replacement of nutrients, the crop yields decrease.

Various nutrients required by plants in large quantities are the macronutrients and these are nitrogen, sulphur, phosphorus, potassium, magnesium and calcium. In addition there are some mineral elements required in small amounts. These micronutrients are iron, boron, zinc, manganese, copper, molybdenum, and chlorine. In all sixteen elements are essential for the plants to grow and mature properly. Carbon, hydrogen, and oxygen are the elements that the plants get from the air and water, rest they obtain from the soil.

Also if a land is for the first time brought under cultivation, it is necessary to check, and correct the nutrient deficiencies or imbalances in the soil, if any.

11.3.1 Concept of Nutrient Management

As discussed above, the loss of nutrients through harvest, and the inherent nutrient deficiencies of the soils can be managed by the following four ways.

i) Adopting measures to lessen the rate of removal/depletion of nutsients from a farm. The residues of crops, the excretory wastes of farm animals, and at places the night soil or sewage is supplemented to the soil.

ii) Nitrogen is added by biological nitrogen fixation from legumes or other biological systems.

iii) Nutrients are allowed to accumulate under a fallow.

iv) Fertilisers are used to provide nutrients that would otherwise be deficient in the amounts required.

11.3.2 Nutrient Status in Soil

Plant nutrients must occur in the soil in available forms if they are to be taken up and used by the plants, e.g., NO^-_3 and NH^-_4 are the forms of nitrogen that are available to plants. Similarly the micronutrient molybdenum is taken up as MoO^-_4. The available forms of nutrients are located at or near the surface of soil particles such as clay, silt, and humus. As the growing plant roots come in contact with these soil particles and the soil solution that surrounds these particles, the available nutrients are taken up by the plants. Although soils may contain large quantities of plant nutrients, amounts available for plant use at any given time are relatively small. The remainder remain unavailable and cannot be used by plants unless they are converted to available forms. The common forms of nutrients unavailable for plants include the insoluble chemical compounds (phosphorus and micronutrients included in many of these), unweathered or undecomposed soil mineral or rock fragments (most nutrients included), organic matter or plant residues (nitrogen and sulphur are the main ones), and the ones trapped by soil particles (lots of K and some NH_4 may be in this form).

One of the main properties of soils that influences nutrient availability is pH. Soil pH is especially important for maintaining fertilizer nutrients in available forms. If the pH is not suitable, available fertilizer nutrients may rapidly become unavailable by forming insoluble compounds.

Nutrient interaction is another factor that may either help or hinder the uptake of another nutrient. In some instances, a certain nutrient may increase the uptake of one nutrient and decrease the uptake of another nutrient. Also, a given nutrient may increase the uptake of a nutrient under one set of conditions but reduce the uptake of the same nutrient under another set of conditions. Some examples of such interactions are given below:

i) NH_4-K interaction: Ammonium nitrogen has been found to interfere with uptake of K.

ii) K-Mg interaction: K has been shown to reduce the uptake of Mg.

iii) P-N interaction: The uptake of P is often increased by the presence of N.

iv) P-Zn interaction: High levels or rates of P have been found to reduce zinc uptake by plants.

1.3.3 Restoring Soil Fertility

laintenance and improvement of soil fertility is key to raising crop production. From ie above discussion it is clear that factors like soil pH, nutrient status govern the ealth and fertility of soils. The declining soil fertility due to problems like soil acidity r nutrient impoverishment can be restored by application of lime and fertilizers. How iuch of lime and fertilizers would be necessary for the best plant growth can be etermined accurately by soil testing.

etermining nutrient needs of soils – A soil test measures soil pH and the amounts of vailable nutrients the soil contains. By knowing the amounts of nutrients already resent in the soil, it is much easier to determine the kinds of fertilizers to apply. Most f the fertilizer related problems are associated with the improper use of fertilizers. A rucial aspect of soil testing is the way the soil sample is collected. The sample should present the total area in which fertilisers or other agro-inputs are to be applied. A rge composite sample should be collected consisting of small portions of soil taken om different locations. These samples be placed in a clean container and thoroughly iixed before sending for analysis. In addition to soil testing, foliar symptoms of crops lso indicate the nutrient status in soil. These two aspects, if used in conjunction can ive an accurate nutrient picture of the field, for deciding – i) The appropriate method f supplying nutrients or taking any remedial measures, ii) the source, and iii) timing f application.

The materials that provide one or more particular nutrients are known as fertilizers. If a fertilizer contains only one primary nutrient, it is called a straight material, for e.g., urea or muriate of potash. Materials containing each of the three primary nutrients are referred to as complete or mixed fertilizers.

Choosing the fertilizer source – There are many kinds of fertilizers available that can be used to supply the recommended nutrients. Fertilizers may be solid or liquid, and both perform equally well when equivalent amounts are properly applied. Nutrient availability of water soluble, dry or liquid fertilizers is similar. Therefore fertilizers should be selected based on economy, market availability, and other factors – not as solid or liquid. Regarding foliar application of nutrients, i.e., feeding the plant nutrients through their foliage—leaves, stems and blooms, it should be considered a supplementary method to soil application. The reason is that it is an expensive method. However, it can be applied and is useful when a rapid uptake of a small amount of particular nutrient, usually a micronutrient is needed to correct a deficiency problem.

Other fertilizer sources – In addition to the largely used chemical fertilizers, many other options for use as fertilizers are available. Several natural sources also referred to as the green inputs, constitute this category. These may be used by persons wanting to use only naturally occurring materials, as in the case of organic farmers. The common examples of green inputs are - biofertilizers, farmyard manures, sewage sludge, and vermicompost.

Biofertilizers – include biological forms like *Rhizobium, Azotobacter, Azospirillum,* Blue-green algae, Vesicular arbuscular mycorrhizae (VAM) and other Phosphate nobilising organisms, and *Azolla.* These are low cost, effective and renewable sources of plant nutrients and are used to supplement the chemical fertilizers. Biofertilizers hus refer to biologically active products, and selective strains of microorganisms which can contribute nutrients to plants. The suitable strains of microorganisms may ilso be used for decomposition of organic wastes for use as organic manure in igriculture.

Farmyard manures – These have been used as fertilizers for centuries. It consists of faeces, urine, and bedding materials of farm animals which is usually the cereal straw. Although their nutrient content is low, these contain some quantities of all the essential elements. In many situations, the application of even a modest quantity of manure provides enough of a deficient nutrient, especially a micronutrient, to dramatically increase the plant growth. The nutrient content of manure is quite variable. Factors influencing the quality include the age and kind of animal, the feed it consumed, the amount and kind of bedding used, and the manner in which the manure was handled. Nutrients can be leached from it if exposed to heavy rain, and ammonia can be lost by volatalization. Biofertilizers besides restoring or increasing soil fertility also improve soil structure. If applied frequently it increases the soil organic matter. Because it decomposes slowly in soil, the nutrients not available to crops after application become available in later season.

Animal slurries, another form of farmyard manure, are semi-liquid form of faeces, urine and floor washings from cattle houses. These are found to contain all the essential plant nutrients. When sprayed on field, they have been found to have offensive smell.

Sewage sludge – is the organic material produced from domestic and industrial waste water and direct runoff from roads. The composition of sewage sludge is very variable. It depends on the local industrial processes and on the amount of sand and silt that it contains. It is useful as a source of nitrogen and phosphate, but has only a small content of potassium because most remains in the liquid wastes that are discharged into rivers. The organic matter in sewage sludge helps to improve soil structure. When applied to land it has beneficial effects. Problems arise if these are applied too frequently and over prolonged periods, as it contains high concentration of metals that are toxic to plants and animals.

Vermicompost – There has been an increase in its demand because of its organic nature and increase in its use in the kitchen garden and for cultivation of high value cash crops.

- *Enhancing fertilizer use efficiency in plants* – By 2020, with India's population likely to be around 1.3 billion, an additional 4-5 million tonner per annuum will have to be produced to feed the increased populations. This would place additional demand for fertilizers, along with the other resources, to increase agricultural productivity. This is a big challenge for our country. It has come to light that the continuous and unbalanced use of fertilizers is leading to decrease in nutrient uptake efficiency of plants resulting in stagnation, and sometimes decrease in crop yield. At the same time, the use of chemical fertilizers at a very high rate has lead to the problem of soil health deterioration, ground water and atmospheric pollution. In addition, there are problems of losses in fertilizers after application through leaching, volatalization, denitrification of nitrogen, and fixation of phosphorus in soil. The chemical fertilizers especially the nitrogen fertilizers are in short supply and expensive because the industrial fixation of nitrogen is an energy-intensive process, which is solely based on natural petroleum products. Thus there is a need to use chemical fertilizers in balanced proportions along with integrated use of all the available sources of plant nutrients for sustainable agriculture. Integration of chemical, organic and biological sources of plant nutrients and their efficient management have shown promising results not only in sustaining productivity and soil health, but also in meeting a part of chemical fertilizer requirement of different crops (integrated nutrient management). Two such recent examples are described below:

The production of grape is influenced by a variety of factors, nutrition being one of them. Fertilizers and manures comprise almost 30-40 percent of the total cost of crop production. Use of chemical fertilizers excessively, and over the years has been linked with deterioration of soil health. An integrated approach involving biofertilizer, viz. VAM, and inorganic fertilizers has proved to be highly beneficial for the soil health, the yield, the quality of grapes, and above all fertilizer economy.

<u>Glomus</u> <u>deserticola</u> was used. For more details you may log on to : <u>http://www.hinduonnet.com</u>, of September 5, 2003. Title of the article is - 'Improving quality of grapevine with biofertilizers.'

Likewise another example of integrated management of rainfed tapioca in Tamil Nadu has showed great promise. The biofertilizers – Phospho-bacteria and *Azospirillum* helped the plants to utilize nutrients more effectively, resulting in remarkably enhanced productivity.

- *Need to develop green-inputs commercially* – The green-input markets need to be developed as the potential applications are on the increase. At present, the Indian market is diverse in terms of products, but is rather unorganized. The reason being, most of these inputs are either not traded or even if they are, it is at informal levels. There is need to know of the production capacities of units engaged in production of various green-inputs, and also the demand and sales characteristics of the markets. Among the various green-inputs, biofertilizers are the most organized presently. The amount produced and traded so far can meet only 4.8% of the estimated demand. Since there has been a steady growth in demand since mid 1990s, it is necessary to take steps for these to be made available, and at price that is within the reach of the farmers. This aspect is of enormous importance for the promotion of integrated use of fertilizers for sustainable agriculture.

11.4 BIODIVERSITY MANAGEMENT

This section builds-up on the biodiversity aspects discussed in Unit 8, wherein the importance of biodiversity, and the threat to agriculture because of the loss of biodiversity have been highlighted. It is now increasingly being realized that biodiversity is an invaluable natural resource that needs to be effectively managed with a sense of responsibility. Crafting the right strategies as per the objectives, and the prevailing agricultural practices in the socio-economic settings of the region, is crucial for the effective management of this resource.

The term biodiversity and agrobiodiversity are used here interchangeably. Agrobiodiversity refers to that part of the full spectrum of diversity on which humans directly depend for food and plant-based needs.

11.4.1 Conservation, Maintenance and Use Approach

A conservation-maintenance-use approach seems to hold great promise for both getting the high returns from agriculture, as well as maintaining the resource pool in a rejuvenated form. Various location-, and need-specific practices like reduced or no-till farming, bio-pest control, use and recycling of organic wastes, crop rotation, polyculture, mixed farming or intercropping, and integrated farming systems help tremendously in managing the agrolandscapes to increase their species diversity, as well as conserve the genetic material. It is a well known fact that a species diverse agrolandscape with a temporal continuum, promotes development of a large number of links between its resident species. The greater number of such links impart stability to the agrolandscape or the agroecosystem. Many local populations have historically managed biodiversity, and such a knowledge is valuable for learning to improve practices in other locations.

11.4.2 Integrated Management Strategies

Joint production of crops and mosaics of wildlife is both a traditional as well as a new emerging concept. Traditional because such practices have been used by farmers, whereby, some areas such as belts or corridors or bunds around the agricultural land are left uncultivated. In such areas that are set aside, natural vegetation along with its associated fauna survives and evolves along with the forces of nature. From the agricultural point-of-view such areas also harbour the escapes of crops that thrive all by themselves. Also the insect populations, in such uncultivated areas have been found to be effective in countering the crop-pests. This is a new concept wherein this activity of maintaining the native or wild species is done in a planned and more organized way. The advantages thereof need to be impressed upon the farmers. Issues like devoting the agricultural land for this locked investment, considering the economic returns the crops would have brought from this piece of land, are to be thought of. For the farmers with small holdings and lesser economic returns this could be a state-supported or a private agri-business institutions or agricultural university backed endeavour.

The form of conservation we have just discussed, that is, at the natural site of occurrence of the flora and fauna is known as *in situ* conservation. As for crops, *in situ* conservation is largely a neglected strategy. Here too, the issue of financial support as discussed a short while back holds good. *In situ* conserved crop plants are of great value for crop breeders, owing to their inter-, and intra-specific variability. This is because conservation permits continuous evolution and adaptation to take place, whether in wild or in on-farm conditions where human selection also plays a critical role. In view of the long-term interests, the modalities for making *in situ* conservation a practical proposition, needs to be worked out.

In another form of conservation, crop plants, particularly their seeds and other reproductive plant parts are conserved under controlled environmental conditions in gene or seed banks. This is known as *ex situ* conservation. Plant evolution, however, is effectively frozen at the time of storage, in this way of conservation. The *ex situ* conserved materials, in technical terms are referred to as **germplasm collection**. It provides easy access to a large collection of plant materials with variable characteristics, that is of immense value for breeding and crop improvement purposes. A number of issues associated with *ex situ* conservation need addressal. Some of these are – who controls such a stored germplasm? Is it a national asset? Can anyone both within and outside the country freely access it? This is because controversy erupted around the proposal endorsing the free exchange of germplasm. Continued evolution and use of collected germplasm and an effort to preserve landraces and wild crop relatives where they still exist are the critical steps needed for maintaining the germplasm collection in viable condition. Funding for establishing and running of *ex situ* collection facilities is yet another issue. Many nations give low priority to maintenance of such genetic resource efforts.

In the light of the above discussed issues, and the weaknesses and strengths of these two forms of conservation, integrated conservation strategies involving both *in situ* and *ex situ* conservation in a complementary manner are recommended for effective management of agrobiodiversity. Also there exists the need to integrate and interface natural, agricultural, urban and suburban systems to manage the agrolandscapes in a truly sustainable manner. In the next millennium, new sciences and technologies such as information and communication technology and space technology, besides biotechnology will provide powerful tools for developing genetically modified organisms, making plants and organisms responsive to more stresses and helping in identifying new and useful species, cropping and land use systems, which could bring in the needed sustainability in agriculture.

Effective management on sustainable terms in the changed scenario would surely require facilitated exchange of biological and genetic resource, and also of technology on prior informed consent and mutually agreed terms, release of alien species and transgenics into the new environment only after intensive testing and due precaution for biosafety, using the familiarity criteria and equitable sharing of benefits in a transparent manner. Accordingly, there must be wide ranging awareness campaign and literacy missions on technological, regulatory and legal matters.

SAQ 5

a) Explain how plant nutrients behave in soil.

b) What aspects you would pay special attention to while getting a farm soil tested for determining its plant nutrient needs and in choosing the right fertilizer sources.

c) If you are asked to prepare the biodiversity list of the given agricultural land, which biodiversity categories would you include in your list?

d) Discuss the importance and utility of biodiversity management.

e) Devise an integrated biodiversity management strategy under the heads – planning, action, monitoring, evaluation, and remedial measures, pertaining to an area of your choice.

11.5 SUMMARY

The essence of the unit is:

- Land use, land grading, excessive salt contents in soil and water resources, soil erosion, acute shortage of water, and drainage of soils are the major **soil and water related management** issues in our country. For managing these in an effective manner, it is essential to understand that each of the resource - soil, water, energy in various forms, and biodiversity are linked to each other in very complex, interdependent and in an intricate manner. This relationship has been highlighted throughout the unit.

- Change in any parameter of a resource has percolating effects on the others. To put it in another way, none of these resources stands alone in nature. These are to be viewed as components without boundaries, yet they make the whole of the global ecosystem. These resources need to be efficiently used and effectively managed in order to meet our food and other crop based needs, as well as for maintaining an environment that is congenial for the health of humans and all the life forms.

- Various dimensions of the resource-use, and the corrective ways and remedial measures have been discussed for each resource. There is no one specific solution or way of management in modern times when the number of problems, and the complexities of problems are increasing by the day.

- For drawing an effective management strategy for any resource, two things are important: Firstly, we should consider as many dimensions as possible of a resource and form a larger or more complete picture of the problem, for devising strategies that satisfy or fulfill the environmental, socio-economic, and cultural aspirations and needs of the society. Secondly, integration of traditional knowledge, modern tools and techniques, and innovation in areas without any precedence is the key to resource management.

11.6 TERMINAL QUESTIONS

1. 'Change in land use from agriculture to housing or industry-setting are the signs of development'.

   i) Discuss the appropriateness of such land use changes in the name of development.
   ii) Taking a pragmatic view, suggest realistic measures to make such land use changes for sustaining quality of environment, and health of human beings.

2. Determine the crop rotation practices in an agricultural community in your vicinity.

3. Study the effects of continuous cropping practices on yields and soil erosion.

4. Collect local examples of use of tree planting in controlling soil erosion.

5. Discuss the importance of land management practices in dryland farming.

6. Why is scheduling of irrigation important from the point of economic and environmental consequences? Discuss.

7. What parameters would you take into account for combating the drainage problem in an agriculture land?

8. Outline an integrated energy conservation approach for an agricultural land.
9. Discuss how soil pH influences the availability of nutrients.
10. Write the chief constituents of any four commercial fertilizers from a garden shop or farm chemicals business.
11. Explain why manure alone is considered as an unreliable fertilizer.
12. What would be your considerations for biodiversity management in an agrolandscape?

REFERENCES

1. Barrow, C.J. 1999. Alternative irrigation - The promise of runoff agriculture. Earthscan, U.K.
2. Briggs, D. & Courtney, F. 1995. Agriculture and environment - The physical geography of temperate and agricultural systems. Longman, U.S.A.
3. Brundtland G.H. (Chairman). 1991. Our common future. World Commission on environment and development. Oxford University Press, U.K.
4. Collins, W.W. & Qualset, C.O. 1999. Biodiversity in agriculture. CRC Press, U.S.A.
5. Dadhich, L.K. & Sharma, A.P. (Editors). 2002. Biodiversity: strategies for conservation. APH Publishing cooperation, India.
6. Deshmukh, A.M. 1998. Biofertilizers and biopesticides. Technoscience Publications. India.
7. Dewan, J.M. & Sudershan, K.N. 1996. Irrigation management. Discovery Publishing House. India.
8. Dover, M. & Talbot, L.M. 1998. To feed the earth: Agroecology for sustainable development. Oxford & IBH Publishing Co. Pvt. Ltd. India.
9. Glaeser, B. 1995. Environment, development, agriculture. Integrated policy through human ecology. UCL Press, U.K.
10. Gliessman, S.R. (Author) & Engles, E.W. (Editor). 2000. Field and laboratory investigations in agroecology. Lewis Publishers, U.S.A.
11. Gupta, S.K. & Gupta I.C. 1997. Crop production in waterlogged soils. Scientific Publishers, India.
12. Khan, T.I. & Shishodia, Y.S. 1998. Biodiversity conservation and sustainable development. Pointer Publishers, India.
13. Knuti, L.N.; Williams, D.L.; and Hide, J.C. 1984. Profitable soil management. Prentice Hall, Inc., U.K.
14. Lal, R. (Editor). 1998. Soil quality and agricultural sustainability. Ann Arbor Press, U.S.A.
15. Mitsch, W.J. & Jorgensen, S.E. (Editors). 1989. Ecological engineering. An introduction to ecotechnology. John Wiley, U.S.A.
16. Murthy, V.V.N. 1985. Land and water management engineering. Kalyani Publishers, Ludhiana.
17. Parker, R. 2000. Introduction to plant science. Delmer Publishers, U.S.A.

18. Pillai, K.M. 1987. Water management and planning. Himalaya Publishing House, India.

19. Rathore, N.S.; Mathur, A.N. & Solanki, A.S. 1994. Integrated rural energy planning. Agrotech Publishing Academy, India.

20. Reddy, K.R. 1995. Irrigation and agricultural development in India. Ashish Publishing House, India.

21. Somani, L.L. & Totawat, K.L. (Editors). 1993. Management of salt-affected soils and waters. Agrotech Publishing Academy, India.

22. Thorne, C.E. 1999. Farm manures. Allied Scientific Publishers, India.

23. Vision 2020. Indian Council of Agricultural Research. New Delhi, India.

24. White, R.E. 1987. Introduction to the principles and practice of soil science. Blackwell Scientific Publications, U.K.

25. Wild, A. 1993. Soils and the environment. An introduction. Cambridge University Press, U.K.

26. Various Internet sites can provide enormous information on the subject discussed in the unit. Some addresses of the relevant websites are given below:

- The URLs for worldwide websites can change. Using one of the search engines like Google, Yahoo, Hot Bot, Alta Vista etc., you can find more information by putting in the keywords/phrases pertaining to the topic of your interest. An expandable list of keywords/phrases follows the website addresses.

- Use your judgement for accepting any information obtained from the internet for its authenticity. Websites of renowned institutions/societies could be taken for their words.

- **Website addresses.**

  i) Central Arid Zone Research Institute
  http://cazri.raj.nic.in

  ii) Central Water Commission
  http://cwc.nic.in.

  iii) Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India
  http://agricoop.nic.in

  iv) FAO Regional Office for the Asia and the Pacific
  http://www.fao.or.th

  v) Indian Agricultural Research Institute
  http://www.iaripusa.org

  vi) Indian Council of Agricultural Research
  http://www.icar.org.in

  vii) International Crop Research Institute for the Semi-Arid Tropics
  http://www.icrisat.org

  viii) M.S. Swaminathan Research Foundation
  http://www.mssrf.org

  ix) Ministry of Consumer Affairs, Food & Public Distribution -
  http://fcamin.nic.in

x) National Environmental Engineering Research Institute
http://www.neeri.nic.in

xi) Central Water Commission
http://cwc.nic.in

xii) United States Department of agriculture
http://usda.gov

- **Some keywords/phrases for Internet search.**

Agricultural universities in India, alkali soils, characteristics of soil, energy management, farmyard manures, green manuring, land capability classification, land grading, leaching, saline-alkali soils, saline soils, soil drainage, soil subsurface drainage, soil surface drainage, soil management, water management, and this list can be expanded with your interest and curiosity about the topic.

UNIT 12 INTEGRATED FARMING SYSTEMS

Structure

12.1 INTRODUTION

Over the last three decades, green revolution technologies have enabled India and other countries of the South Asian region to attain self sufficiency in food production. Advantage was taken of the high yielding varieties of grain and the existing irrigation potential was exploited. As a result the production and productivity have increased several folds. If fast growth in agricultural production has to be maintained to feed the growing populations of this region, then the new challenges that arise as a result of the very factors that have ushered the green revolution, have to be met appropriately.

In the earlier unit you read about the interrelationships between the resources needed for food production and for maintaining an environment congenial for the health of humans and other life forms. You also learnt about the integration of traditional knowledge, modern tools and techniques, and innovations in resource management. Recent years have witnessed a rapidly growing concern about the quality of life and natural resources. Integrated farming systems may comprise more than one farm enterprises (viz. crops, dairying, poultry, beekeeping, fisheries, agroforestry mushroom cultivation etc.) subsystems on a farm to harness maximum efficiencies and obtain. Sustainable resources use systems which will optimize their use minimize degradation and induce regeneration capacity as well as increase overall productivity, income and employment. This needs intensive cooperation between the various agricultural sectors that could contribute to the sustainability of the region's broad base agriculture.

In this unit we will discuss farming systems, their components, and the need for their development for leading the region to meet the food security challenges coming ahead.

You will also learn about the role of integrated farming systems in avoiding risk due to environment constraints and providing farmers a basket of multiple choices comprising alternate but matching enterprises for fulfilling household needs. In this unit we devote a section to discuss the concept and need for organic agriculture as an alternative to the current unsustainable agricultural practices in the South Asian region.

Objectives

After studying this unit, you should be able to:

- discuss the concept and various components of integrated farming systems;
- explain the role of integrated farming system in sustaining overall agricultural production;
- state the effectiveness of integrated farming systems in supplementing the farm family income;
- state the future possibilities of farming systems in providing food security in the region;
- explain the need and benefits/advantages/constraints of organic farming;
- suggest more efficient use of external inputs in farming systems; and
- exchange and discuss various strategies and experiences concerning integrated and organic farming systems.

12.2 FARMING SYSTEM

Farming system represents an appropriate combination of farm enterprises like cropping systems, livestock, poultry, fisheries, forestry and the means available to the farmer to raise them for increasing productivity and profitability. What kind of a farming system a farmer adopts and what suits the farmer's resources are of prime importance to sustain the natural resources, farm income and meet the diversified demands of the growing population for food, fodder, fibre and fuel.

12.2.1 Concept and Components

Farming has been divided into disciplines viz. crop production, dairy, husbandry etc., each being the domain of different subject specialists. However, farmers are not specialists; they regard farming as a whole and this whole is more than the sum of the parts seen by the subject specialists. Moreover, farming is not just a collection of crops and animals to which certain inputs are applied and immediate results are available. Rather ,it is a complicated network of soil, plants, animals, implements, workers, other inputs and environmental influences with the reins held and manipulated by the farmer, who given his or her preferences and aspirations, attempts to produce output from the inputs and technology available.

The term **farming system** refers to a particular arrangement of farming enterprises that are managed in response to the physical, biological and socioeconomic environments and in accordance with the farmer's goal, preference and resources. A farming system can be viewed as a system in which the farm household is the basic unit that focuses on:

i) the interdependencies between the various components under the control of the farm household members and

ii) how these components interact with the physical, biological and economical factors not under the control of the household.

Components of the farming systems are the individual pieces that make up the system of concern. Almost every component is a system in itself with multiple components at a smaller scale, and it plays its specific role in relation to the system as a whole. Farming systems can be characterized according to their biophysical and human setting:

Biophysical setting: The genetic resources, techniques and strategies chosen by farmers to develop and maintain their farming system, depend on their ecological conditions. Farmers generally depend on their local resources to the greatest extent ossible but many physical (climate and soil)and biological(pests and diseases) factors nay limit the farming options.

Iuman setting: Farming systems are determined by regional, socioeconomic, ultural, and political characteristics. Each farm household provides the management, nowledge, labour, capital and land for farming and consumes at least a part of the roduce. The household thus is a centre of resource allocation, management, roduction and consumption. Certain factors may also limit the farming options like, vailability of land, labour or capital, or market demands, transport facilities and uman skills.

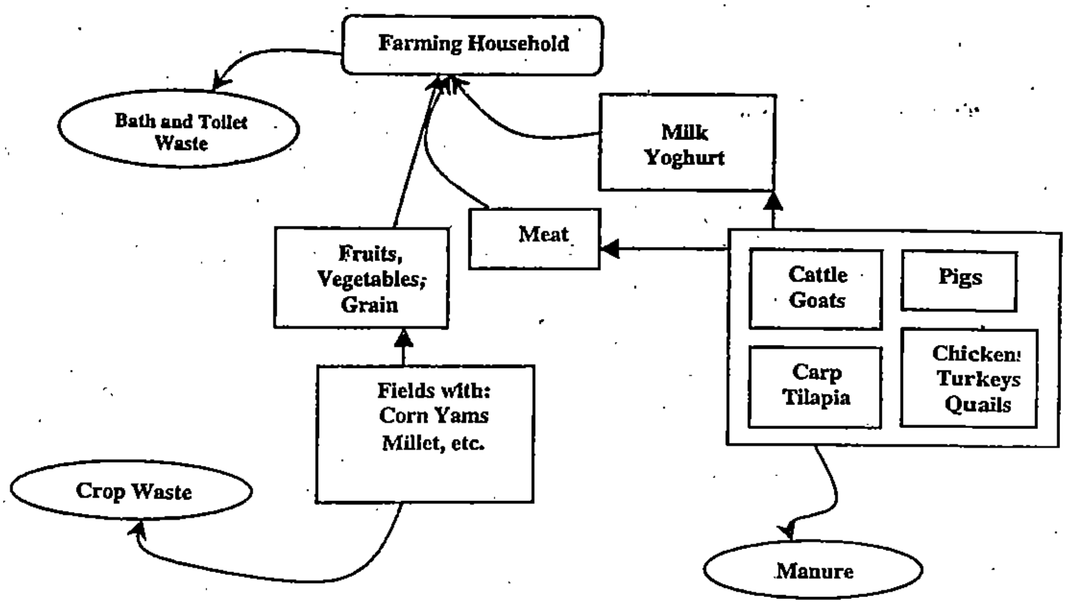
The aim of farming systems is to integrate farm enterprises for optimum utilization of esources, minimize environmental damage, increase the farmer's income, create mployment opportunities throughout the year, increase export potential and support gro-industry and food security.

A sustainable agricultural farming system aims at improving agricultural production while conserving the regenerative capacity of the natural resource base. It combines raditional ecological understanding and results of modern scientific research on atural processes. It is thus maximizing use of knowledge of natural processes. Sustainable farming systems include both organic and integrated agricultural systems.

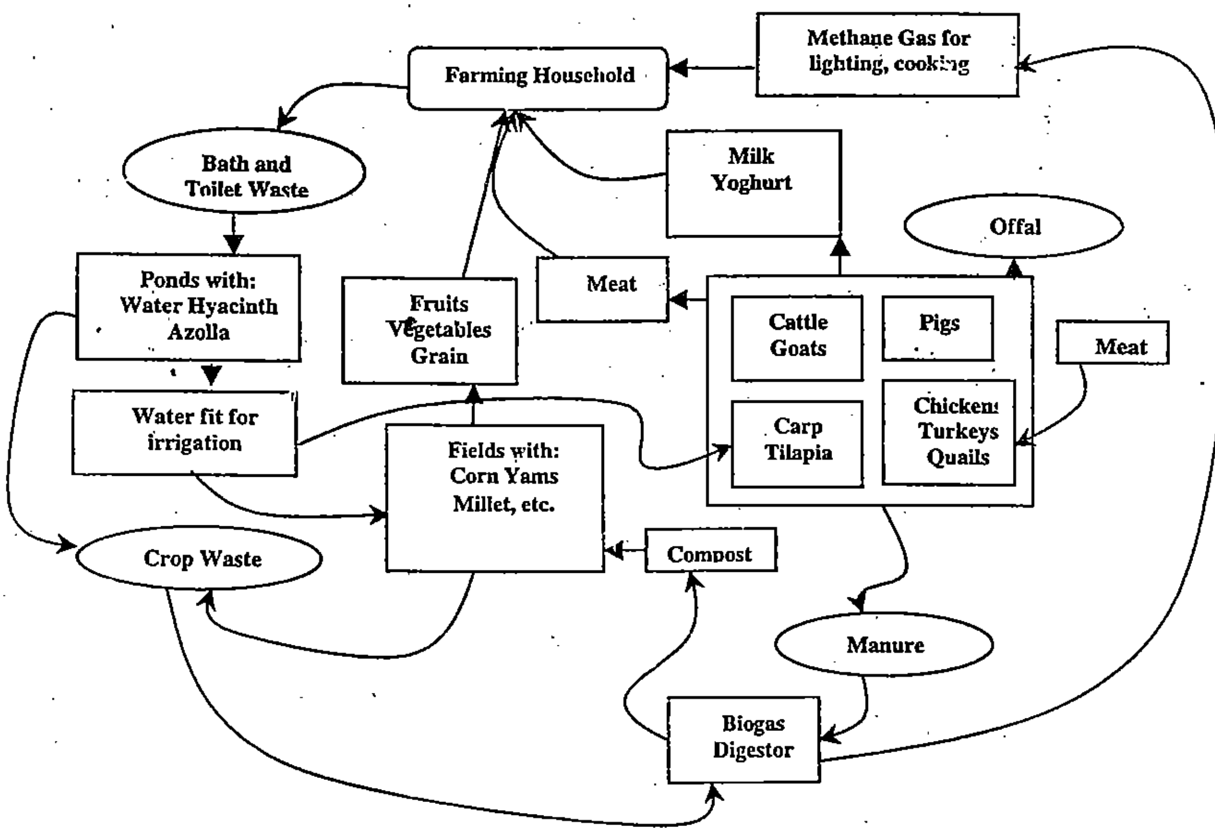
12.2.2 Integrated Farming

In view of the geometric rise in the population of the South Asian region and shrinkage of agricultural land and operational holdings in the post green revolution era, farmers have to include some more enterprises like animal husbandry, bee keeping, fisheries, piggery etc., apart from cropping systems to augment their income and conserve the natural resources and to attain food security. Farmers feel the need to shift from low profit field crop farming system to a diversified multi- enterprise farming system. The traditional mixed or **integrated farming system, (IFS)** which had been less productive, but ecologically more sustainable, is coming back.

The integrated farming system aims at a sustainable, highly-productive, socially desired mixed farm. This will be reached by minimizing the nitrogen supply and biocide use per unit produce while maintaining high yields and product quality. This aim is characteristic for the so-called globally-oriented agriculture where high productivity and efficiency are combined by making maximal use of the biological mechanisms that dictate the functioning of these agricultural systems. This type of agriculture does not exclude particular inputs such as fertilizers and biocides, but maximizes their efficiency and effectively at the global scale. It is based on lower external inputs and a (more) natural crop protection system than conventional farming. Thus integrated farming is particularly useful for developing countries, as it requires minimal inputs in terms of expensive chemicals or technology. This has a core component of the most dependable farming system, for instance field crop, around which other complementary farming systems, like livestock/aquaculture/ beekeeping/mushroom culture/poultry/ agro forestry etc., are integrated for obtaining maximum productivity, profitability and sustainability. An integrated farming system could comprise agri- livestock or agri- livestock- poultry, or agri-horticulture-silviculture, etc. By using the by-products or wastes of one component as inputs to another, such farming systems are able to increase the net efficiency of the entire system and at the same time minimize overall waste production and reduce dependency on industrially derived external inputs. Figure 12.1 shows the material flow in a conventional farming system and an integrated farming system. However, before an integrated farming system is designed, 'the farmers' needs, financial implications, opportunities available and the socio-economic conditions and marketing facilities of the region are to be kept in mind. At the same time one has to be aware of the changes taking place in regional, national and international agricultural scenarios and in environmental parameters.



Conventional Farming System



Integrated Farming System

Fig.12.1: Comparison of material flow in a conventional farming system and an integrated farming system.

The farming system should be fully integrated in order to use the locally available alternate resources,. For example, in Asian countries, in a system consisting of livestock as one of the components, animal manure is an important source of fuel. It is estimated that out of the world's population 8 to 12% depend on manure for heating and cooking. Animal manure is a valuable fertiliser too and forms a link between crop cultivation and animal production systems throughout the developing world. At the same time, manure can be put to good use through biogas production and cultivation of earthworms. Biogas is probably the cheapest source of energy for the rural areas of developing countries. Its production would not only save fuel wood, it would also be beneficial for integrated farming systems by providing alternative to fertiliser for crops, fish and water plants (Fig 12.2). Other benefits would be reduction of smells and elimination of smoke during cooking and destruction of pathogens, thereby improving the farm environment.

The beneficiaries of the use of local resources in integrated farming systems are the farm families, in particular the women as they are the one to collect the firewood an activity that can be largely replaced by biogas when livestock are confined and local feed resources are also used in the bio-digesters. Thus the role of livestock in farming systems is multifaceted and must be seen as contributing to the total farming system and not only as a primary form of production of meat, milk etc.

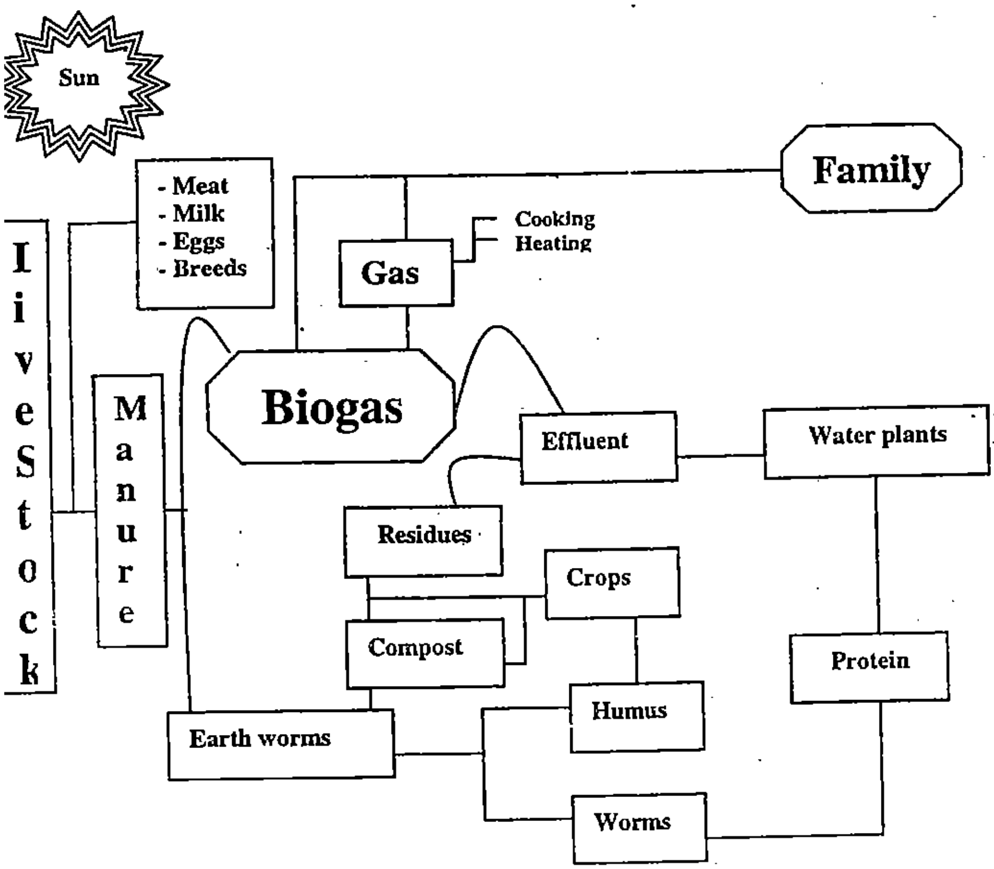


Fig.12.2: Integration of livestock and crop cultivation making maximum use of the manure

Integrated poultry-fish farming is practiced in many countries of the world, and especially in Asia. It is not only an efficient way of recycling farm wastes but also produces high economic returns Studies have revealed that livestock manure is an important source of nutrients for fish cultivated in ponds. In India , the production of poultry birds with fish resulted in fish production of 4,500 to 5000 kg/ha. Chicken manure is considered a complete fertiliser as it has the characteristics of both organic as well as inorganic fertiliser, and fish culture in an integrated poultry- fish system, uses free manure as a pond fertiliser. Raising poultry over fish ponds has a number of benefits for the south Asian region viz. i) chicken houses constructed over ponds do not have to compete for land needed for other purposes in a region where growing populations is reducing the area of land available for farming; ii) hygienic conditions are better in chicken houses constructed over ponds, as the excreta falls directly in to the ponds; and iii) chicken excreta provides food and fertiliser for fish culture.

- **Use of marginal and waste land**

  Marginal and wastelands can be efficiently used for a combination of fisheries, poultry, dairying, mushroom cultivation and bee keeping with crop raising.

- **Increased employment**: Studies conducted on integrated farming systems in India show that adoption of crop+fisheries+ livestock on arable land can give three times more gainful employment than crop alone. If other farm enterprises like silviculture, beekeeping and mushroom cultivation are also adopted, they can provide greater income and gainful employment to farm families to increase their standard of living.

- **Restoration of soil fertility and conservation of the environment:** With efficient recycling of crop residue and farm waste in crop- livestock- poultry-fishery system, soil fertility can be restored. It will also reduce the dependence on chemical fertilizers and a cleaner environment can be maintained.

In material as well as social terms, integrated farming can affect human development in the following ways:

- It can make farmers more self sufficient as well as self-reliant. There is a substantial generation of knowledge and innovations because of the different systems are involved.

- Poor and landless farmers can be assisted to generate income and thus participate in the development process.

- External inputs needed in the system are minimized. It also provides for better utilization and distribution of labour. Costs are generally reduced and productivity of labour is increased.

- In areas where farmers face problems of land fragmentation, integrated farming has the potential for giving opportunities for productive activities.

- By appreciating that women contribute far more to household security, integrated farming will go a long way in improving the condition and welfare of women.

Therefore, there is a general improvement in the sustainability of the system, creating more wealth on a more equitable and environmentally friendly basis.

Thus integrated farming system approach is not only a reliable way of obtaining fairly high productivity with substantial fertilizer economy, but also a concept of ecological soundness leading to sustainable agriculture.

Box 12.1: Resource optimizing in coffee and cardamom based faming system — a case study

Robusta coffee and cardamom are perennial crops and can be grown together for efficient utilization of natural resources. An experiment was conducted for nine crop seasons (1985 to 1994) of a monoculture of coffee and mixed crop of coffee and cardamom. The net returns in mixed cropping were 4.06 times more than mono cropping. Bee keeping can also help the small and marginal farmers growing cardamom as the natural forest flora offers abundant pollen and nectar for honey bees. Indian honeybee *(Apis cerea Fab)* is the principal pollinator of cardamom flowers. The small farmer can keep 25-30 beehives and earn a profit of approximately Rs. 20,000 per year.

Similarly scientific piggery using exotic varieties like Yorkshire, Hampshire and landrace in the high ranges of the western ghats, has been found to gain faster growth rates, better feed conversion and higher yields. These pigs can be fed concentrated feed as well as kitchen waste, garbage, green fodder and aquatic weeds. Long term study showed that a commercial piggery unit with 250 piglets resulted in a net profit of Rs 7,17,900 over a period of 12 years. Since there is a great demand for pork in the western ghats, hence piggery offers a good scope for organic recycling of farm waste and high returns for the farmers.

Water harvested in the farm pond would normally be used for irrigating the plantation crops. Using intensive fish culture known as composite fish culture which uses several indigenous varieties like catla, rohu, mrigal and exotic varieties like carp, grass carp and silver carp can offer better yields and profits than conventional fish culture in the farm ponds. This kind of intensive mixed farming can not only increase the overall productivity and economic returns but also help the farmer in effective utilization of natural resources.

SAQ 1

What are the elements of integrated farming?

12.3 ORGANIC FARMING

Organic farming is a method in which land is cultivated or crops raised in such a way so as to avoid or exclude the use of synthetic inputs like fertilizers, pesticides, hormones, antibiotics, feed additives etc; and to largely rely on crop rotations, crop residues, animal manure, farm waste and other biological material along with beneficial microbes for release of nutrients and plant protection. As per FAO definition, **organic agriculture is a unique production management system which promotes and enhances agro-ecosystem health, including biodiversity, biological cycles and soil biological activity, and is accomplished by using on-farm agronomic, biological and mechanical methods in exclusion to all off-farm inputs.**

The concept of organic farming is not new to the countries of the South Asian region. The traditional agricultural practices followed from ancient times in the region have evolved through centuries to create agricultural systems adapted to local environmental and cultural conditions. Owing to their nature, traditional systems do not use synthetic agricultural inputs and many if not all traditional systems fully meet the criteria for organic agriculture. But over time, the use of inorganic fertilizers, chemical pesticides and other synthetic inputs has led to enormous levels of chemical buildup in our environment, in soil, water, air, in animals and even in our own bodies. Fertilisers have a short-term effect on productivity but a longer-term negative effect on the environment where they remain for years after leaching and running off, contaminating ground water and water bodies. The use of hybrid seeds and the practice of monoculture has led to a severe threat to local and indigenous varieties, whose germplasm can be lost for ever. This has led to the renewal of interest in the age old practice of organic farming to ensure uncontaminated food production as well as keep the land in a healthy condition. The primary goal of organic farming is to ensure optimum health and productivity of interdependent communities of soil life, plants, animals and people. Even though organic agriculture cannot ensure that products are completely free of residues, methods are used to minimize pollution from soil, air and water.

It is also being realized increasingly that 'Green Revolution' involving technologies such as mechanization, intensive irrigation, improved seeds, synthetic fertilizers and pesticides has reached a plateau, and is now sustained with even higher inputs and is giving diminishing returns. In the name of growing more to feed the earth, we have taken the path of unsustainability. The effects already show - farmers committing suicide in growing numbers with every passing year; the horrendous effects of pesticide sprays (endosulphan) by a government-owned plantation in Kerala, (India) some years ago; the pesticide-contaminated bottled water and aerated beverages are only some instances. The bigger picture that rarely makes news however is that millions of people are still underfed. Developing countries that traditionally have had a net surplus in agricultural trade have to depend on food imports. The present food production model ties farmers into conditions of dependence on large corporations who buy agricultural inputs in terms of seed, fertilizers, and pesticides and to sell their produce. Another negative effect of this trend has been on the fortunes of the farming communities worldwide. Despite this so-called increased productivity, farmers practically in every country around the world, have seen a downturn in their fortunes. The only beneficiaries of this new outlook towards food and agriculture seem to be the agro-chemical companies, seed companies and – though not related to the chemicalisation of agriculture, but equally part of the "big money syndrome" responsible for the farmers' troubles – the large, multi-national companies that trade in food, especially food grains.

In the present conditions to attain food self reliance, agriculture in the region would have to depend on local resource management without having to rely on external inputs. This would involve substituting purchased goods by knowledge of natural processes that optimize competition for nutrients and space within the agri-ecosystem. Organic farming has the capability to take care of each of these problems. Besides, the obvious immediate and positive effects, organic or natural farming has on the environment and quality of food, it also greatly helps a farmer to become self-sufficient in his requirements for agro-inputs and reduce the investments on farming costs. Thus organic agriculture offers a means to address food self- reliance, rural development and conservation of biodiversity, and natural resources.

12.3.1 Steps of Organic Farming

Organic agriculture is the most regulated form of ecological agriculture though it is not limited to certified organic farms and products alone, but includes all productive agricultural systems that use natural processes rather than external inputs to enhance agricultural productivity. Agriculture that meets the organic criteria but is not subject to inspection, certification and labelling is referred to as non-certified organic agriculture as distinguished from certified organic agriculture. However, both rely on the same technology and principles but an organic farm reflects an intentional management system according to organic principles. Non- certified organic agriculture therefore includes the traditional farming systems following ecological approaches to enhance their production without the use of chemicals.

The techniques and practices integral to organic farming may be adapted and made suitable to the surrounding of the farmers. Organic farming requires that the answers to a problem should come from the farmer, his fields and his surroundings rather than from a chemical factory or the pesticide shop. Moreover, there cannot be a fixed package of practices - every area is unique in its own way, has its own endemic species - both plant and animal - and its own natural conditions, problems and solutions.

1. **Conversion of land from conventional management to organic management.**

   In the case of a chemical farm converting to organic however, there is often a loss in yield and it takes a few years before yields increase and stabilize at a level often higher than that achieved under a chemical regime. It is therefore, recommended to convert gradually over a period of three to four years to obtain full organic status if income from the farm is a key issue. If the land was under exploitative cropping that is, arable cropping, with crops other than legumes, before the beginning of conversion then some fertility building crop like grasses and legumes must be planted.

2. **Crop production with the use of alternate sources of nutrients**

Building of soil fertility is the cornerstone of organic agriculture. Organic practices create suitable conditions for soil biota and abiotic resources through manipulation of crop rotations, green manuring, reduced tillage and organic fertilisation (animal manure, crop residue, green manuring, compost etc,). Let us look at some of these alternate methods of increasing the nutrient content of soil.

Crop residues

Huge quantity of crop wastes/residues and animal wastes are always available on a farm. The common practice is to burn plant wastes which, besides being an environmental disaster, is also a waste of the huge potential. Properly recycled, these residues form excellent compost in one to six months, depending upon the composting process used. Every farm can choose or even develop a suitable compost process depending upon its own needs and resources, including availability of labour, managerial time and investment potential (Fig.12.3).

One method of composting farm wastes is by **vermin-composting**, which uses earthworms to eat and break up the organic wastes. There are a number of other methods innovations, adaptations and improvements which always possible. Methods can be aerobic or anaerobic and above ground or below, though the best way to get high quality compost quickly, is to make a heap above the ground.

Composts can be fortified using various natural additives and enriched/improved by using effective micro-organism preparations.

Fig.12.3: Composting pit (Photo courtesy Vikas Chadda, Satavic Farm)

Mulching

Mulching is the use of organic materials to cover the soil, especially around plants to keep down evaporation and water loss. Besides this, mulching adds valuable nutrients to the soil as they decompose. Mulching is a regular process and does require some labour and plenty of organic material, but has excellent effects, including encouraging the growth of soil fauna such as earthworms, preventing soil erosion to some extent and controlling weed.

Green Manuring

This is an age-old practice prevalent since ancient times. A crop like *dhaincha* (*Sesbania aculeata*), sunnhemp or horsebean or a mix of all three is sown (usually) just before the monsoons. Around flowering (30-45 days after sowing), the crop is cut down and mixed into the soil after which the season's main crop is sown. Green manuring is beneficial in two ways - firstly it fixes nitrogen, and secondly the addition f biomass (around five to ten tons/hectare) greatly helps in improving the soil texture nd water holding capacity. Green leaf manuring can also be carried out if sufficient eguminous tree leaves are available.

Cover cropping

Cover cropping is normally carried out also with nitrogen-fixing crops that grow fast nd require little or no inputs like water or additional manuring. While cover crops an yield some returns, they are mostly used for covering the soil in the fallow ionths, adding nitrogen to the soil, suppressing weeds, preventing soil erosion and iter used as biomass or fodder. Velvet bean is an example, and it finds use as a fodder rop and biomass generator. Another useful cover crop is *Dolichos lablab* which is a ource of fodder and food.

Crop Rotation and Polyculture

ne of the most important aspects of organic farming is the strict avoidance of ionoculture, whether annuals or perennials as monoculture systems are unhealthy for ie ecosystem of which they are a part.. Traditional farmers till date follow the ystems of crop rotation, multi-cropping, inter-cropping and polyculture to make iaximum use of all inputs available to them, including soil, water and light, at a iinimum cost to the environment.

Crop rotation is the sequence of cropping where two dissimilar type of crops follow ach other For example, cereals and legumes, deep-rooted and short-rooted plants and where the second crop can make use of the manuring or irrigation provided some ionths earlier to the first crop (e.g. rice + wheat, rice + cotton). The combinations ossible are endless, and will depend to a great deal on the local situations.
Multi- cropping or mixed cropping is the simultaneous cultivation of two or more rops in a year. In Indian agricultural tradition, farmers have been known to sow as iany as 15 types of crops at one time. An example of multi-cropping is Tomatoes + Onions + Marigold (where the marigolds repel some of tomato's pests). Figure 12.5 hows a cropping system of coconut and banana.

nter- Cropping is the cultivation of another crop in the spaces available between two ows of the main crop. A good example is the multi-tier system of coconut + banana + ineapple/ginger/leguminous fodder/medicinal or aromatic plants. While ensuring io-diversity within a farm, inter-cropping also allows for maximum use of resources.

Fig.12.4: A cropping system of coconut and banana. A mid- storey and a ground crop can also be introduced to make it a truly integrated cropping system.

'he concept of polyculture should not be limited to plants only but extended to cover ıe whole farm. This way, one system's wastes and by-products are another system's ıputs, or one system is comprised of more than one component, which allows for fficient use of available resources.

ın example of such integration is: rice-fish/prawn systems (Fig. 12.5) where the ısh/prawn mature in the waterlogged fields and are harvested before the water drains way (making use of available resources). They have a symbiotic relationship with the ıain crop in two ways - manuring and pest control.

'ig.12 5: **The fish pond shown in the picture is part of an integrated farm where all inputs except fish seed is sourced from the farm it self. Organic practices have increased the yield in comparison to neighbouring farms (Photo: courtesy website of farms).**

\ larger and more permanent example of integrated multi enterprise farming system :ould be: annual crops + tree crops + dairy cows + honey bees.
The animals and tree crops are benefited by the honey bees (pollination); crop esidues and tree pruning are useful as cattle feed and green leaf manure, dung from he cattle are used for bio-gas production, after which the slurry finds use in the fields ıs manure and in the compost heap. As you have read in the earlier section, there is no imit to the diversity of integration that is possible on a farm.

Microbial biofertilisers

These are biologically active (living or temporarily inert) inputs and contain one or more types of beneficial micro-organisms such as bacteria, algae or fungi. Every microorganism – and hence each type of biofertiliser – has a specific capability and function. There are broadly seven types of biofertilisers :

1) Rhizobia is a group of bacteria that fixes nitrogen in association with the roots of leguminous crops. Rhizobia can fix 40-120 kgs. of nitrogen per hectare annually depending upon the crop, rhizobium species and environmental conditions. They help improve soil fertility, plant nutrition and plant growth and have no negative effect on soil or the environment. Every leguminous crop requires a specific rhizobium species.

2) *Azotobacter* is also a group of nitrogen-fixing bacteria but unlike rhizobia, they do not form root nodules or associate with leguminous crops. They are free-living nitrogen fixers and can be used for all types of upland crops but cannot survive in wetland conditions. In soils of poor fertility and organic matter, *Azotobacter* need to be regularly applied. In addition to nitrogen-fixation, they also produce beneficial growth substances and beneficial antibiotics that help control root diseases.

3) *Aazospirillum* species also do not form root nodules or associate with leguminous crops. They are however not free-living and live inside plant roots where they fix

nitrogen, and can be used in wetland conditions. This group of microorganisms also produces beneficial substances for plant growth, besides fixing atmospheric nitrogen. *Azospirillum* does well in soils with organic matter and adequate moisture content, and requires a pH level of above 6.0.

4) Blue-green algae or Cyanobacteria are free-living nitrogen-fixing photosynthetic algae that are found in wet and marshy conditions. They are easily prepared on the farm but can be used only for rice cultivation when the field is flooded.

5) *Azolla* is a free-floating water fern that fixes nitrogen in association with a specific species of cyanobacteria. *Azolla* is a renewable biofertiliser and can be mass-produced on the farm like blue-green algae. It is a good source of nitrogen and on decomposition, a source of various micronutrients as well. Its ability to multiply fast, means it can control weeds in (flooded) rice fields. Azolla is also used as a green manure and a high-quality feed for cattle and poultry.

6) Phosphate solubilizing organismse are a group of bacteria and fungi capable of breaking down insoluble phosphates to make them available to crops. Their importance lies in the fact that barely a third of phosphorous in the soil is actually available to the crop as the rest is insoluble. They require sufficient organic matter in the soil to be of any great benefit.

7) Mycorrhiza is a sweeping term for a number of species of fungi which form a symbiotic association with the plant root system. Of these, the most important in agriculture is vesicular-arbuscular mycorrhiza or VAM. Plants with VAM colonies are capable of higher uptake of soil nutrients and water. VAM strands act as root extensions and bring up water and nutrients from lateral and vertical distances where the plant root system does not reach.

Reduced Tillage

Reduced tillage or conservation tillage is a practice of minimising soil disturbance and allowing crop residue or stubble to remain on the ground instead of being thrown away or incorporated into the soil. Reduced tillage practices may progress from reducing the number of tillage passes to stopping tillage completely (zero tillage). Reduced tillage is important from the viewpoint of organic farming too. The cover of crop residue helps prevent soil erosion by water and air, thus conserving valuable top soil. Soil structure improves because heavy machinery (which causes soil compaction) is not used and soil tilth is not tampered. With earthworms not being disturbed, their numbers increase bringing with them the accompanying benefits of better soil aeration and improved soil fertility. Microbial activity in soil also increases for the same reason.

3. Non-chemical Management of Weeds and Pests

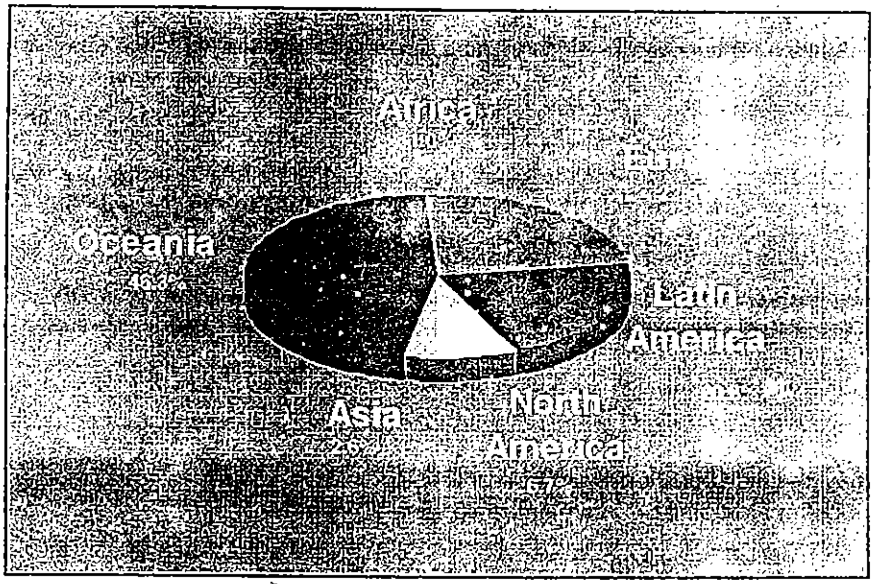
In a well-managed organic farming system, pests and weeds are considered to be part of the system itself as they do not usually get out of control. Many organic farmers believe, and perhaps rightly so, that any pesticide, should not be used. Where prophylactics do not work, and pest populations reach proportions where economic loss is a surety, there are a number of non-chemical methods of pest control. These include:

1. Picking off the pest by hand (where the pest is a large caterpillar for example),
2. Use of pheromone traps,
3. Use of light traps (for moths and other insects),
4. Use of predator species,
5. Growing trap crops (e.g. Mustard with cabbage; Maize around cotton),
6. Use of microbial pesticides and biological agents like *Heliothis, Spodoptera, Trichogramma, Trichoderma*, etc.,
7. Using easily-prepared natural pesticides.

or preparing natural bio-pesticides, a number of plants can be used. Neem, ginger, ıillies, *Vitex negundo* (Indian pivet tree), custard apple (the seeds), *Pongamia innata* (pongam/karanj), asafoetida, turmeric, garlic, tobacco, sweet flag, *Nux omica*, tulsi and Persian lilac are among the many plants that are commonly used in est control. Each pest requires a specific preparation.

2.3.1 Organic Farming Scenario

rganic farming is a fast growing segment of agriculture world wide. The total area ıder organic management is shown in Fig. 12.6(a).and the total number of organic rms in each continent is shown in Fig. 12.6(b). Organic food products like fruits and getables are becoming more popular in the foreign markets like USA, Europe and pan and get sold at a higher price than conventional food products: World trade in ganic products was estimated at 17.5 billion dollars in 2000 and is growing gnificantly in European countries, USA and Japan and at present the demand tpaces the supply. Amongst all nations of the world, Austria and Denmark lead in nsumption of organic foods. The average consumption of organic food in EU and SA is approximately $15 per capita per year.



Fig,12.6: a) Share of each continent in the total area under organic management.

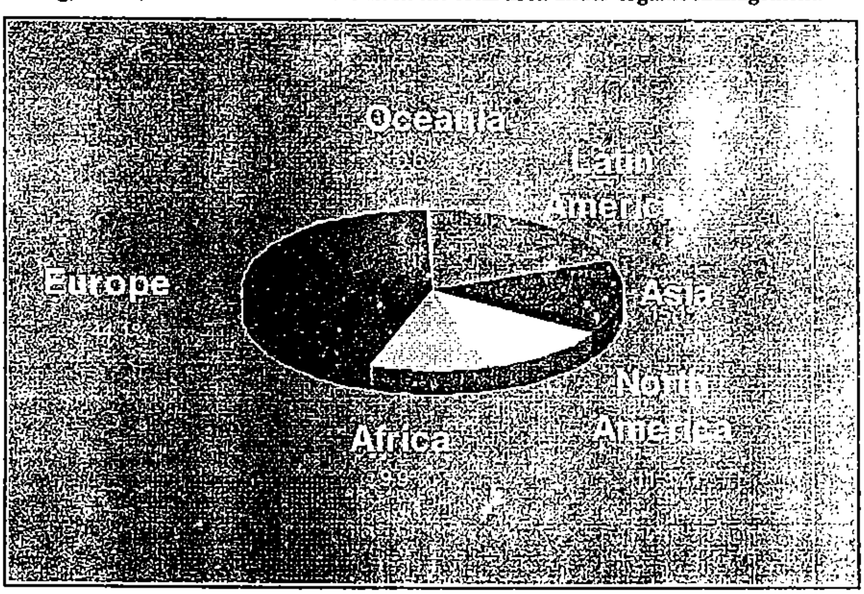


Fig.12.6: b) Total number of organic farms, share for each continent.

The recognition of the role of organic agriculture in achieving environmental objectives including sustainable use of land, led to the adoption of agri-environmental measures to encourage organic agriculture. Consumers in the North concerned with food quality, as well as protection of the environment were the first to initiate a demand for organically produced food products. The crisis over dioxin contaminated food and livestock diseases such as foot and mouth disease and Bovine Spongiform Encephalopathy (BSE) further increased the demand for organic foods. These concerns have also opened markets for export from developing countries especially in the south Asian region enhancing their foreign exchange earnings and diversified exports. Price premiums of about 10-50 percent over non-organic products can help to tide over the expense incurred in switching over to organic approaches. Many countries offer good export opportunities for supply of organic foods not grown domestically for instance coffee, tea, cocoa, spices, sugar-cane, tropical fruits and beverages as well as off season fresh produce.

12.3.3 Organic Agriculture in India

In a study conducted by Food and Agriculture Organisation (FAO) in mid-2003, India has 1,426 certified organic farms supplying approximately 14,000 tons of organic food / produce annually. But the fact is that there are a number of farms in India which have either never been chemically-managed / cultivated or have converted back to organic farming because of their farmers' beliefs or purely for economic reasons. These farms use crop residues, manures, legumes and neem to grow their crops and rely on crop rotation and interplanting to do their job. Although the products grown under these systems are not defined as organic products, they are by all means genuinely organic. Their produce either sells in the open market along with conventionally grown produce at the same price or sells purely on goodwill and trust as organic through select outlets and regular specialist bazaars. These farmers will never opt for certification because of the costs involved as well as the extensive documentation that is required. Now it is high time that these products are classified accordingly and the farmers get a premium on their produce. This will also go a long way to alleviate their poverty and raise the standard of living.

There are a number of farmers that grow organic vegetables, fruits, plantation crops, spices and tea organically and export it to Germany and Netherlands. Usually farmers associated with big export houses do not have to bother about the sale of their products or about certification, it is the small and marginal farmers that face the difficulties.

Organic Sugar Cane Cultivation in Belgaum, Karnataka, India – Case Study

The organic farmer's club in Belgaum, Karnataka has 400 members, some of whom are already growing organic crops, while others are in the process of converting to organic farming. One of its founding members- Suresh Desai has been caring for the family property of 4.5 hectares of sugar cane growing farmland. Conventionally sugar cane is grown in a three year cycle. The crop takes about 18 months to mature, after which it is cut and the ratoon crop is left to grow. After cutting the cane the remaining trash in the field is either used as roofing material or burned in the field. This burning releases the nutrient in the trash as well as helps to eliminate the pests in the field. However the nutrients in the ashes are leached out after the first irrigation, and Desai's yield was like other farmers of the region about 70to 90 tons per hectare. With escalating prices of external inputs he realized that he could stop and even reverse the process of degeneration in his fields. With this realization began his experiments that ultimately changed his sugarcane cultivation practices.

At first he tried composting his crop residue to fertilize his crops but that involved additional labour and time. This brought him to his second step in which he tried leaving the residue in the fields that produced them. With this method Suresh was able to reduce the application of chemical fertilizer by 50 percent while maintaining the ame productivity. But irrigation related problems started appearing and he tried ıulching to prevent evaporation losses and with this he devised another way of rigating his fields- the two in one irrigation system (Fig.12.7). In this system he kept ıe trash in one row and made water channels in the second row. By connecting the wo parallel irrigation rows with perpendicular trenches at the ends he was able to vater his fields more easily. Thus, Suresh Desai was able to reduce the irrigation equirement and after harvesting the cane he put the trash in the rows that were used reviously as water channels.

After three years Suresh observed a remarkable improvement in soil and increase in oil life. After using green manure between the rows of cane he found that there was ıo need to use chemical fertilizers. He also found his crops healthy thus, eliminating he use of chemical pesticides.

Furthermore, because of the healthy condition of his fields Suresh has stopped ploughing or turning his field. The only soil work left is the periodic maintenance of he irrigation channels.

Ever since ploughing of the field has stopped, the water retention capacity of the soil ıas increased and frequency of irrigation has decreased from once in 10 or 12 days to 20-25 days. In this way the water usage has reduced to 75-80 percent in comparison to conventional usage.

Soil fertility in Suresh's field is maintained by the combined effect of:

- Reduced irrigation by which salt build up is minimized and nutrient leaching is prevented.
- Trash composting which prevents evaporation of moisture from the soil, improves the soil structure and quality and as the trash decomposes it provides nutrients back to the roots.
- Green manuring which is a source of nitrogen and other elements, thus compensating for the high carbon content of trash and according to him also combats the effects of continuous mono-cropping without rotation.
- Soil conditioning that hastens the decomposition of trash by enhancing the proliferation of fungi.

The benefits of Suresh's methods are:

- His canes mature in 8 or 8.5 months in comparison to 11 or 12 months of the conventional farming system.
- Sugar recovery is better than the chemically grown ones.
- His canes are healthy with no smut or grassy shoot and no chemicals or botanical sprays have been needed.
- Suresh's cane yield is 100tons in comparison to his fellow farmers whose yield is 110 tons but then his investments are much less in comparison to that by his fellow farmers.
- He claims that water requirement is even less than that required through sprinkler irrigation.
- As minimum tillage is practiced there is no fallow or replanting of sugarcane. Thus labour cost is significantly reduced.
- Since he used the natural biological cycles as the main input, there was an impressive increase in soil biodiversity, which is now maintaining the yields.

- The use of traditional dry farming crops as green manure, functions as a gene pool for the rapidly disappearing species.
- Suresh has been able to reduce the costs per hectare, mainly due to decrease in labour requirement. As he uses few external inputs investment is low and his yields are average, but his net profits are higher than those of a conventional farmer.

More and more farmers are following Suresh's model of sugarcane cultivation and some have obtained even better results than Suresh himself! Through out his experimentation Suresh has learnt a variety of lessons, all of which are fundamental to organic agriculture, and the sustainable use of natural resources. His experiments have shown that a diverse soil biodiversity is a powerful tool for organic agriculture and can substitute external inputs entirely (*Source* FAO).

12.3.2 Benefits of Organic Farming

Organic farming differs from other farming systems in a number of ways:

- It favours renewable resources and recycling of wastes so that nutrients are returned to the soil. A succession of micro-organisms (bacteria, fungi, detritus feeding invertebrates) occurs in the detritus , until organic matter is reduced to elemental nutrients.
- It generates only non-accumulative and biodegradable waste and by-products.
- Organic farmers build upon the environmental services and help to enhance soil fertility. Soil structure is improved through nutrient mining by deep rooted crops, improvement of nutrient availability through mycorrhizal associations, crop rotation crop residues green manures etc. Minimum tillage favours carbon retention in the soil and avoids soil compaction. Integrating trees and shrubs conserves water and provides defence against adverse weather conditions. Due to change in soil structure and increased organic content of the soil in organic management, water efficiency is likely to be high on organic farms.
- It respects the environment's own system for controlling pests and disease in raising crops and livestock and avoids synthetic pesticides, herbicides, chemical fertilizers, growth hormones antibiotics and gene manipulation.
- It helps in maintaining environmental health by reducing pollution and reduces health hazards due to absence of residues in the agricultural products.
- It promotes and enhances agro-ecosystem health, biodiversity, genetic heterogeneity, biological cycles and soil biological activity.
- It reduces cost of agricultural production in terms of energy use. In organic farms, mechanisation is often replaced by labour, especially for weeding and harvesting of diversified crops. Indirectly, substituting natural for synthetic fertilizers saves non-renewable energy and nitrogen leaching is minimized.
- Diversification of crops and livestock varieties on organic farms means that risks are spread. There may be less chance of a bumper year for all enterprises but then there is less chance of low production in all crops and livestock simultaneously. This contributes to food security and stability of supply.
- Although yields in organic farms are less than yields of intensive-input conventional farms, they are still within acceptable limits and experiences of low productivity agro-ecosystems show potential to double or triple average yields.
- Organic farming and integrated farming also represent real opportunities for contributing to vibrant rural economies through sustainable development.

Nevertheless, organic farmers face huge uncertainties. The constraints in adoption of organic farming practices by farmers are often the high managerial costs and risks of shifting to a non chemical way of farming, limited awareness and lack of marketing infrastructure, inability to capture marketing economies and limited access to capital.. Lack of information is a major obstacle to organic conversion. Most people in all kinds of areas including scientists, researchers, extension officers and politicians strongly believe that organic agriculture will not be able to contribute to food security.

Let us now examine the linkages between organic agriculture and biodiversity in the next section.

SAQ 3

List the three most important issues in your opinion that are related to organic agriculture.

12.4 ORGANIC AGRICULTURE-BIODIVERSITY LINKAGE

Organic agriculture offers a means to address food self-reliance, rural development and conservation of nature. The common thread in all this is the sustainable use of biodiversity. Successful organic agriculture needs appropriate functional groups of species and essential ecosystem processes as its main input to compensate for the restriction on the use of synthetic inputs of fertilizers and plant protection chemicals is imminent. In fact, a close relationship exists between organic agriculture and biodiversity conservation. A natural ecological balance between below and above ground is the key to success in organic agricultural systems. Therefore, a organically healthy soil is the base for food production and a diversity of plants and animals on land prevents pests and diseases.

- Organically managed soils significantly increase biological activity and total density of soil micro-organisms. Such biodiversity improves nutrient cycling and soil structure.
- Organically managed soils have an abundance of earthworms and other beneficial arthropods living above the ground and this improves the condition of crops. The biomass of earthworms in organically managed soils is 30-40 percent higher than in conventional systems. More abundant predators help to keep the pests in check.
- Organic crops benefit from root symbionts (see section 12.3 too). On an average mycorrhizal colonization of roots is highest in crops unfertilized grown under organic systems. Conventional crops have 30 percent lower colonization levels.
- Organic soils have higher micro-organisms that mineralize more actively and also contribute to stable soil organic matter and thus nutrients are recycled faster and soil structure is improved.
- Enzyme activity in organic soils is much higher than in conventionally managed agro-ecosystems
- Wild flora including endangered species are more abundant in organic fields. Weeds often sowed in strips in inorganic fields to reduce the incidence of aphids, influence the diversity of arthropods. Flowering weeds are useful in attracting pollinators and parasitoids.
- Organic agriculture has a closed nutrient cycling on the farm and therefore, has high energy efficiency..

There are several hundreds of small and marginal farmers in the South Asian region who still follow the traditional system of agriculture which promotes the use of local varieties or breeds of live stock that are better adapted to local conditions. Besides the fact that organic farmers cannot use synthetic inputs, their use of organic fertilizers and natural pesticides are uneconomical in the long run. Therefore, the comparative advantage of certain local varieties that are able to withstand local natural stress, especially in marginal lands makes organic farmers adopt biodiversity management as an important productive strategy.

In addition large pool of genetic resources for food can be maintained and other useful organisms such as predators, pollinators and soil micro-organisms are increased. Thus organic farmers are providing an important contribution to the *in situ* conservation, restoration and maintenance of agricultural biodiversity and conserve and improve the natural environment.

12.5 SUMMARY

In this unit you have learnt that:

- Farming System is a concept that puts together the components of soils, water, crops and cropping systems, livestock, labour, capital, energy, and other resources with the farm family at the focal point, thus aids in integrated management of agriculture and other related events.
- The main concept of integrated farming system is that the farm consists of subsystems which all work together in a synergistic manner, one subsystem creating inputs for the other and eventually ending in a more closed cycle. It is based on the fact that since resources are finite and so they must be used judiciously to bring about a positive change in the economic and social framework of the people.
- Integrated farming involves the utilization of locally available resources that may involve feeds, wastes and other outputs from the subsystems within. There is a high degree of nutrient cycling and reduction of energy cost. This holistic approach in total farming system helps in reduction of waste and creating interdependence and overall economic efficiency. Thus the system is more sustainable ecologically, economically and socially.
- Organic agriculture is an earth friendly system that promotes biological cycles and soil biological activity. It is based on minimal off- farm inputs and on farm management practices that restore and maintain ecological balance and harmony. All kinds of agricultural products like grain, eggs, poultry, meat, fibres, cotton etc can be produced organically without the use of synthetic fertilizers and pesticides.

Organic agriculture seeks to optimize the primary efficiency of agro-ecosystems, keeping the local environmental conditions and social needs of a region in mind. It makes use of many more varieties of plants and animals than conventional system of agriculture. Thus organic farmers are providing an important contribution to the *in situ* conservation, restoration and maintenance of natural resources including agricultural biodiversity.

12.6 TERMINAL QUESTIONS

1) Explain what is a farming system. How integrated farming system's different from organic farming system?
2) What constitutes organic agricultural system?
3) How do organic farmers fertilize their crops? How do they control crop pests and weeds?

REFERENCES

1. Anon., 1985. Package of practices for increasing production; Fish-cum- livestock Cardamom based Farming System. National Symposium on Farming Systems farming, Central Inland Fisheries Research Institute,Barrackpore, India.Extention Manual No. 5, p 12.

2. http://www.fao.org/organicag/doc

3. Jayanthi, C. Rangaswamy S., Mythili S, Baluswamy M., Chinnusamy C.,and Sankaran N. Sustainable productivity and profitability of integrated farming systems in lowland farms, 2001. National Symposium on Farming Systems Research in New Millennium 15-17 Oct, Modipuram, Meerut, India.

4. Korikanthimath, V. S. 2001. Resource optimization in Robusta Coffee and

5. Research in New Millennium 15-17 Oct, Modipuram, Meerut, India.

6. Scialabba Nadia Organic Agriculture: The Challenge of Sustaining Food Production while enhancing Biodiversity United Nations Thematic Group, Sub Group Meeting on Wildlife, Biodiversity and Organic Agriculture Ankara, Turkey, 15-16 April 2003.

7. Swaminathan, M.S. 1987. Inaugural address at the International Symposium on Sustainable Agriculture. The rate of decomposition of green manure crops in rice farming systems, 25-29 May, Int. Rice Res. Inst. Banos, Phillipines.

2. Uddin MS, Buddha Das, Hossain A, Rahman M V,Mazid M A and Gupta M V Integrated Poultry Fish Farming- A way to increase productivity and benefits., in 'Integrated Fish Farming' Proceeding of Workshop on Integrated fish Farming, Eds,Mathias,Jack A., Charles Anthony T., Bautong Hu. Oct 11-15, 1994, People's Republic of China.

8. Vikas Chadha, http://www.satavic.org.

UNIT 13 INTEGRATED DISEASE, PEST AND WEED MANAGEMENT

Structure

13.1 INTRODUCTION

In the previous unit, you have studied about eco-friendly strategies for Integrated Resource Management and also about Integrated Farming Systems. Another area that needs intervention from this stand point is that of integrated pest control. South Asian countries face significant crop losses every year due to pests. For example, in India, annual crop losses due to pests have been estimated at around Rs.200, 000 million per year. Therefore, eco-friendly management of these pests is an important aspect of sustainable crop production.

In this unit you will study about various pest control measures with special focus on Integrated Pest Management (IPM). You will learn about the concept and goals of IPM and its components. We also present some case studies for effective implementation of IPM.

Objectives

After studying this unit, you should be able to:

- list some common pests of agricultural importance;
- explain the concept and goals of IPM;
- describe the pest control techniques adopted traditionally and in the Green Revolution era; and
- discuss the components of IPM, and analyse the major issues involved in the implementation of IPM.

The standard dictionaries define pest as *'a troublesome or destructive person, animal or thing'*. The term "pest" comes from the Latin word, "*Pestis*" meaning plague or a widespread disease and it is often casually used.

13.2 WHAT IS INTEGRATED PEST MANAGEMENT?

The concept of Integrated Pest Management (IPM) was originally mooted in the 1960s to bring about a compromise between chemical control and biological control of agricultural pests. Now the scope of IPM has widened to embrace not only chemical and biological control but also other means of control to keep the pest populations below economic injury level. In this section, we discuss the concept, goals and future scope of IPM.

13.2.1 The Concept of IPM

Integrated Pest Management (IPM) may be defined as **"a comprehensive approach to pest control that uses combined means to reduce the status of pests to tolerable levels while maintaining a quality environment".**

Thus, the concept of integrated pest management contains *three* basic elements:

- Maintaining insect populations below levels that cause economic damage,
- The use of multiple tactics to manage insect populations, and
- The conservation of environmental quality.

Integrated means that all appropriate methods and tactics from many scientific disciplines are combined into a systematic approach for optimising pest control and plant protection.

Pest includes insects, mites, nematodes, plant pathogens, weeds and vertebrates which adversely affect crop quality and yield.

Management refers to the attempt to control pest populations in a planned, systematic way by keeping their numbers or damage within acceptable levels.

IPM implies an integration of approaches and methods into a management system, which takes into consideration the ecology and the environment and all relevant interactions that pest management practices may have upon the environment in which one or more pest problems may exist. When IPM principles are applied to a given pest problem, it is generally assumed that environmental impact and economic risks have been minimized. Since IPM considers all applicable methods, it is also assumed that emphasis on chemical methods may be reduced when effective non-chemical alternative methods are available. To sum up,

The term pest is anthropocentric (anthropos: man), and is defined differently by diverse segments of the human population. There are no pests in an ecological sense, in the absence of humans, all organisms are just part of an ecosystem.

The IPM Concept

IPM integrates the management of all pests. It is an ecologically based holistic approach that can be applied to any ecosystem.

- IPM integrates
  - management of multiple pests (insects, weeds, disease pathogens, nematodes, vertebrates, etc.)
  - pest management tactics on an area-wise basis (many pest control situations are better handled on a large-scale or regional basis).
- IPM reduces pests to tolerable levels but does not emphasize pest eradication or elimination.
- IPM incorporates economic sustainability as well as environmental and social concerns.

In Table 13.1, we list some important pests and in Fig. 13.1 you can see the damage caused by pests to some crops.

Table 13.1: Important agricultural pests

Fig.13.1: Damage to crops due to pests

13.2.2 Goals

The goals of IPM are:

- Improved pest control and increased crop yield,
- Pesticide management,
- Economical crop protection,
- Reduction of Environmental Contamination.

Let us elaborate these further.

- **Improved Pest Control:** IPM aims to provide more effective pest control to maintain crop quality and yield. By implementing alternatives to strict dependence on pesticides, IPM makes use of a balanced approach. It relies, for example, on cultural practices, natural enemies (parasites or pathogens) of pests and host plant resistance as well as chemicals. By reducing the use of pesticides, IPM emphasizes on biological control and the conservation of natural enemies already occurring in the field.

Pesticide Management: Whereas the use of pesticides is not altogether done away with, IPM aims at a more efficient and sensible approach to pesticides, thus increasing their effectiveness and useful life span, decreasing possible adverse effects, ensuring a more rational use and minimizing pesticide resistance problems. Pest resurgence and secondary pest out breaks (often caused by elimination of natural enemies with pesticides) are minimized.

Economical Crop Protection: IPM aims to control pest populations more economically. For example, simply by treating crops as needed, instead of merely by the calendar, IPM reduces crop protection costs by reducing the amount of pesticide used and the number of applications.

Reduction of Environmental Contamination: IPM's social goal is to better safeguard farm workers' safety, people's health, plant life and the environment from possible harmful side effects associated with pesticides. It aims to ensure food safety through reduction of pesticide residue in food products, and decrease the contamination of soil, surface water, ground water and air though. Practices that maintain environmental quality can conserve natural enemies and beneficial pests that may help lower the pest status of target insects. In this approach, the pollinators, wild life and endangered species are also protected from potential hazards of pest control.

While there is general agreement about the multiple goals of IPM, different people prioritise them according to their background, interests, and local needs. Thus, farmers, researchers, agricultural input suppliers, environmental activists, and the public may have different legitimate viewpoints on the relative importance of a particular goal.

Extension personnel working in the implementation of IPM programmes usually rank IPM goals as follows:

1. reduced costs;
2. reduced risk of output loss;
3. reduced chemical use;
4. improved environment; and
5. improved on-farm health and safety.

For agricultural suppliers, the most important IPM goal is profitability, followed by increased options based on increased information, reliability and company reputation, and environmental safety.

For crop and pest management experts, the most important goals could be increased options and benefits followed by profitability, reduced chemical use, and reliability.

The relative importance of the goals of IPM is likely to change, depending on local need, from the early emphasis on farm-level profitability to the current emphasis on reduction of pesticide use. People are currently focusing on the harmful effects of the use of pesticides as a social goal.

The goals of IPM are quite in tune with sustainable agriculture and a brief discussion on this point here will not be out of order.

Sustainable Agriculture and IPM

You know that sustainable agriculture is a food production system which is ecologically, economically, and socially viable, in short term as well as in long term. It:

- yields plentiful, high-quality food and other agricultural products,
- promotes the health of the environment without depleting or damaging natural resources (such as soil, water, wildlife, fossil fuels, or the germplasm base),
- supports a broad base and diversity of farms and the health of rural communities.

All these goals are compatible with the goals of IPM for the following reasons.

IPM has had a traditional "low input" approach. From the beginning of what may be called the "IPM era" the judicious use of pesticides was emphasized. This is underlined in the economic threshold concept wherein pesticides are not applied unless pest levels are high enough to potentially reduce profits. Thus, IPM programmes have reduced costs yet preserved crop quality and yield.

IPM is founded on systems approach which requires that all crop management practices be carefully evaluated with respect to its impact on the system and utilized, modified or rejected based upon its influence upon the entire system. This well founded philosophy of pest management coincides and supports the stated objectives of sustainable agriculture.

IPM recognizes the importance of protecting the environment. Consideration for off-site effects, non-target organisms, pesticide resistance, destruction of beneficial organisms, and other negative aspects of pesticide use are avoided in pest management programs to the extent possible.

Thus, IPM provides practical support for sustainable agriculture. A sustainable agriculture system requires flexible pest management programmes which allow farmers to test various components and utilize tactics which prove useful. IPM programmes have developed this flexibility through the years and are able to help farmers devise individualized plans.

The specific practical contributions IPM can make to sustainable agriculture are

- proven scouting procedures and economic thresholds for a wide array of crops and pests;
- crop management considerations when designing pest management programmes;
- practical experience on designing and operating on-farm tests and demonstrations.

13.2.3 Future of IPM

The future of IPM promises to be an exciting and challenging era with tremendous scope for advancement in technology. The technological era with Internet capabilities provides tremendous opportunities to access information quickly, but it also presents challenges in reaching masses appropriately. We now briefly discuss the future scope of IPM from different perspectives.

Research, Development and Extension

Technological research and development is expected to revolutionise the IPM strategies. Although IPM concepts have already proven themselves, much research needs to be done, e.g., to determine the economic thresholds for many crops. Technologies are available only for few pests/crops, e.g., sugarcane, rice, cotton, vegetables etc. The IPM techniques, which have been successfully employed, are mainly the use of resistant varieties and bio-agents/bio-pesticides and these have been so far demonstrated on a limited scale; the user confidence in these approaches is still rather low. Effective IPM programmes could reduce substantially the expenditure on pesticides and ensure a better, safer environment.

Computer programs are required to integrate the vast material and data needed for simulation, prediction and control of pest populations. Technologies to develop non-human or automated scouting equipment need to be researched. Weather and geographic data need to be taken into account. On the whole, a massive boost to research and development efforts on IPM is required, which implies availability of trained manpower at all levels.

There is a lot of scope in the services sector, setting up of bio-control labs to make available bio-control agents, pesticide/bio-pesticide application services and maintenance of plant protection equipment.

Policy environment

Most of the plant protection techniques used in IPM are not yet very attractive to private entrepreneurs and farmers in South Asian countries do not have easy access to IPM methods. There is a need for appropriate policies to promote more widespread adoption of IPM and requisite financial support to take up these activities on a large scale.

Legal aspects also need to be explored so that in the ultimate analysis, IPM becomes more efficient and economical. For example, stricter regulations concerning pesticide use on farm need to be implemented.

Socio-economic considerations

IPM is considered knowledge intensive and requires much more understanding of the agro-ecology which inhibits farmers from readily adopting them. Despite the great appreciation of IPM approach, the adoption of IPM at the field level is generally poor in most developing countries, barring in rice especially in selected South-East Asian countries. The usual implementation tactics have been to give instructions to farmers to follow certain recommendations. This was attributed to component approach, which viewed IPM as an integration of tactics. However, this approach did not empower farmers.

More participatory approaches for adoption of IPM should be encouraged to expand the scope of IPM in the future. The Farmer Field School (FFS) approach (see 13.5) made a significant impact on improving farmers' overall skill in IPM. Future improvement of the FFS should involve the following:

- Upgrading and encouraging further technical studies,
- Focusing more on processes rather than results,
- Developing steps to encourage farmers to continue experimenting after FFS,
- Working with interested national researchers who are committed to ecological IPM.

Training by voluntary or non-governmental organizations has also been found effective in imparting knowledge and skills to the farmers. Active participation of greater number of NGOs would help considerably in popularizing the eco-friendly IPM practices among farmers.

Society's concern for the safety of food supply and preservation of endangered wildlife will direct major changes in the future of IPM. IPM must be viewed as a sound investment for preserving or protecting natural resources. IPM's future will depend upon how communication flows between the scientific community, the public and decision makers.

Certification of crops raised according to IPM or some other ecology-based standards may give growers a marketing advantage as public concerns about health and environmental safety have increased.

By using labels and other active marketing strategies (newspapers, brochures etc.), awareness and acceptance of IPM by consumers is enhanced because it will have positive consequences for human health.

These "eco-labels," as they are known, are becoming more popular, with over a dozen brands now in existence. They may provide for a more certain market and perhaps a price premium to help farmers offset any costs associated with implementing sustainable farming practices.

Having discussed the concept, goals and future scope of IPM, we now turn our attention to the pest control techniques and see how these have evolved from the past to the present IPM era. This will also give you an idea of the need for IPM. But first, we would like you to ascertain whether you have grasped the concepts discussed so far.

SAQ 1

a) Outline the concept of IPM
b) In your opinion, how should the goals of IPM be ranked? Give reasons for your answer.

13.3 FROM TRADITIONAL PEST CONTROL TO THE IPM ERA

Three distinct phases can be identified in the evolution of pest control: The traditional era, the era of pesticides and the IPM era.

Traditional approaches in pest control

Traditional approaches like crop rotation, field sanitation, deep ploughing, flooding, collection and destruction of damaged or infested plants etc. were among the oldest methods employed by humans to minimize the damage caused by pests. This was accompanied by the use of plant products from neem, chrysanthemum, rotenone, tobacco and several other lesser known plants in different parts of the world and a number of synthetic inorganic insecticides containing copper, arsenic, mercury etc. The focus of pest control shifted from traditional control practices to chemical control in the late 1930's.

Era of pesticides (1939-1975):

The era of chemical pesticides, started with the discovery of insecticidal properties of DDT in 1939. Then came a number of other insecticides, which played a major role in by successfully controlling the pests and increasing crop production. The success of high yielding varieties that ushered the **"Green revolution"** was partially due to the crop protection umbrella of pesticides. Pesticides consumption increased all over the world from a few hundred tonnes in the 1950s to more than hundred thousands tonnes in recent years, a large fraction of which is used in agricultural sector.

For example, the consumption of pesticides in India increased from 434 tonnes in 1954 to more than 90,000 tonnes in recent years. Still, the average use of pesticide in ndia is about 500 grams per hectare against about 1.5 to 3 kg per in USA and 10 to 12 g per hectare in Japan.

lthough chemicals have been extremely beneficial in crop protection, an almost total ependence on pesticides resulted in unintended and unforeseen problems such as:

- Environmental Contamination
- Pest Resistance
- Improper use of Chemical Pesticides
- Secondary Pest Outbreaks
- Natural Enemies Targeted
- Ecological Imbalance Created Resurgence of Original Pest Population
- Energy Crisis and Pesticide Cost Escalated

ince pesticide use began to be legally restricted due to above said possible adverse ffects on people and on the environment, and since some pesticides became less ffective for the variety of reasons listed above, a more comprehensive, ecologically ased approach to crop protection was clearly called for.

ra of Integrated Pest Management (IPM)

he Agenda 21 of the United Nations Conference on Environment and Development JNCED) at Rio de Janeiro in June 1992 approved and accepted IPM as an approach reduce the use of pesticides in agriculture. In view of the global concern and the enefits of IPM programme, developing countries are also adopting IPM as the main rategy of plant protection in the overall agricultural production programmes. lthough chemical pesticides continue to play an important role in the IPM program, ese products are used selectively and judiciously and the dependence on pesticides s the exclusive tool for pest control is getting reduced.

ffective IPM consists of the following approaches:

- **Exclusion** seeks to prevent pests from entering or establishing in areas currently not infested, thus stopping problems before they arise.
- **Suppression** refers to the attempt to reduce pest populations below the level at which they would be economically damaging, so that they are no longer a problem. This includes temporary limitations of localized pest out breaks on an emergency basis.
- **Eradication** strives to eliminate entirely certain pests whose presence, however minimal, cannot be tolerated.
- **Plant resistance** stresses the effort to develop healthy, vigorous strains that will be resistant to certain pests.
- **Management of within-field populations** occurs at the within-field spatial scale on a continuing basis because the pest is well established in an area.
- **Area-wide pest management:** For some pests, management must be extended to the regional level to achieve population regulation, especially for many viral diseases and for some mobile insects. This strategy is referred to as **area wide pest management**, and requires the cooperation of people throughout the range of the pest.

n order to implement these approaches, the following steps are often taken:

- **Pest surveillance and monitoring:** The identification of key pests and beneficial organisms is a necessary first step. In addition, biological, physical and environmental factors which affect these organisms need to be ascertained. This involves the systematic collection of pest and crop data from the field (pest distribution, growth stage, population, crop stage, etc.). The information is used, in the short term, to make predictions about pest populations. It is also used to make immediate pest management decisions to reduce or avoid economic crop loss.

In the long term, field scouting and monitoring is important in evaluating the success or failure of pest management programmes and for making sound decisions in the future. Monitoring helps in pinpointing early outbreaks and the progress of infestation. It also enables decisions to be made on control strategy and the efficiency of the treatment. The application of suitable control strategy at the right time results in its efficient use and reduces the frequency of treatment.

- **A prediction of loss and risks** involved is made by setting an economic threshold. Pests are controlled only when the pest population threatens acceptable levels of quality and yield: Remedial action is taken. The level at which the pest population or its damage endangers quality and yield is often called the **economic threshold.** The economic threshold is set by predicting potential loss and risks at a given population density. This estimation takes into account weather data, state of crop development, markets, risk benefit, costs and kinds of control available.

- **An action decision must be made.** In some cases pesticide application will be necessary to reduce the crop threat, while in other cases, a decision will be made to wait and rely on closer monitoring.

- **Evaluation and follow-up** must occur throughout all stages in order to make corrections, assess levels of success and to project future possibilities for improvement.

In this section you have studied about the evolution of pest control techniques and approaches from the past to the present. You may like to stop for a while and review what you have learnt.

SAQ 2

a) Explain in you own words why did the need for IPM arise.
b) Outline the major approaches to pest control followed in the IPM era.

13.4 COMPONENTS OF IPM

So far we have discussed the concept of IPM, and the approaches to IPM. You may like to know: What are the pest management practices followed in IPM? Preventive cultural control, mechanical control, chemical control, biological control, pest modelling and remote sensing, and legislative control are the major components of IPM and we now discuss these briefly.

13.4.1 Preventive Cultural Control Methods

You have learnt in the previous section that prior to the advent of the chemical era, people relied on cultural control. It is one of the major control methods in IPM; it involves the use of practices which make the environment less favourable for the survival, growth, reproduction or dispersal of pest species. It is also called **ecological control.** A number of cultural control techniques are currently practiced in pest management and here we describe a few of the most common and potentially useful ones.

Sanitation involves the removal or destruction of breeding, refuge, and over-wintering sites of pests. Control of annual weeds, especially before seedling stage not only reduces weed pressure, but also reduces crop pests and diseases that shelter in, or

:ed on them. Seeds are treated with pesticides, hot water or solar energy to control ests and diseases. Seeds, manure and irrigation water free of weed seeds, pests and iseases, are used. Sanitation also involves the removal of the whole plant infected ith pest or diseases and destruction of weeds.

:rop rotation is effective for pests that have a narrow host range and dispersal apacity and cannot survive for long periods of time (i.e., one or two seasons) without :op or favoured host contact. This includes all plant pathogens, nematodes, insects id a number of weeds. This technique is economical and important in the control of iany nematode problems. Crop rotation also provides the opportunity for using a idér range of herbicides for controlling weeds. Strip farming, intercropping and iulti-cropping have also shown reduction in pest problems.

illage timing and its type can markedly influence the soil environment and affect the irvival of insect pests or their natural enemies. Tillage practices can kill pests by echanical injury, starvation, desiccation and exposure. For example, deep ploughing imediately after harvest destroys insect pests and seeds of various weeds by :posing them to their natural enemies like birds and to the action of sun and wind.

rap cropping is a technique of growing crops that attract insects and other ganisms so that the target crop escapes pest attack. The attractiveness of trap crops ay be enhanced by use of insect pheromones, plant kairomones or insect food ipplements.

rigation management can be used for pest control purposes. Small pests such as ihids are easily washed off plants by overhead irrigation, and soil insects may be lled by the pressure of swelling soil particles in saturated soils.

[ulches help to retain moisture in the soil and can impact insect populations.

Fig.13.2: Plastic mulching in field

owing and harvesting schedules can be altered to control pests. Sowing period can : suitably advanced or delayed to avoid the egg-laying period of the pest or to allow ie plants to reach an age where they are resistant by the time the pest appears. Short iration varieties of the crop may be sown or harvesting may be done without any :lay after the crops mature. Early harvesting may also remove pests (especially :real pests in the straw and grains) from the field before they can emerge and :rpetuate the population in the area.

Transplanting ensures that plants cross the stage of growth which is susceptible to diseases of germinating seeds. The transplanted crop is much larger/older than germinating weeds and thus has a competitive advantage in comparison of the direct sown crop.

13.4.2 Mechanical Control

The reduction or suppression of insect populations by means of manual devices is referred to as mechanical control.

The main mechanical methods are:

- **Collection** and **destruction** of pests, which includes handpicking.
- **Mechanical exclusion** consists of the use of devices like door and window screens, digging trenches, and row covers to physically prevent insects from reaching crops and agricultural produce.
- **Trapping and suction devices** are used for collecting insect pests. Other than insect control, traps also provide valuable information for estimating pest intensity/crop loss assessment, monitoring initial infestation and periodicity of pest activities. Various types of traps used are light traps, air suction traps, pheromone traps (Fig. 13.3a).

Fig.13.3: a) Pheromone trap in field; b) pruning

- **Mowing/interculturing** is used to limit weed growth without killing the plants. **Dredging**, i.e., physical removal of soil and plant material is very useful particularly for aquatic weed control.
- **Clipping, pruning, flaming** and **burning** of infested shoots and floral parts are useful against many pests (Fig. 13.3b).

Temperature, sound, controlled atmospheres and radiations are employed as important methods of physical control. Stored grain insects are controlled by physical methods effectively.

13.4.3 Chemical Control

Under certain circumstances like heavy incidence or pest epidemics, the use of pesticides becomes unavoidable. Often pesticides are the only feasible means of control and provide convenient and economical protection from pests that would otherwise cause significant losses. However, injudicious, careless or excessive use of pesticides can result in poor control, crop damage and hazards to human and animal health and the environment. Pesticide resistance, pest resurgence and secondary pest outbreaks are the major problems created by prolonged use of esticides. It is desirable that pesticides should be used only when needed. Different roups of available pesticides (including insecticides, fungicides, weedicides, odenticides) may be used according to the demand of the situations.

3.4.4 Biological Control

he successful control of a pest species through the manipulation of another rganism/natural enemy is called **biological control**. Insect pests may be preyed upon r parasitized by other insects. Most insect pests are attacked by bacterial, fungal or iral pathogens. Specific weeds may be controlled by insects with specialized feeding abits. Biological control offers a sustainable, ecologically sound and economically iable solution to the pest problems. The implementation of biological control iethods has been categorized into three basic approaches, namely,

- classical,
- augmentation, and
- natural.

he classical approach of biological control is employed when a pest is not native to a iven area, assuming that the biological organisms that regulate its population ynamics in its native environment are lacking. In this approach, farmers:

- determine the pest's native home,
- locate beneficial organisms that naturally control the pest organism in its native area, and
- if feasible, import, multiply, release and establish the beneficial organisms in the problem area to facilitate biological regulation of the pest problem

f successful, the importation and establishment of the beneficial organisms results in long term reduction of the pest problem and repeated releases of the beneficial rganisms are not required. The process of importing and releasing beneficial rganism is complex, since many precautions need to be taken to prevent the ntroduction of organisms that may have adverse effects.

Augmentation is the approach in which beneficial biological organisms are mass eared and released periodically to supplement the natural enemy complex to achieve eduction of a pest problem. This approach may be applied to pest populations that are either native to the area or of foreign origin. In general, augmentation may be considered when it is economic and feasible to rear, multiply, and release a natural enemy of a pest to the point that reduction of the pest problem is achieved. Successful augmentation efforts have been developed for greenhouse environments where altering the balance between a pest and its natural enemy is feasible.

Natural biological control is carried out through natural **predators, parasites** and **diseases.** If such forces are not in effect in nature, we would be overrun by pest populations. Populations of natural enemies can be enhanced by selective use of cultural practices or decimated by indiscriminate use of pesticides. In some cases, pesticides have been developed that effectively control a pest population without having a significant effect on beneficial species. For example, a new pesticide for control of alfalfa weevil could effectively kill weevils without harming beneficial parasitic wasps and pollinating bees.

An example of natural control includes the impact of predatory ground beetles on early pests of corn such as cutworms and armyworms. It is observed that the efficacy of a given soil insecticide to reduce cutworm damage may be related to the lack of toxicity of the compound to the ground beetles that prey upon cutworms. Spiders, birds, insects like lady bird, praying mantis, beetles, and several fungi, bacteria, viruses are important bio-control agents.

Fig.13.4: a) Predatory spider (b) A praying mantis feeding on a moth (c) Lady bird beetle predating on mealy bug.

Biopesticides (Pathogens)

Biopesticides are defined as pesticides of biological origin including micro-organisms and natural products. The term biopesticide or biological pesticide as defined by FAO, 1996 pertains to **"a generic term, not specially definable, but generally applied to a biological control agent, usually a pathogen, formulated and applied in a manner similar to a chemical pesticide, and normally used for the rapid reduction of a pest population for short term pest control"**. The biopesticides are broadly classified into two groups:

- Microbial pesticides.
- Botanical pesticides.

Microbial pesticides are biopesticides formulations containing bacteria, fungi, virus, protozoa or nematodes as pest control agents (Fig.13.5).

Fig.13.5: Castor semi looper larva attacked by a virus

The prospects of microbial control of agricultural pests seem to be very good. We present below some success stories of biological control in India.

The work on biological control of crop pests in India commenced with the introduction of vedalia beetle, *Rodolia cardinalis* for the control of cottony cushion scale, *Icerya purchasi* and *Dactylopius opuntiae* for the control of prickly pear in the first quarter of the previous century. In recent years the successful biological control programmes in the country include sugarcane *Pyrilla, gram* caterpillar, water hyacinth, etc.

i) **Sugarcane *Pyrilla*:** The outbreak of this injurious pest was successfully controlled by utilization of potential biocontrol agents like *Epincania melanoleuca* in Uttar Pradesh, Punjab and Haryana in 1985. This saved the loss to the tune of Rs.80.00 million in two years. This parasite has also been successfully introduced for sugarcane *Pyrilla* control in the State of West Bengal, Orissa, Gujarat, Maharashtra, Tamil Nadu, Karnataka and Kerala. During 1994, the severe incidence of sugarcane *Pyrilla* in Karnataka could be successfully controlled by release of *E. melanoleuca* from northern states and by augmentation of *Tetrastichus pyrillae*.

ii) ***Heliothis*:** Use of Nuclear Polyhedrosis Virus (NPV) against gram pod borer has given spectacular success in biological control of *Heliothis*, one of the dreaded pests of pulses, cotton, vegetables, oilseeds, etc., in Tamil Nadu, Karnataka, Gujarat and other States.

iii) **Water Hyacinth:** Two exotic weed control insects viz., *Neochetina eichhorniae* and *N. bruchi* have been successfully employed for the biological control of water hyacinth in the States of Karnataka and U.P.

iv) ***Salvinia* weed: *Cyrtobagus salviniae*** has successfully controlled the *salvinia* weed (waterfern) in the water bodies in Kerala which has provided relief in navigation and irrigation.

v) ***Agrobacterium tumefaciens*:** Crown gall is a serious bacterial disease caused by the bacterium ***Agrobaterium tumefactiens***. Biological control of this pathogen was achieved by dipping bare-root transplants into a suspension of a nonpathogenic strain of the bacterium ***Agrobacterium radiobacter***.

Botanical pesticides are insecticides of plant origin extracted from seed, flower, leaves, stem and roots. Plants are rich sources of bioactive organic chemicals. *Neem, Pyrethrum, rotenone* and *nicotine* are the four most important sources for botanical pesticides. The bioactivity of neem products has attracted the attention of scientists the world over. All parts of the neem tree (leaves, fruits, seed kernel) posses insecticidal activity but seed kernel is the most active one (Fig.13.6).

Fig.13.6: Different parts of *neem* tree: leaves, fruits, seeds, seed kernel, kernel powder.

The potential for development of biological control for a wide range of pest problems is significant. However, development of successful biological control technologies often requires significant investments into research that may or may not readily produce satisfactory results. To date, biological control has not been a marketable product like chemical controls and research efforts into the field have been limited. Furthermore, implementation and evaluation of biological controls are often more complex than that of chemical methods.

Host Plant Resistance is an inheritable trait that enables the plant to inhibit the growth of insect population or to recover from injury caused by populations that were not inhibited to grow. Interaction between host plants and insects are spread over a wide range of intensity. Breeding insect-resistant varieties is an essential feature of host plant resistance for which development and standardization of screening techniques is an essential pre-requisite.

Transgenic plants are plants with a gene or genetic construct that has been introduced by molecular techniques for specific tasks. Genetic engineering may serve as a boon to pest management if exploited correctly. Bt cotton is a transgenic cotton in which a special type of protein called cry protein is produced by introducing a bacterial gene. Bt cotton is highly effective against cotton boll worms (Fig. 13.7).

Fig.13.7: Insect infestation on Bt (right) and non-Bt (left) cotton bolls.

Examples of approved virus-resistant varieties include the following:

i) Cucumber mosaic virus, watermelon mosaic virus and zucchini yellow mosaic virus resistance has been available in squash varieties.

ii) Papaya rings pot virus resistance in papaya is one of the few examples of transgenic varieties.

iii) Potato leaf roll virus resistance has been available since 1998 and only in combination with insect resistance.

13.4.5 Pest Modeling and Remote Sensing

A simplified representation of a system is termed as model. Agricultural systems are dynamic and continuous systems as these show gradual continuous changes. The models representing them are termed as dynamic continuous models, which are also known as crop growth simulation models. A crop growth simulation model coupled with pest damage mechanisms is called a **crop-pest model**. Simulation models can be used for determination of economic injury levels of pests, pest risk analysis, pest forecasting and assessing effects of climate change on crop growth and productivity.

Observation of objects from a distance is called remote sensing. By remote sensing, pest incidence on plants is detected by change in the colour of leaves. In India, remote sensing has been used for locating favourable places for locust breeding in desert areas and assessing severity of white fly incidence in Andhra Pradesh.

13.4.6 Legislative Control

The pests introduced from outside have frequently been found to inflict greater damage than the indigenous ones. Legislation is required to:

a) Prevent the introduction of foreign pests, diseases and weeds.

b) Prevent the spread of already established pests, diseases and pests from one region to the other within the country.

c) Motivate the farmers for the application of effective control measures to prevent damage by already established pests, diseases and weeds.

d) Prevent the adulteration, misbranding and mishandling of pesticides or other devices used for the control of pests and to determine their permissible residue tolerance in food stuffs.

e) Regulate the activities of men engaged in pest control operations and take precautions in the application of hazardous pesticides.

In India, at present two categories of regulatory measures are in operation for control of pests, diseases and weeds, viz.

i) legislative measures through plant quarantine, and
ii) legislative measures through State Agricultural Pests and Diseases Act.

SAQ 3

a) List the major practices adopted in cultural and mechanical control of pests.
b) What do you understand by biological control? Why is it an important component of IPM?

13.5 IPM Initiatives

IPM has been implemented world wide and has been found to work well on many crops. Its principles are being applied to many other areas around the world. In this section, we describe some examples of successful implementation of IPM.

13.5.1 Community Based IPM Approach-Farmer Field School (FFS)

The training approach, which has been used to help farmers learn about IPM is called the Farmer Field School (FFS). The concept of the farmer field school (FFS) as an extension activity was initially developed by FAO, validated by Indonesians and subsequently by India and other countries. FFS has given small farmers practical experience in agro ecosystem analysis, providing the tools they need to practice IPM in their own fields. FFS also provides a natural starting point for farmer's innovation covering the whole range of issues relating to crop management and plant health. The success of FFS has opened up a new approach to the development of sustainable, small scale agricultural system. The approach places farmers at the centi of the IPM, empowering them as the key pest management decision maker.

Once this foundation has been laid, farmers are better able to act on their own initiatives, and to sharpen their observation, research and communicative skills. Thus the Farmer Field School sets in motion a longer-term process, in which opportunities are created for local leadership to emerge and for new, locally devised strategies to be tested.

13.5.2 Examples from Around the World

IPM programmes for various crops are being successfully implemented in different countries. For example, since 1972, IPM programmes have been implemented in the USA for 16 crops (including cotton, corn, sorghum, soybeans, alfalfa, citrus, apples and peanuts), on about one million acres. Many farmers in these programmes have reduced pesticide use and cost by 30-50% compared to conventional approaches. Some examples are: One cotton farmer reduced the number of pesticide applications from 27 to 17. Texas farmers reduced insecticide use on sorghum by 73%. New Jersey sweet corn growers cut insecticide usage by as much as 20% with no sacrifice in quality of this high value, low threshold crop.

In 1975 Evaluation of 25 Integrated Pest Management Programs for Cotton, Peanuts, and Tobacco in the U.S. revealed:

- Crop yield actually increased in 72% of the programs.
- Pesticide use was decreased in 86% of the programs.
- Production costs decreased in 85% of the programs.
- Profit increased in 95% of the programs.

In Table 13.2, we summarise some more successful IPM initiatives in developing countries.

Table 13.2: Successful IPM initiatives in different countries for various crops

Crop	IPM Components	Pesticide reduction	Savings and other benefits
Rice (Indonesia)	Parasitoid conservation, plant resistance, need based pesticide use, pesticide subsidy abolished	50% number of applications from 4 (1986) to 0.8 (1991). Pesticide production decline by 75%	Subsidy abolition benefit of 67-100 million/yr. Net profit up by 12%.
Cotton (Egypt)	Pheromones for key pest scouting, pest thresholds used	70% reduction nationally, application from 8 to 2-4	35 million/yr reduction in import cost of pesticides
Sugarcane (Pakistan)	Release of parasitoids, avoiding post-harvest burning to conserve beneficials	Aerial application avoided, chemical application effectively removed	Net farmer income up by 9.15% per yr
Soybean (Brazil)	Scouting, natural enemies, need based pesticides especially NPV biopesticide	Reduction in annual applications from 12 to 9	Superior crop yield

Mango (Pakistan)	Shelters for predators, traps for fruit flies, reduced chemical treatment for hoppers	Pesticides eliminated for all pests except hoppers where application restricted to part of the tree. Application reduced from 5 to 1	14 fold reduction in cost of chemical control. Reduced outbreaks of scale insects
Cabbage (Taiwan)	Exotic parasitoids, timing of planting, need-based biopesticide	Spray frequency halved	Substantial reduction in cost.
Banna (Costa Rica)	Economic thresholds developed for moth pests. Fruit bagged for thrips control	Complete removal of pesticide use after several years	Removal of pesticide cost and environmental and health benefits

With this, we end our discussion on IPM and summarise the contents of this unit.

13.6 SUMMARY

- IPM may be defined as **"a comprehensive approach to pest control that uses combined means to reduce the status of pests of tolerable levels while maintaining a quality environment"**.
- The goals of IPM are: Improved pest control and increased crop yield, Pesticide management, Economical crop protection, Reduction of Environmental Contamination.
- Effective IPM consists of **exclusion, suppression, eradication, plant resistance, management of within-field populations** and **area-wide pest management.**
- The various types of pest control measures that are integrated in pest management practices include physical, mechanical, cultural, behavioral, chemical, biological, genetic and legislative control methods.
  - Rotation of crops, trap crops, strip farming, intercropping and multi cropping mowing, tillage, transplanting, dredging and sanitation are important **cultural control** methods.
  - **Mechanical** methods bring about reduction or suppression of insect populations by means of manual devices, viz., hand picking, exclusion by screens and barriers, trapping and suction devices, use of hand-nets and bag-nets, clipping, pruning and crushing, beating and hooking, shaking or jarring, sieving and winnowing, and burning.
  - **Chemical control** in IPM involves judicious and minimum use of chemicals to manage pest populations.
  - Control of pests through natural enemies as encouraged and disseminated by man is called **biological control**. These organisms include fungi, bacteria, viruses, nematodes, protozoa, predators, parasites and pathogens (bioagents).
  - **Biopesticides** are chemicals obtained from plant sources, which can kill pests. Biopesticides are not readily available and they have shorter shelf life.

- Breeding insect-resistant varieties is an essential feature of **host plant resistance** for which development and standardization of screening techniques is an essential pre-requisite.

- **Pest modeling** and **remote sensing** and advancement in information technology will further add value to the approach towards IPM.

13.7 TERMINAL QUESTIONS

1. What are the common goals shared by IPM and sustainable agriculture?

2. Discuss the future scope of IPM.

3. What do you understand by

   a) Pest surveillance and monitoring,
   b) Biological control?

4. How can different components of IPM be integrated for its effective implementation? Give examples.

5. How can FFS play an important role in popularizing IPM?

JNIT 14 SOCIETY AND AGRICULTURE

tructure

4.1 INTRODUCTION

.griculture is one of the most important economic sectors of South Asian Countries. contributes significantly to the gross domestic product (GDP) and employs a large ection of the population. The GDP shares of agriculture sectors of the SAARC ountries are: Bangladesh-30 per cent, Bhutan-45 per cent, India-31 per cent, Nepal-5 per cent, Pakistan-25 per cent and Sri Lanka-25 per cent. In comparison the shares f industrial sectors are: Bangladesh-14 per cent, Bhutan-25 per cent, India-29 per ent, Nepal-14 per cent, Pakistan-24 per cent and Sri Lanka-26 per cent. The figures or the labour force engaged in agricultural sector in SAARC countries are: angladesh-65.5 per cent, Bhutan-90 per cent, India-63.2 per cent, Nepal-91.7 per ent, Pakistan-47.4 per cent, Sri Lanka-49.1 per cent and the SAARC average-67.8 er cent. Agriculture provides the bulk of various goods required by the non gricultural sector as well as numerous raw materials for industry. The direct and ndirect share of agricultural products in exports is quite high.

'he increase in agricultural productivity improves the well being of our people. When ural people have enough left over in their storage bins after satisfying their food equirements, they sell it and in turn buy non-agricultural goods and this creates narkets for industrial goods and services. Since small cultivators and workers omprise a significant proportion of the poor, an increase in agricultural productivity lirectly increases the family incomes of small cultivators and resource-less iouseholds, and hence their purchasing power.

ncrease of agricultural productivity is one of the key to poverty alleviation in the SAARC countries. Therefore, the stimulating factor in economic growth is agricultural production. Thus, there is a considerable stake of the agriculture-based economies of South Asia in providing economic, infrastructural and social support to ncrease agricultural productivity and competitiveness in the world markets. In this unit, we shall discuss the aspects of infrastructure development, policy support, institutional capacity building and people's participation that delineate the interface of society and agriculture.

Objectives

After studying this unit, you should be able to:

- analyse the need for infrastructure development in agriculture, particularly, storage facilities, markets, roads and irrigation in your region/country;
- outline the policy support required to improve agricultural productivity;
- discuss the need for institutional capacity building in support of agriculture; and
- appreciate the importance of people's participation in agriculture related activities and programmes.

14.2 INFRASTRUCTURE DEVELOPMENT

Rural areas in the countries of South Asia and South-east Asia have serious inadequacies in physical infrastructure which limit their prospects of rapid growth in agriculture. An equally, if not more seriously limiting factor for socio-economic growth in rural areas is the low level of human resources development. Factors such as low literacy levels (much worse in the case of women), high levels of morbidity, and shortage of skills demanded by a competitive, globalizing economy pose serious hurdles for sustaining levels of growth necessary for eradicating poverty. Unfortunately investments in developing infrastructure and human resources in rural areas have been neglected as compared to the urban areas.

More than half of rural households in these countries do not have access to electricity even though a large number of villages are reported to be electrified. The power supply is erratic and unreliable. Most villages in dry land regions and in inaccessible mountainous regions face shortage of good quality agricultural inputs. Implements and facilities for post harvest operations like threshing, winnowing and storage and transportation are lacking resulting in high on-farm wastages. For agricultural perishables like fruits and vegetables, there is lack of cold chain due to which distress sale and spoilage is quite common in agriculturally under-developed areas. The facilities for marketing them are meagre.

Unrealistic pricing policy and inefficient management of movement, storage and distribution system creates problems for farmers as well as consumers. Weekly *haats* in rural areas are the mainstay of rural poor for marketing produce and purchasing their daily necessities. The first and foremost aid to agricultural development is "information". Due to lack of information on prices and markets, farmers in agriculturally backward areas suffer from exploitation by middlemen and local traders. Sound information infrastructure is thus essential for agricultural marketing research, education and extension.

We now present an overview of the issues involved in the development of infrastructure in the agricultural sector viz. rural transport and irrigation facilities, storage facilities, marketing etc.

Transport in Rural Areas

There is a wide disparity in connectivity among various regions of the South Asian countries. Countless villages in these countries still rely on tracks that are unsuitable for motorized traffic particularly during the rainy season. Much of the rural road network is under-developed, of low standard and poor quality, structurally weak, poorly maintained, and extremely deteriorated. The lack of roads means that an estimated 20-30 percent of the agricultural, horticultural and forest produce gets wasted because of inability to transport the produce to marketing and processing centres.

A good infrastructure of rural roads and means of transport is required for transporting agriculture produce and for rural industrialization. It is vital for improving the quality of life and socio-economic transformation of the majority of people in the rural areas. It is important to have rural areas linked with markets through all weather roads with motorized transport. Improvement in rural transport leads to substantial reduction in freight charges, increase in household incomes, more employment opportunities, and expansion of cultivated land.

Keeping in view the socio-economic benefits accruing from providing road connectivity to the villages, there is a need to impart greater thrust to provide road connectivity and means of transport to rural areas.

The key issues in the sector include: inadequate funds, outdated planning, programming and budgeting, outdated design and construction standards, poor construction quality, gross neglect of maintenance, lack of inter-agency coordination, limited implementation capacity, and lack of accountability. In view of these problems and constraints, it is necessary to prepare rural master plans and develop national policies for rural roads and transport.

Irrigation

Most of the agriculture in South Asian countries is monsoon dependent.
The dependence on seasonal variations in rainfall leads to bumper harvests in some seasons and crop failures due to drought in others. The importance of irrigation cannot be overemphasized. The overall strategy so far has been to concentrate public investments in surface systems, such as large dams, canals, and other large-scale works requiring huge outlays of capital over a period of years, and in deep-well projects that also involve large capital outlays. Ecological and socio-economic implications of large irrigation projects are being studied and compared with sustainable localized efforts on water harvesting and conservation, which are being encouraged and supported. You have read about these issues in much more detail in Unit 7.

Many areas receiving water through irrigation are poorly managed or inadequately designed; the result often is too much water and water-logged salt affected fields incapable of production as very little efforts are made to integrate drainage with irrigation projects. To alleviate this problem, more emphasis is being placed on using sustainable methods of irrigation. Use of sprinkler irrigation over flood irrigation is being encouraged. But we still have a long way to reach the stage when agriculture will be free from the dependence on monsoon.

Marketing and Storage

The agricultural marketing system operates primarily according to the forces of supply and demand in the private sector. Government intervention is limited to protecting the interests of producers and consumers and promoting organized marketing of agricultural commodities. For example, in India there are regulated markets to which the central government provides assistance in the establishment of infrastructure and in setting up rural warehouses. A network of cooperatives at the local, state, and national levels assist in agricultural marketing. **There is a crying need for technical improvement, financial management, raw materials development, and inventory control in processing and marketing of agricultural produce.**

Warehouses and other storage facilities for storing agricultural produce and farm supplies have played an increasing role in price control programs and in distributing farm commodities and farm supplies. Since the public warehouse issues a receipt to the owners of stored goods on which loans can be raised, warehouses are also becoming important in agricultural finance. The growth of the warehousing system has resulted in a decline in weather damage to produce and in loss to rodents and other pests.

Most agricultural produce in these countries is sold by farmers in the private sector to money lenders (to whom the farmer may be indebted) or to village traders. Produce is sold in various ways. It might be sold at a weekly village market in the farmer's own village or in a neighbouring village. If these outlets are not available, then produce might be sold at irregularly held markets in a nearby village town. Farmers also can sell to traders who come to the work site. Where the farmers have access to telecommunication facilities such as STD telephones and INTERNET, they have been found to make good use of these to price and sell their produce. Establishment of cold chain, low cost pre-cooling facilities near farms, cold stores and grading, sorting, packing facilities to reduce wastage, and improve the quality and shelf life of products are very much required.

To sum up, to meet the transitory and emergency food requirements of the developing countries, increased attention is required to develop storage facilities and adequate transport infrastructure and strengthen existing collective food reserves as well as development of agro -processing facilities to meet emergencies. Implementation of long term integrated programmes for disaster mitigation and strengthening the basic elements of disaster preparedness must be given priority in disaster prone areas. The acute problem of arsenic contamination needs to be addressed collectively.

You may like to consolidate these ideas before studying further. Attempt the following SAQ.

SAQ 1

Outline the major infrastructural needs for improving agricultural productivity in your area.

14.3 POLICY SUPPORT

The well-being of the people of any country depends in a significant way on the adequate and sustained production and distribution of food. The problem of low agricultural productivity and lack of access to food continues to persist in South Asia. Nearly 37 percent of the world's malnourished are in South Asia. A major concern of these countries is to ensure adequate food for all at reasonable prices at all times with special provision for the chronically undernourished, underprivileged and other vulnerable groups of the society.

Greater investment in agriculture and rural development is necessary to move towards the desired goal of attaining food security for all. It is a well known position of the governments of South Asian countries that **public policies and programmes must ensure access to land, credit, water, agricultural inputs, technology, information, employment and markets for the rural poor and the small farmers.**

The Governments of the SAARC nations need to undertake sustained measures to extend micro-credit and cooperative programmes with focus on farmers and the disadvantaged groups of the society. Due emphasis has to be laid on the promotion of indigenous skills, small scale and cottage industries to address rural poverty, as well as cooperation in agricultural research and extension. The adoption of improved agricultural technologies and farming practices can have a direct impact on household food security provided they are suitable to the poorest farmers, generate net income growth and address the needs of the community.

Policies of decentralisation and building up of grassroots level institutions can sustain efforts of food security programmes. The effective implementation of programmes for social mobilisation and decentralisation and for strengthening institution building is a very important issue along with good governance, rule of law, transparency and accountability.

SAARC countries should harmonise individual efforts and forge a common action plan to combat mal-nourishment, under-nourishment, rural and urban hunger through **appropriate policies that promote sustainable agriculture and food production with ecological conservation.**

Trade in food within and between countries is also important for world food security. While South Asian countries should welcome globalisation, they need to move with caution and protect the vulnerable groups from the adverse impacts of liberalisation of food markets.

Among the least developed South Asian countries there must now be effective cooperation on social and economic policies. No single country can act effectively and alone. Going beyond this, there must be coordination in national social policies, agricultural policies, measures to meet environmental needs and the other substantive programmes of these poor countries in the new millennium.

Subsidies should be targeted to benefit the poor and marginal farmers who grow food for the domestic market. International community should strive to ensure removal of subsidies on export-oriented agricultural crop production to prevent dumping of agricultural products.

Effective partnership of governments, international bodies, NGOs, civil-society and private sectors can ensure synergies in resources and actions to address poverty and food security. Donor countries, international financial institutions, as well as UN Specialized Agencies, including FAO, should support, facilitate and encourage transfer to and access by developing countries of new farming technologies through preferential terms and concessions. NGOs and civil society organisations in South Asia are playing an important role in social mobilisation and advocacy for agricultural and rural development, empowerment of women and the marginalised groups. They are also partners in implementing social development programmes. NGOs should complement government efforts to reverse the declining trend in the flow of resources to the food and agricultural sector.

To increase crop yields in South Asian Countries, the governments have devised specific policies and programme to provide agricultural inputs, such as seeds, fertilizers, power and irrigation water at subsidized prices and have made public investments in agricultural research, and extension. The governments also formulate national agricultural policies of price support, procurement, subsidies, investments, credits, insurance, taxation and trade and fix minimum support prices for major commodities each year.

The policies seek to promote technically sound, economically viable, environmentally non-degrading, and socially acceptable use of the countries' natural resources-land, water and genetic endowment to promote sustainable development of agriculture. Water is a prime natural resource, a basic human need and a precious national asset. Planning, development and management of water resources need to be governed by national perspectives.

A well developed information system, for water related data in its entirety, at the regional, national level, is a prime requisite for resource planning. Standards for coding, classification, processing of data and methods/ procedures for its collection should be adopted. Advances in information technology must be introduced to create a modern information system promoting free exchange of data among various agencies and countries.

Seeds are the most important determinant of agricultural production potential, on which depends the efficacy of other agriculture inputs. Seeds of appropriate characteristics are required to meet the demand of diverse agro-climatic conditions and intensive cropping systems. Sustained increase in production and productivity is dependent, to a large extent, on development of new and improved varieties of crops and an efficient system for timely supply of quality seeds to farmers.

The creation of a facilitative climate for growth of a competitive and localized seed industry, encouragement of import of useful germplasm, and boosting of exports are core elements of the agricultural policy of the new millennium.

We also need to have policies to motivate farmers and food processors, and to provide an interactive coupling between technology, economy, environment and society for speedy development of food processing industries. We need to build up a substantial base for production of value added agro food products for domestic and export markets with a strong emphasis on food safety and quality, enabling the farmers especially to realize direct benefits of new technology and marketing network and to ensure adequate availability of quality food products for the consumer at economic prices. It will also generate employment potential and safeguard environmental sustainability.

Low margins, seasonality and high perishability being the distinct features of this industry, the access to seed capital and working capital is not easy. With the coming in of WTO regime the countries have to prepare for meeting the requisite quality standards in order to compete with imported goods in the domestic as well as the market.

Appropriate environment for entrepreneurs needs to be created to set up Food Processing Industries through

- fiscal initiatives / interventions like rationalization of tax structure,
- harmonization and simplification of food laws,
- strengthening extension services to the farmers and co-operatives in the areas of post harvest management of agro-produces, and
- simplification of documentation and procedures under taxation laws.

Agricultural Credit

Cooperative agencies, commercial banks and regional rural banks have gradually ensured that credit reaches the most remote agricultural and rural areas. Cooperative societies not only serve as a channel for providing credit but are also a means of broadening the experience of villagers in activities like marketing, community farming, and consumer purchasing. Credit societies are the most extensive and important group of cooperatives. Cooperatives have also played a significant role in the production and distribution of agricultural inputs such as fertilizers, pesticides, and agricultural implements.

A recent phenomenon witnessed in these countries is that of micro-credit through people's participation. The Grameen Bank of Bangladesh is a success story that stands out and we shall take it up in Sec.14.5.

Agricultural Insurance

Crop insurance schemes are instruments of risk management in agriculture and act as measures of providing relief to farmers whose crops are damaged due to natural calamities. Certain crop insurance schemes also cover small and marginal farmers. There are also livestock insurance schemes for the value of the animal at the time of death.

During the last one decade there has been a significant change in the economic and trade policies around the world. In order to cope with fast changing global economic and trade scenario, the national policies have been suitably modified. An example is **the export and import (EXIM) policy** of the Government of India.

The objectives of the EXIM policy are:

- To facilitate sustained growth in exports to attain a share of one percent of the global merchandize trade.

- To stimulate sustained economic growth by providing access to essential raw materials, intermediates, components, consumables and capital goods required for augmenting production and providing services.

- The enhance the technological strength and efficiency of Indian Agriculture, industry and services, thereby improving the competitive strength while generating new employment opportunities and to encourage the attainment of internationally accepted standards of quality.

- To provide consumers with quality goods and services at internationally competitive prices while at the same time creating a level playing ground for domestic producers.

'o sum up, appropriate policies and programmes have an important role in not only oosting agricultural productivity but also ensuring maximum returns to the farmers nd food security for the people and environmental safety. You may now like to ttempt an SAQ on this aspect of society and agriculture.

AQ 2

)iscuss the policy measures required to boost agricultural productivity and to prosper ı the current international trade regime.

.4.4 INSTITUTIONAL CAPACITY BUILDING

'ou have studied that the fight against poverty and food insecurity, necessarily a ɔng-run effort, is based on agricultural development fuelled by growing productivity nd supplemented by suitable policies in South Asian countries. Modern agriculture is nowledge-based, in which education at all levels, particularly higher and vocational ducation has an important role. The developments in science and technology have reated immense possibilities of reaching information and education to billions of ural masses irrespective of geographic, administrative, socio-political and economic onstraints. The ICTs which essentially are about increasing productivity and ıformation access anytime, anywhere thus appear to have an important role in this ffort. The new technology also has the potential to link policy makers, dministrators, researchers and commercial set-ups to the farmers, thereby putting griculture in the front line of economic growth of these countries.

n recent times, several initiatives have been made in the countries of Asia, Africa, ınd Latin America, which primarily aims at use of ICT for **governance**, **increase of ıgricultural production**, and **poverty alleviation** which lead to overall development ɪf humankind. Several governments in the world have implemented ICT projects vhich promote **e-governance, government online** and **automation of office ıdministration** with an overall aim of providing **transparency**, **accountability** and ɔeoples' **participation** in governance. The importance of ICTs is recognized as a tool hat serve the poor in rural areas who predominantly depend on agriculture by mproving the access, quality and current relevance of information to support their ivelihood and food security strategies.

The ICT plays an important role in providing timely and right information awareness :o the poor to participate in and take advantage of globalization. The ICT also allows ɔroducers to interface directly with the client to know the demands and accordingly change the production and marketing strategies in a manner most suitable for their capacities and socio-economic conditions.

The SAARC countries, whose economic backbone is agriculture, have greater role in implementing ICT applications for improving the agricultural productivity / production with an ultimate aim to eradicate poverty in the region. Realizing the potentials of ICTs, the countries in the south Asian regions started several projects each with a different approach such as **e-governance, information villages, grameen phones, wired villages, rural information kiosks, agricultural marketing portals, knowledge networks** and many such initiatives. Cyber parlours have been started to cater to information needs of rural people such as land needs, markets, social aspects etc. These experiments have been appreciated by the people and have helped them to improve their knowledge in various aspects of agriculture and markets.

Issues relating to **ICT capacity building, sensitizing and training people to take advantage of Internet connectivity, e-governance, e-commerce, e-learning, networking, and knowledge management, and public-private sector partnerships form the major dimensions of institutional capacity building.**

The ultimate objective is to improve the quality of life of the populations through digital democracy and e-governance. In a decentralized democracy the IT could have the following applications:

- Resource mapping at the micro and macro levels.
- Seminars aided by internet on pooling of resources and effective utilization of resources, based on social justice and social development oriented priority.
- Electronic conferencing at every level of policy analysis, project preparation, planning, implementation, monitoring, evaluation, project/ plan modification, and referrals and consultation.
- Teaching and training at various levels through internet, web publishing, and e-mail.
- Transparency in governance, quick access to data and speedy retrieval.

Education and Research

The paradigm shifts in the agricultural production systems which foster the diversification of farming based on sustainable use of natural resources and input management have highlighted the role of education as an essential resource for agricultural development. The increasing recognition for integration of farmers' knowledge and innovations with the agricultural research strategies has necessitated for the creation of forward and backward flow of relevant information in the agricultural system. Knowledge-based agriculture propelled by the precision farming mechanism is becoming future age agriculture in all countries.

This mode of agriculture uses information and knowledge based management systems to increase production efficiency by adjusting farmer inputs to specific agro-ecological situations within each area of a field. The new worldwide agricultural extension policy framework that promotes public – private partnerships with emphasis on participatory approaches has increased the multitude of agricultural institutions and information sources.

The integration of research, education and extension is important to modernize the practice of agriculture. Technologies developed for commercialization need to be transferred to the farmers who should also have the capacity to understand and use them. We find today that farmers continue to struggle with out-dated implements and if at all they have made improvements, it is by themselves.

SAARC countries, of course have made significant contributions in agricultural research as a whole but there are still such areas which need more attention and priority. Cost effective post-harvest technology is one of them. In practice, even the accepted technologies are not being utilized due to various reasons. One of them is lack of awareness and absence of well established information network.

There is also a need to think of teaching about agriculture along with health care and sanitation in schools, colleges and Universities. It is time that we make agriculture as an integral part of university and school education and broaden the outlook of teachers and students.

Women in Agriculture and Environmental Protection

Women in South Asian Countries play an important role in all walks of life in general and in agriculture in particular. Due to unabated degradation of life support systems particularly land, water and forests, the drudgery of women is increasing. The pre- and post- harvest technologies are not sensitive to the requirements and convenience of women; hence intensification or diversification in agriculture results in increased work loads for them. In spite of significant contributions made by women to household income through on and off farm activities, there is least social and economic recognition and their work as family labour is grossly underestimated. There are great variations in gender roles in agriculture across the region influenced by culture, agriculture, physiographic and climatic factors.

A sharp decline in common property land resources on one hand and the deterioration of the remaining land have contributed to hardship for the rural community, particularly for women of the poor households. Deforestation has increased time and distance involved in grazing and collection of fuel and food. Due to shrinking forests, the distance from rural human habitats to forests has increased considerably. Moreover, it has also threatened availability of fuel and fodder and income generating opportunities for women by affecting livestock rearing and collection of Non-timber forest products (NTFP). Reduced or non-availability of NTFP has shifted women from self-employment to wage employment.

Women in rural areas generate income in various ways. This includes basket, broom and rope making, tasar silk cocoon rearing, lac cultivation, oil extraction, and bamboo works, etc. Women constitute the larger of the total employed in forest-based small-scale enterprises. Women's key role in the production of major grains and minor millets illustrates their valuable contribution to the food security. In addition, women play a crucial role in ensuring supply of food as food vendors and post-harvest processors of livestock and fishery products. As major buyers of family food and meal-makers, women ensure adequate food security. As primary providers of nutrition to the young children, women are the major decision-makers in ensuring nutrition to the next generation.

Therefore, planning at the local level should be gender-sensitive and should have gender-segregated information to support local development efforts. Existing policies related to targeting women and gender-equity should be widely communicated to all involved in development work including women clientele.

Women-managed rural production and marketing ventures should be supported in horticulture, floriculture and post-harvest processing in commodities and provided technology training and input support to women to take advantage of emerging high-value agribusiness sector including bio-technology and forest products.

SAQ 3

Discuss how institutional support can help in improving agricultural productivity and bettering the lot of farmers, and women in particular.

14.5 PEOPLE'S PARTICIPATION: SOME CASE STUDIES

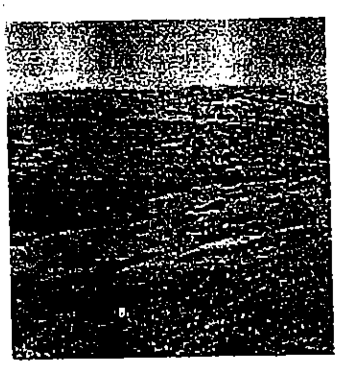
So far you have studied about measures like infrastructure development, support through appropriate policies, education of farmers, e-governance etc. required to improve agricultural productivity as well as the economic conditions of the farmer. But the peoples' active participation in all such initiatives is the most important ingredient as the following case studies illustrate.

The Pani Panchayat Experiment

The experiment of organizing the local population to harness the available water resources for agriculture was initiated by Mr. V.B. Salunkhe in a drought prone area characterized by high levels of poverty in Pune district of Maharashtra, India. In order to optimally utilize the locally available meagre water resource for protective irrigation and in order to fulfil the need of food and shelter of the local people on a sustained basis, the initiative for water conservation and utilization of water by organized collectives of water users known as **Pani Panchayat** was taken by Mr. Salunkhe and his wife during the early 80s.

In a country where rural people failing to get returns from their agricultural lands migrate to the big cities in search of jobs, in the 30 odd villages of Pune district where Vilasrao Salunkhe's pani panchayats are in operation, reverse migration is the order of the day. Farmers who were getting barely 50 kg of bajra and jowar per acre and whose annual income was Rs.2500 to Rs.4000 now earn Rs.10000 to Rs.1 lakh from the same land. In addition to the traditional cereals, farmers in this area grow wheat, onions, vegetables, and a variety of flowers like marigolds, lilies etc., fruits and a cash crop that is not a water guzzler. The villagers practice organic farming. They have been able to provide employment to people from the adjoining villages and farmers who had gone to Pune and other cities for work no longer migrate.

Vilasrao Salunkhe
'Pani Baba'
1937 ~ 2002



The man who pioneered the radical technological and social innovations that repair and restore degraded water sheds and guarantee each family within the community an equal share of the water harvested, was an engineer with his own factory. It was in 1972, after the terrible drought that affected some 4-lakh people of Maharashtra that Mr. Salunkhe realised the need to intervene. There was just no water available for agriculture of any kind. Even drinking water was scarce and tankers would supply water for basic needs. Travelling extensively in the drought affected area, he found villagers breaking stones for road construction in a desperate bid to earn subsistence allowance from the government. The engineer in him realised that environmental regeneration and water shed development with the full participation of the community was the only solution.

Rainfall in this region fluctuated between 250 mm and 500mm.He initially tried his ideas of water shed development on a 16-hectare plot of hillside in Naigaon village in Purandhar block. The land belonged to the temple trust but it was barren and uncultivable. He got the land from the trust on a 50-year lease and built a hut where he and his family lived and worked with the community.

Conserving soil and harvesting water was given top priority. A series of contour bunds were raised to trap water and check soil erosion. At the base of the hill slope, a percolation tank that could hold up to a million cubic feet of water was constructed. A well was dug below it and water pumped from there up the hill slope for irrigating the fields. Trees were planted in the rocky areas; fruit trees grown in the more fertile areas and grass and shrubs regenerated on lands not being cultivated. Slowly production from the land increased. As against two to four bags of grain in a year, 100 quintals was harvested and enough employment was generated for the survival of five households and their cattle. Half an acre of irrigated land could provide a man's food needs for the whole year.

'he Naigaon experiment was ready for duplication in other parts of the state. Water ad to be treated as common property resource with all villagers having equal rights nd access to it. So the basic principles of the pani panchayat or Gram Gaurav 'ratishtan were evolved. These are in operation to this day:

- Irrigation schemes are undertaken for groups of farmers, rather than for individuals. Water is allocated on the basis of number of members in a family, rather than in proportion to the land holding. A family unit five is given water rights for irrigation of one hectare of land.
- Cropping is restricted to seasonal crops with low water requirement. Crops that require perennial irrigation and large amounts of water like sugarcane, bananas and turmeric cannot be cultivated in pani panchayat areas.
- Water rights are not attached to land rights. If land is sold, the water rights revert back to the farmers' collective.
- All members of community, including the landless have right to water.
- The beneficiaries of the panchayat have to bear 20 percent of the cost of the scheme. They have to plan, administer and manage the scheme and distribute water in an equitable manner.

With farmers paying 20 percent of the cost of lift irrigation, the government provided another 50 percent and the remaining 30 percent was provided by pani panchayat as interest free loan.

In about ten years the number of lift irrigation schemes has gone up to more than 100 and most of them are functioning in a sustainable fashion. As a result of these schemes, now the villagers are able to produce two crops a year with an irrigation provision of eight months whereas earlier the land could sustain only spare amount of rain fed cultivation.

Another direct impact of the Pani Panchayat has been the increase in employment opportunities. Many Pani Panchayat members were formerly working as agricultural labourers, construction workers, and stone breakers under the Government employment schemes. But after the formation of Pani Panchayats in the villages, employment was generated in the village and as a result, people left their jobs in order to work and settle on their own lands. The process also induced reverse migration. The reason behind the success of these schemes and their sustainability is the unity amongst the villagers and strict adherence to the rules and regulations laid down by the pani-panchayat, which is a unanimously elected body among the villagers.

Grameen Bank: Bangladesh

The Grameen Bank of Bangladesh has become one of the most well-known micro credit banks in the world. Its fame is well deserved. Started in 1976, the Grameen Bank today has roughly 2.3 million borrowers. Grameen Bank has reversed the conventional banking wisdom by removing collateral requirement and created a banking system which is based on mutual trust, strict supervision, accountability, participation and creativity. Grameen Bank sees credit as an empowering agent, an enabling element in the development of socio-economic conditions of the poor who have been kept outside the banking orbit on the simple ground that they are poor and hence not bankable. According to Professor Muhammad Yunus, the founder of Grameen Bank and its Managing Director if financial resources can be made available to the poor people at terms and conditions which are appropriate and reasonable, "these millions of small people with their millions of small pursuits can add up to create the biggest development wonder".

The "Grameen Bank Project" (Grameen means rural) came into being with the following objectives in mind:

- To extend the banking facilities to the poor men and women;
- To eliminate the exploitation of the money lenders;
- To create opportunities for self employment for the vast unutilized and under-utilized manpower resources;
- To bring the disadvantaged people within the framework of some organizational format which they can understand and operate and can find socio-political and economic strength through mutual support; and
- To reverse the age-old vicious circle of "low income, low savings, low investment" into an expanding system of "low income, credit, investment, more income, more credit, more investment, more income".

The project demonstrated its strength in the village Jobra (a village adjacent to the – Chittagong University - the initial site of the action research project) and some of the neighbouring villages during 1976-1979. From there, with the sponsorship of the central bank of the country and support of the nationalized commercial banks, the project was extended to Tangail district (a district north of Dhaka, the capital of Bangladesh). With the success in Tangail, the project was extended to several other districts in the country. In October 1983, the Grameen Bank Project was transformed into an independent bank by a Government Ordinance with the name Grameen Bank. The Government provides 10% share capital of the Bank while 90% is held by the borrowers of the Bank.

Mohammad Yunus has transformed the lives of thousands of impoverished people through the Grameen Bank. Money is lent only to the poorest of the poor-for tools to husk rice, to buy a cow or a sewing machine. Many of the 1.2 million Grameen borrowers, 90 percent of them women, had been reduced to begging for a living. Now most of them have a roof over their heads and can support themselves.

> "I got really frustrated and out of disgust...began walking through a village just outside the campus" Yunus recalls. "I was trying to find what the poor people's economics...is so that the village became a university for me."

One of the first people he met was a widow with two daughters: Sufia Khatun was a landless peasant, one of the 55 million in Bangladesh a country with a population twice that number. She had borrowed money to make bamboo stools which she then sold. But as the loan had to be repaid, her daily profit was a mere two US cents. Yunus says that he "couldn't accept why anybody should make only two cents for such a beautiful skill."

All Sufia needed to improve her income was the equivalent of four dollars. Yunus lent her the money and her profits soared to one and a quarter dollars every day. The spectacular result prompted Yunus to approach a local bank to lend Sufia money. Sufia repaid the loan and continued to make profits. But the bank refused to deal with her directly.

It was then that Yunus decided to set up a bank which would cater only to those rejected by traditional banks -- the poor, the illiterate, and women. What began with a few small grants and loans from international donors has now provided over 100 million dollars in loans. Ninety eight percent of all loans are paid back. The secret of Grameen's success is the trust between the bank and its borrowers, a result of their regular interaction.

he bank also aims to raise health and environmental consciousness. Each of its embers must plant at least one sapling a year as part of an afforestation programme.

Lending money does not help the poor individual," says Yunus "unless at the same me you help bring out inner potentials that help the individual overcome seemingly superable odds."

he Grameen approach emphasizes the creation of enabling conditions in which every uman being may have the opportunity to carve out dignified ways of living for er/him. GB views its loans as a means to gain command over resources. With its fective use a poor person converts her/his latent skills in generating an income and eates self-employment without having to be constrained by the limitations of wage nployment. Besides, self-chosen economic activities increase the sense of articipation and strengthen the base of self-help. Professor Yunus puts it as "creating vourable conditions for making a living through self-employment is a much more ignified way of solving the unemployment than initiating a system of doles and elfare payments".

irameen Bank in recent years has not only expanded its credit operations which are irgeted at the poorest of the poor in rural Bangladesh, it has also rapidly diversified s activities. Grameen today is the focal point of a global network of institutions and idividuals who provide micro-credit to fight poverty. Within Bangladesh, the Bank as undertaken major investment initiatives in those sectors where the poor have the omparative advantage in terms of their skills, enterprise and productive capacity. A umber of social development oriented companies have been established under the Companies' Law to boost economic growth of vital economic sectors like agriculture, sheries and rural industries.

ndia's Milk Revolution: Operation Flood

White Revolution that holds the promise of raising the nutritional status of nderprivileged sections of the people has quietly swept India during the past few ecades. India is now one of the largest milk producers in the world and an exporter. Ailk has become India's most important farm commodity, the value of its output (in 994-95) of Rs.500, 000 million exceeding that of paddy. These achievements have een realized against great odds: a national herd of poor yielders, crop residues and gricultural by-products as the main feed, and a lack of adequate marketing support nd finance.

mul and the Anand Pattern

ndia's White Revolution had its origin in a single small enterprise started in Gujarat State. In 1946, at the suggestion of Sardar Vallabhbhai Patel, the farmers in Khera listrict formed a cooperative union to supply milk directly to the Bombay Milk Scheme (BMS). Right from the inception of the dairy cooperative, a vital link was established between the producer and Bombay's market, ensuring the incentive of a table and remunerative price to the farmer.

The structure of the Anand pattern was established from the beginning. Initially it ncluded two tiers, the primary village Dairy Cooperative Societies (DCS) of milk producers at the base, with a cluster of such societies forming a District Milk Producers' Union entrusted with procurement and processing. As Khera District was oined by other unions in Gujarat, an apex Federation of Unions was created to market their produce. They have their own bylaws and are managed by democratically elected boards. The facilities at all levels are entirely farmer owned. By appointing qualified technologists and professional managers, the cooperatives also made sure that the farmers' productive genius was linked to modern management and technology.

Operation Flood

In contrast to Amul's remarkable progress, the government tried various animal husbandry and dairy development schemes during the period 1951-70 at a total cost of Rs. 11,400 million, but none of them yielded the desired results; many were dismal failures. It was at this juncture that the then Prime Minister of India, late Shri Lal Bahadur Shastri, paid a visit to Khera district to inaugurate a modern cattle feed plant, then – as now – the largest in the country. Spending a night in a village in the company of farmers and unaccompanied by officials, the Prime Minister saw and heard first hand from the farmers the transformation brought about by the Anand pattern of milk cooperatives. On his return to Delhi, he set in motion the effort to create Anand in all parts of India. The National Dairy Development Board (NDDB) was formed in 1965 and was charged with the responsibility of building cooperative dairies in India on the Anand pattern.

Operation Flood, the programme to replicate Anand and create a flood of milk in India's villages, was launched in 1970. The Amul experience had established, tested and proved the guiding principles for dairy development: a three-tier cooperative structure owned and controlled by farmers, professionally managed, providing the inputs for production enhancement, purchasing all the farmers milk, processing and marketing it in urban markets.

The objective of "Operation Flood" was to eliminate middlemen in milk trade and to hand over tools of socio-economic transformation in the hands of milk producers. Village-level diary cooperatives were organized with the required physical and institutional infrastructure to support production and procure milk. Union-owned and managed modern production enhancement, processing and marketing facilities were created and metro dairies were established. The thrust was to link Bombay, Calcutta, Delhi and Madras with the country's 18 best milk sheds.

Operation Flood has helped dairy farmers direct their own development, placing control of the resources they create in their own hands. In the 25 years since the launch of Operation Flood, national milk production has more than trebled and per capita availability almost doubled. A National Milk Grid links milk producers throughout India with consumers in over 700 towns and cities, reducing seasonal and regional price variations while ensuring that the producer gets a major share of the consumers' rupee.

The bedrock of Operation Flood has been village milk producers' cooperatives, which procure milk and provide inputs and services, making modern management and technology available to members.

Research in products, processes and biotechnologies, both in-house and in collaboration with government and non-government agencies, supports the cooperative dairy industry. Product research is aimed at diversification, extension to the product range and shelf life through suitable packaging. Processes have been established for the mechanized and hygienic production of traditional products, sweets such as well as flavoured milk drinks. These products are now marketed in long-life packaging.

Operation Flood has been one of the largest and most successful rural employment schemes in the world. Cooperative dairying means regular income to millions of small farmers. Cooperative dairying has not been merely the modernization of milk production but has larger technological, economic and social dimensions. It has created and nurtured democratic structures at grass root levels. Such gains should not be endangered.

Though, thanks to Operation Flood, India today is the largest milk producer in the world, milk production still falls far short of national requirements for adequate nutrition. As against the present production of about 74 million tones, national requirement will be as high as 173 million tones by 2020. Milk productivity per animal in India (1,250kg/lactation) is still very poor compared to international levels (2,038 kg/lactation) due to gradual breed deterioration. Thus, while we have every reason to feel gratified with the success achieved so far, there is no room for complacence. We must build on the achievements of Operation Flood.

With these examples of peoples' collective power to tackle the problems of boosting productivity in the agricultural sector and alleviating poverty, we come to an end of this unit and summarise its contents.

14.6 SUMMARY

- The development of infrastructure such as rural transport, roads, and facilities for storage, irrigation and marketing is an area of top priority in order to improve agricultural productivity in developing countries, in general and South Asian Countries, in particular.
- The governments have devised specific policies and programme to provide agricultural inputs, such as seeds, fertilizers, power and irrigation water at subsidized prices and have made public investments in agricultural research, and extension. The governments also formulate national agricultural policies of price support, procurement, subsidies, investments, credits, insurance, taxation and trade and fix minimum support prices for major commodities each year.
- Modern agriculture is knowledge-based, in which education at all levels, particularly higher and vocational education has an important role. The developments in science and technology, particularly information technology have created immense possibilities of reaching information and education to billions of rural masses irrespective of geographic, administrative, socio-political and economic constraints. The new technology also has the potential to link policy makers, administrators, researchers and commercial set-ups to the farmers, thereby putting agriculture in the front lines of economic growth of these countries.
- The active involvement of people is an important ingredient in bringing about an improvement in the agricultural sector as has been illustrated by three case studies, namely, the Pani Panchayat, Operation Flood and Grameen Bank.

14.7 TERMINAL QUESTIONS

1. Discuss the major socio-economic factors that influence the agricultural sector in a developing country.
2. Outline the measures that respective governments can take to accelerate the growth of agricultural sector in the South Asian countries.
3. Explain what you understand by institutional capacity building.
4. What are the motivations and common features in the case studies described in Sec. 14.5 that led to their success?

SAFLI

South Asia Foundation
Learning Initiative

Towards Participatory Management

Department of Environmental Science
Allama Iqbal Open University Islamabad

Uttar Pradesh
Rajarshi Tandon Open University

PGD-ESD - 03

Agriculture and Environment

Block

4

TOWARDS A GREENER FUTURE

BLOCK 4 TOWARDS A GREENER FUTURE

UNIT 15 IMPERATIVES

Structure

15.1 INTRODUCTION

So far in this course, you have been acquainted with the agriculture-environment relationship and the concept of sustainable agriculture. You have learnt about various resources such as soil, water, biodiversity, energy, fertilizers, etc. needed for agriculture and the issues and challenges involved in their environmentally sustainable management. In the previous block, we have discussed various strategies for eco-friendly agriculture viz. Integrated Resource Management, Integrated Farming Systems and eco-friendly strategies for plant protection. You have also studied about several socio-economic issues that influence the practice of agriculture in South Asian countries such as agriculture and trade policies, institutional capacity and people's participation.

In this unit, we take up some important issues that have implications for **the practice of sustainable agriculture in future**. The first and foremost among these is the challenge of ensuring food security for the poorest of the poor in a manner that the ecological security is not endangered. Since modern agriculture depends heavily on technology, the questions of technology transfer and appropriate technologies for resource poor farmers assume great significance if we wish to ensure food security and remain competitive in the world markets. We also discuss the issue of genetic conservation, which is equally important in a scenario where biotechnology in agriculture is enabling manipulation at the genetic level. You will learn more about the new technologies and the issues involved in their use in the next unit.

Objectives

After studying this unit, you should be able to:

- discuss various aspects of the issue of ensuring food security in the era of globalisation;
- explain the concept of ecological security and analyse the issues involved; and
- discuss the various dimensions of technology transfer and the appropriate technologies for resource poor farmers.

15.2 FOOD SECURITY

You have studied in Unit 14 that the well-being of the people of any country depends not only on adequate and sustained production of food but also its distribution. The problem of low agricultural productivity and lack of access to food continues to persist in South Asia. Nearly 37 percent of the world's malnourished and hungry people belong to this region. Emergencies, such as drought, floods, and war, are responsible for only 5-10% of the hunger in the world. For most hungry people, however, food shortages are simply a fact of everyday life.

Therefore, a major social objective of these countries is to ensure adequate food for all at reasonable prices at all times with special provision for the chronically undernourished, underprivileged and other vulnerable groups of the society. This is the crux of the issue of food security. Let us begin the discussion on the issue by understanding what it means in our context.

According to the FAO Committee on World Food Security, food security means that "all people at all times have physical and economic access to the basic foods they need." To elaborate further, sustainable food and nutritional security may be defined as a condition in which every individual at all times has physical, economic, social and environmental access to **safe, nutritionally adequate and personally acceptable foods in a manner that maintains human dignity.** This means that in order to enjoy food security, there must be on the one hand a provision of safe, nutritious, and quantitatively and qualitatively adequate food and, on the other, rich and poor, male and female, old and young, all must have access to it.

Food security requires that at all levels - **production, distribution, consumption and waste management** - measures need to be taken to guarantee a democratic and sustainable food system. A sustainable food system aims for the satisfaction of basic human needs without compromising the ability of future generations to meet their own needs. It involves maintaining ecological integrity, and incorporating conservation and development.

We now discuss various dimensions of the issue of food security.

Availability

Availability refers to the assured and reliable supplies of sufficient quantities of food of appropriate quality, now and in the future through increase in domestic agricultural production or imports.Sufficient supply of food for all people at all times is a precondition for food security and has historically been a major challenge.

In 1979 the World Food Programme Report conceptualized food security, equating it with an "assurance of supplies and a balanced supply-demand situation of stable foods in the international market." The report also emphasized that increasing food production in the developing countries would be the basis on which to build their food security. For a long time, there was a tendency on the part of planners, policy makers, economists and agricultural scientists to understand the issue of food security *only* from the point of view of increased supply through increase in production. It was thought that increased food production would automatically lead to assured food supply to all people. Thus, the monitoring of food insecurity in the early years focused only on the availability of food in the world marketplace and on the food production systems of developing countries.

The Green Revolution of the 1970s was seen as the answer to the problem of hunger. But such a largely technological approach has come under rigorous critical scrutiny both on the counts of environmental sustainability and social equity. In countries like ours, it has largely benefited rich farmers at the expense of poor farmers. We shall visit this aspect in detail shortly. Here we briefly talk about the limitation of the technology per se.

Most of the technologies used to bring about the Green Revolution have been focusing on the *quantity* of food (mostly wheat and rice) produced, and *economies of scale* without paying enough attention to the sustainability of the practices. Not much attention has been paid to the production of the nutritionally superior grains such as coarse cereals and pulses, which has been extremely uneven over the last several years. It has had an adverse implication for the country's nutritional security. One-third of the population living below the poverty line is afflicted with wide-spread protein deficiency and malnutrition. Coarse cereals and pulses are known as the cheap

)urces of protein for the common man, but the per capita availability of both has :clined consistently.

ou have studied in the previous blocks about how the wide use of chemical :rtilizers and pesticides has thrown up serious ecological problems in many parts of ıe world. The intensive land use and widespread biomass shortage have led to the :pletion of essential nutrients and organic matter in cultivated soils. Resources such ; water, forests, fisheries, and livestock are also under tremendous strain. This has d to a rethinking about the Green Revolution and to a quest for more sustainable)proaches to increase food production.

xperience has also shown clearly that global food availability does not ensure food :curity to any particular country because what is available in the world market (or the ırplus in the developed countries) cannot be accessed by hunger/famine-affected :ople in developing countries; the economies of these countries, in general, cannot 'ford to purchase food from the world market.

ioreover, an increase in national food production does not by itself guarantee food :curity. Availability of food at the national level is but one factor for food security. ıe assumption underlying this perspective is that whatever food is produced in the ıuntry will be evenly distributed to each region and to each household. But the fact is fferent. **People will have access to the surplus in the country** (through the arkets) **if, and only if, they have the required purchasing power.** In most poor ıuntries, however, many people do not have such power. National governments, too, 'ten lack the necessary financial resources to purchase the surplus and to distribute it the have-nots, especially when millions become destitute. Therefore, food 'ailability at the national level alone does not provide food entitlement to households ıd individuals.

s the world's population continues to swell toward 8.1 billion by 2030, even lvocates of the Green Revolution agree that increasing food production alone will ıt ensure assured food supply for all. "Despite the successes of the Green :volution, the battle to ensure food security for hundreds of millions of miserably ıor people is far from won," says Norman Borlaug, who received the 1970 Nobel :ace Prize for his work to increase food production around the world that sparked the reen Revolution. It is now a well accepted fact that technological innovation is no ınacea to all problems of poverty and sustainable development - it is just one stone a large and complex socio-economic mosaic.

ırther, there is no relationship between the prevalence of hunger in a given country ıd its population. For every densely populated and hungry nation like Bangladesh, ere is a sparsely populated and hungry nation like Brazil and Indonesia. The world day produces more food per inhabitant than ever before. Enough is available to ovide about 2 kg of food for every person every day: more than 1 kg of grain, beans d nuts, about half a kg of meat, milk and eggs and another half a kg of fruits and getables. The real causes of hunger are **poverty, inequality** and **lack of access**. Too ıny people are too poor to buy the food that is available (but often poorly stributed) or lack the land and resources to grow it themselves. **Access to food** is w recognized as an important parameter of food security. But before we move on to you may like to consolidate these ideas.

ıQ 1

:plain why food availability is a necessity but not a sufficient condition for food :urity.

Accessibility

Distribution and access by households and individuals to appropriate foods for a nutritious diet are as important aspects of food security as food production. It is not enough to produce surplus food if it can't get to those who need it, if those who need it can't afford it, or if they don't know how to use it. Food security depends on household income, access, and knowledge. Thus, the issue of food security is intimately linked with the socio-economic conditions of a given society.

Unequal distribution of wealth, power and resources are seen today as major barriers to food security. Other constraints include commodification of food, environmental degradation, trade agreements that encourage cash cropping rather than food production, and agricultural research carried out without farmer participation. **Inequities**, within and between societies, have resulted in class, gender, ethnic, racial and age differentials in access to food and other resources. There are also national and regional gaps in development within and between the segments of the societies. In developing economies inequalities in access to food and the resulting food insecurity are most acute among the marginalized segments of the population. It is evident that if food grains cost, say, Rs. 10 per kg, a person earning Rs. 3000 per month will be in a better position to buy them than a person earning Rs. 1000 per month. Social and cultural disparities are also involved. We now take an in-depth look at the various aspects of access to food.

Let us first understand which sections of the population face food insecurity due to lack of access and why. These are

- Small and marginal farmers who also toil on other fields for their survival,
- Agricultural labourers,
- Wage labourers and unemployed poor in the cities most of whom may have migrated from villages due to lack of employment opportunities, and
- Women, girls and socially disadvantaged people.

You may like to know: Why do small farmers appear in this list? Why do they themselves not have access to food? Why do they not have the required purchasing power?

Let us understand this issue with the help of a concrete example from India. A cursory comparison of the free market price of food products and their minimum support price announced by the government reveals that the farmer gets only a fraction of the market price. The rest goes to the middleman – be it the government or the private trader. After deducting the input costs, farmers are left with a very small profit per unit. A study carried out in the Chattisgarh state reveals that of the Rs. 11per kg of rice paid by the consumer in the market, the middleman gets Rs. 6.50 and the farmer Rs. 4.50 as the official support price. An evaluation of input cost reveals that the farmer invests around Rs. 4.212 per kg. This leaves a profit margin of a meagre Rs. 0.28 per kg.

You must also understand that small and marginal farmers cannot afford to stock their produce to sell it when higher market rates prevail as they have to repay their earlier loans and prepare for the next crop. It turns out that for their own food needs, they have to depend on the market. Thus, the economic compulsions force farmers to sell their own produce at cheaper prices but buy them later at higher (unaffordable) prices. This gives rise to the anomalous situation that the farmers who fill the granaries, lack food security themselves.

Moreover, in a highly resource intensive agriculture dependent on expensive inputs, the share of human labour and wages for labour are progressively declining. In the above-mentioned study, within the input costs, agricultural wages accounted for barely Rs. 0.72 per kg. The wages of the labour put in by the agricultural labourer or the farmer and his family members on their own fields are pegged at much lower rates compared to a daily wage earner, resulting in their impoverishment.

It can be surmised from this analysis that the process of deciding the minimum support price does not rationally account for the input costs, in general, and the cost of manual labour in agriculture in particular. It favours rich farmers who have large land holdings, can use resource intensive technologies along with mechanized agriculture to attain economies of scale and can afford to sell their produce at favourable market rates. A large section of the population comprising small farmers and agricultural labourers is left with limited purchasing power that impacts their food security. The lack of employment opportunities in rural areas forces large scale migration to cities. However, the industrialisation and employment opportunities in the urban areas have not kept up pace with the demand. The result is huge unemployment, devaluation of labour costs and resulting poverty, which affects the food security of the rural migrants.

Another factor that affects food security is the **distribution** mechanism. If the pricing of food commodities is left to market forces, it is the middleman or the rich peasantry that benefits. But the bulk of food is still produced by small and marginal farmers, and so they lose in the bargain. The answer to this lies in a strong public distribution system, a facility that India can boast of. However, the recent process of liberalization and globalization has witnessed a rapid erosion in the public distribution system, which itself is not beyond the purview of a critical evaluation.

We need to evaluate the current public distribution system (PDS) in India around the following issues:

- Who decides what to distribute and at what prices?
- Location of food godowns.
- Who distributes it?

Firstly, the PDS in India distributes mainly rice and wheat. The coarse grains consumed by the majority of the poor people are outside its purview in spite of their better nutritive value. For example, bajra and jowar have 11.6% and 10.4% protein which is comparable to wheat (11.8%) and much more than rice (6.8%). Ragi, bajra and jowar are also rich in iron and other minerals in comparison to rice.
The location of godowns in urban areas and the consequent high transport costs to rural households serves as a disincentive for public distribution in poor economies with the result that the PDS has seen a steady erosion. Corruption is also rampant in PDS with most of the food to be distributed finding its way into the market instead of reaching the poor people for whom it is intended.

Moreover, the problem of access does not automatically get resolved by government intervention to provide aid or by taking special distribution measures for poor people. For example, in many parts of rural India, the poorest of the poor are found to sell their special ration cards for immediate relief from hunger as they do not have even that miniscule purchasing power. There are other socio-economic and cultural inequities that impact food security. For example, the caste system is entrenched deeply in many parts of India. The caste one is born into determines what education and occupation one can have, which determines one's income, one's purchasing power and hence one's food security.

It is also not correct to assume that access to adequate food by households over time will imply that each member of the household is secure. The assumption here is that food is shared equally by each member of the household. However, there are intra-household factors that may affect equitable and adequate access to food by all members. For example, the head of the household may have more power in determining the use of food resources and may misappropriate it. Moreover, household members' nutritional requirements may vary, for example, if some exert more energy in work than others.

Cultural factors can also deprive members of the household (i.e., women and girls) from getting an equitable share. For example, in spite of the plethora of policies and programmes about gender sensitivity and equality, the bitter truth is that tens of thousands of women and girls in India lack access to adequate food, opportunities of education and health care within their own families. Thus we find that individual household members may suffer from inequitable distribution because of cultural and intra-family obstacles.

As parasitic and other diseases substantially hamper the metabolism and assimilation of food, individual state of health and knowledge about health and nutrition also figure significantly in the food security equation. Optimal uptake of nourishment through a sustaining diet, clean water and adequate sanitation, together with health care are essential components of food security.

SAQ 2

Describe the factors that influence access of the poor people to food.

Acceptability

Food security requires **culturally acceptable** food and distribution systems which are respectful of human dignity and social and cultural norms. As an essential ingredient of human health and well-being, the kind of food consumed and the ways of consuming it reflect the social and cultural diversity of humanity.

Food is an integral part of one's culture. Hence, people should have the option of producing what they desire to and the policies and technologies should be supportive of that. Consumers should also have the freedom to choose the food they prefer to buy from the public distribution system just as they have in the free market, so that they can access the food that is culturally acceptable to them. For example, a significant percentage (65%) of the poor people in India consumes coarse grains but the PDS distributes wheat and rice. For a moment, think of the reverse situation: Suppose special measures are taken to increase the productivity of coarse cereals (jowar, bajra, ragi etc.) in the wheat-rice zones, will the people of these regions like to switch over to eating coarse cereals? Then wherein lies the appropriateness of forcing a wheat-rice regimen on coarse grain eating people? Is it because these people have never been asked whether they would like to eat wheat or rice that they do not have any say in deciding what is to be produced and then distributed through the PDS? Thus, the question of cultural acceptability of food assumes significance in any discussion on food security.

Agency

Agency refers to the policies and processes that enable (or disable) the achievement of food security. It reflects our focus on governance and systems for poverty alleviation and enabling citizen participation.

Food insecurity is one of the most terrible manifestations of human deprivation and is inextricably linked to every other facet of the development predicament. Poverty is one of the major causes of food insecurity and sustainable progress in poverty alleviation is critical to improved access to food. Poverty is linked not only to poor national economic performance but also to a political structure that renders the poor people powerless.

So policy matters of a general nature, and in particular good governance are of overriding importance for food security. For example, it requires that poor rural communities be given access to and control over land for food production through agrarian land reform and assistance from capacity-building organizations such as seed banks. Agricultural trade policies under GATT must be changed to prevent cheap imported foods from destroying markets for local production, and intellectual property rights systems must be reformed to take into account farmers' rights. The central role of women to long-term food self-sufficiency must also be recognized, and women's access to land, extension services and technological expertise must be ensured. The main precondition for food security is a constructive political leadership that is responsive and responsible to the people. Secondly, progress for food security requires a proper macro-economic framework. The elements which have been most important for successes on the food security front are known today. **If and when poor small farmers have access to land, to agricultural extension services, to marketing opportunities, to working equipment, agricultural inputs, to fair terms of credit and to environmentally sound technologies,** they can contribute substantially towards food production. Rural employment can be generated and there can be an increase in their incomes. All these measures can be used to bring about noteworthy advantages and more food to the mass of small farmers.

If more can be grown on the available land, if less water and less fertilizer is needed for higher yields, if there is tolerance against major pests, and adverse cropping conditions and if the nutritional quality of food can be increased through appropriate measures, small and large farmers alike will benefit. If there is more pre- and post-harvest work to be done, further stimuli for rural employment and rural development will be the consequence.

Let us end this discussion by asking: Is there an alternative to the present methods of enhancing food production, the skewed public distribution system and providing access to quality food? We give here the example of the Deccan Development Society working for the last 20 years in District Medak of Andhra Pradesh. It has come up with the idea of SDK (Samudayik Dhanya Kothi translated as Community Grain Store) as an alternative production and public distribution system.

The SDK movement has been successful in cultivating wastelands through sustainable agricultural technologies, collecting the local produce and distributing it locally in the region where it is produced. Its control and management is in the hands of the poor women in the area. This is an example of people-oriented growth and decentralised public distribution system which can ensure food security without being subsidised year after year. In fact, this project was started with financial help from the Government of India in 30 villages. Around 80 to 100 farmers in each village were identified and each one of them was given 1.5 acres of waste land. They were trained in appropriate technologies to cultivate the wasteland and they grew coarse cereals that were culturally acceptable to them. They were given wages on the basis of food for work. The results were gratifying.

At an average of 100 beneficiaries per village, each village now stores 150 quintals of food grains, in the Community Grain Store for distribution. This suffices for six months at the rate of 25 kg grains per month to each family. The entire range of activities (from cultivation and collection of food grains to biodiversity management and identification of beneficiaries) is carried out by local women, a majority of whom belong to the Dalit families. Families are no longer dependent on traders to buy grains or on government officials to issue their ration cards and distribute grains. They now decide on what to grow, how to collect it and how to distribute it to the community on a priority cum need basis.

This alternative public distribution system has allowed 1000 hectares of barren land to be regenerated and produce 8000 quintal surplus grains in the very first year. This implied 3 million meals equivalent of excess grain production in 30 villages. Thus each family in these villages could access 1000 extra meals with acceptable food grains as well as fodder for 6000 animals.

The community distribution system has not only given positive results at the quantitative level but also at the qualitative level. It has shown the way to the success of sustainable organic agriculture and provided a road map for people-oriented food security as against special schemes-oriented food security. It shows us that the access to nutritious food is best assured when it is locally produced, processed, stored and distributed.

To sum up, food security deals with food production in relation to food availability; it addresses distribution in that the produce should be accessed by all; it covers consumption in the sense that individual food needs are met in accordance with the individual's cultural preference and ensures that the individual is active and healthy. The only pathway to eventual food security is sustainable human development. This means breaking the vicious circle of continuing poverty, environmental deterioration, and acute institutional deficiencies. Because deficits in food security stem from the combined effects of factors such as poverty, low levels of food production, and diminishing environmental quality, the best way to deal with the challenge lies in strategies that tackle all problems comprehensively, i.e. transforming local agriculture into a sector that generates employment and income for the rural people, stimulates the non-farm sector and the overall economy, and increases food supply.

The principal operational implications of the food security may be summarized as follows:

- Physically, assured food security requires a transition from chemical and machinery-intensive to knowledge and labour-intensive farming technologies. It requires better seeds, soil management and other sustainable agricultural practices. It also requires agricultural systems that maintain farm worker health, biological diversity, farmers' access to genetic resources, soil fertility and watershed protection.

- Economically, food and nutritional security requires the promotion of multiple income-earning opportunities, and provide sustainable livelihoods through appropriate policies, e.g., just distribution of land and production assets, proper support prices that take into account the component of labour wages, value addition to the produce and lowering of input costs.

- Environmentally, food and nutritional security involve attention to sustainable agricultural practices viz. soil and water management, conservation of biodiversity as well as adequate food safety standards and enforcement.

- Socially, food and nutrition security requires addressing social discrimination based on gender, class, and ethnic differences in society, incorporation of women into decision-making processes, and the right of communities to make informed choices regarding healthful eating patterns.

At this point, you may like to take a break and revise these ideas.

SAQ 3

What lessons can be learnt from the example of Community Grain Stores to ensure food security for the poor? Consider all aspects of the issue in your answer.

15.3 ECOLOGICAL SECURITY

The term 'security' reflects a deep seated human longing to be safe. But when we refer to ecological security, you would like to know: Safe in what sense? Safe from what? You would perhaps agree that the end of the cold war was marked by a transition in perceptions of threats to human security. The traditional kinds of insecurities vis-à-vis ajor nuclear/conventional wars are now being replaced by non-military threats. In e wake of the escalation in public concern over environmental degradation in the evious decade - intensified by nuclear fallout from Chernobyl, burning oil wells in e Gulf War, depletion of the ozone layer and predictions of global warming - it is ot surprising to find that the environment has also found its way onto this expanded curity agenda. Environmental problems such as global warming, deforestation, ecies extinction, and pollution are now being added to the range of "threats" to the terests of humanity as a whole.

hat constitutes ecological security? **Clean air, safe and reliable water supplies, utritious and safe food, healthy housing and workplaces, civic services and rotection against disease and disasters for all people form the corner stones of ological security.** Its ambit may be expanded to include ecological sanitation, i.e., fficient, cost-effective eco-engineering for treating and recycling human excreta, aste water, and other wastes.

et us first examine the general threats to ecological security, and then particularly in e context of agriculture.

/e now live in an increasingly crowded, environmentally stressed and resource egraded planet. Clean air, water and land are not available to large sections of people cross the world. These include the economically and socially disadvantaged people, nall farmers, factory workers, street vendors, women, children and slum dwellers, ho are pushed back into the most undesirable areas, forced to live in hunger, and uite often persecuted and jailed. Urban pollution is concentrated in areas where the ost impoverished live, where there are effluents in the drinking water and where eople fight with birds of prey for the scraps in rubbish bins.

he development paradigm itself creates the conditions for ecological insecurity: Vaterways are polluted and fertile soils degraded or flooded to make way for mega rojects, chasing weak people away, extinguishing life, exterminating fish and filling ams in order to generate energy that may even be squandered afterwards. Forests re destroyed to create paper and precious resources squandered in creating and unning a consumerist society unmindful of the consequences of its actions. The ommercialization of water and energy production and distribution has left thousands f people without access to these services.

nstead of invading armies we must now contemplate the likes of 'invading' deserts, vater shortages, air, water and soil pollution, rising sea levels, increased ultra violet adiation and an increased threat of diseases that may be the off-shoots of tinkering at he genetic level. These constitute *direct threats to environmental health and safety*.)ne of their consequences is mass migration of *ecological refugees*, fleeing from wars s well as ecological threats to health and livelihood. For example, on the margins of he Sahara and the Horn of Africa, refugee populations of several millions have rossed borders to escape starvation caused by overgrazing and drought. Sea level ises may trigger even more massive migrations than desertification.

'he ecologically destructive power of the military is itself increasingly seen as one of he biggest threats to ecological security. Military training, production, storage and lisposal of weapons and, above all, armed conflict (especially nuclear, chemical and iological warfare) are themselves major causes of environmental degradation. The se by the US military of Agent Orange to destroy forest cover and food crops during he Vietnam War or the burning of oil wells in the Gulf War are examples of the vilful destruction of ecological assets and natural resources by nations/states.

Technological innovations in transport have increased the speed with which ever-arger number of people and accompanying microbes move and the territory over vhich they range. The large-scale and rapid movement of people and products nternationally has given birth to a host of global hitchhikers – viruses, bacteria and pests – that move fast into new environments where they flourish. Larger migrant organisms have also been transforming the environment and adding to ecological insecurity. Dozens of migrant organisms ranging from mussels to killer bees and weeds to super bugs have flourished when they have been transported into unexploited environments. They cause huge damage to native ecosystems.

In the context of agriculture, ecological security encompasses

- Management of agriculture to minimize environmental damage and degradation; regulatory mechanisms in agriculture for organic production; and scientific advances to improve agriculture and environmental security.
- Evaluation of medical & biological toxicity of agricultural chemicals and environmental pollutants accumulated in agricultural production; new techniques of detecting these substances, their toxicity mechanisms, and methods of removal or minimization.
- Promoting use of ecologically- safe technologies in agriculture – in crop production, in livestock, in processing and storage and new techniques that decrease toxic environmental inputs without lowering productivity.

New methods of producing and distributing food products can also adversely impact security from disease. The centralized production and large-scale distribution of food raises the spectre of potentially more severe outbreaks of disease rapidly spreading through human populations. For example, there have been several recent large-scale outbreaks of disease in many countries. "Mad Cow" disease has devastated herds in England leading to possible illness in human beings, sharply reduced consumption of beef, and a halt in beef exports. In Japan an outbreak of E-Coli bacteria felled thousands of school children. The ongoing bird flu in China is threatening human lives.

The agricultural genetic engineering biotechnology has not been critically reviewed from the stand point of ecological security. The potential risks of eating genetically engineered foods and their effect on human health are yet to be studied. Since genetically engineered (GE) food remains unlabelled, consumers cannot discriminate between GE and non-GE food, and should serious health problems arise, it will be extremely difficult to trace them to their source. The global fight for market share is leading multinational companies to massively deploy transgenic crops around the world (more than 30 million hectares in 1998) without proper advance testing of short- or long-term impacts on human health and ecosystems.

There is a potential risk of generating new virulent strains of viruses, especially in transgenic plants engineered for viral resistance with viral genes. Many results emerging from the environmental performance of released transgenic crops suggest that in the development of 'resistant crops', there is a need to test not only direct effects on the target insect or weed, but also the indirect effects on the plant (i.e. growth, nutrient content, metabolic changes), soil, and non-target organisms. History has shown that a huge area planted to a single crop variety is very vulnerable to new matching strains of pathogens or insect pests.

Furthermore, the widespread use of homogeneous transgenic varieties will unavoidably lead to 'genetic erosion', as the local varieties used by thousands of farmers in the developing world are replaced by the new seeds. Genetic pollution, unlike oil spills, cannot be controlled easily, and thus its effects are non-retrievable and may be permanent.

Unquestioned expansion of this technology into developing countries may not be wise or desirable. There is strength in the agricultural diversity of many of these countries, and it should not be inhibited or reduced by extensive monoculture, especially when onsequences of doing so may result in serious problems of environmental security. In ıct, preservation of bio diversity and genetic conservation is one of the imperatives of ıstainable agriculture.

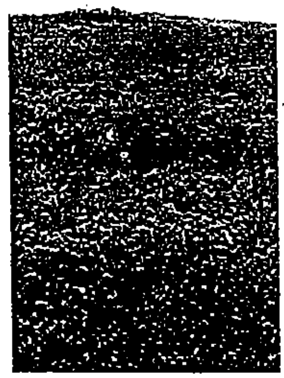
ienetic conservation involves all activities aimed at ensuring the continued existence, volution and availability of genetic resources, in situ and ex situ, e.g.,

The collection, maintenance, storage and sustainable management of genetic resources aimed at ensuring their continued existence, evolution and availability for current and future generations;

The management of human use of genetic resources so that they may yield the greatest sustainable benefit to present generations while maintaining their potential to meet the needs and aspirations of future generations;

Protection of plant and animal habitats;

- **The management or control of human use of resources (biotic and abiotic) and activities on the planet, in an attempt to restore, enhance, protect, and sustain the quality and quantity of a desired mix of species and ecosystem conditions and processes for present and future generations.**



Jltimately, the sustainability of a given ecosystem depends upon the maintenance of liverse and healthy gene pools of the organisms that constitute it. The need to preserve vild-type gene pools for domestication in plantations is vital; having a diverse gene ›ool from which to select, will help in the search for varieties that are resistant to ›athogens, pests and environmental pollutants and have high growth rates and good ¡ualities.

.essons can be learnt from the agricultural experience so far: the genetic identities of ılmost all modern domesticated crop species are now quite different from those of :heir wild progenitors. Indeed, in many cases, those ancestral species no longer exist, ;everely limiting the improvements that can be made. The importance of maintaining ı broad and viable genetic base, therefore, is an accepted principle among agricultural ;cientists.

Thus genetic conservation is positive, embracing preservation, maintenance, sustainable utilization, restoration, and enhancement of the natural environment and is an essential ingredient of ecological security.

The need of the hour is more enlightened global ecological governance, genetic conservation, the 'conversion' of military budgets towards peace and sustainable development, and the redirection of military activities towards research in environment friendly technologies data collection, monitoring, technological innovation and transfer, and restoration. There is also an urgent need to challenge the patent system and intellectual property rights intrinsic to the World Trade Organisation (WTO) which provide multinational corporations with the right to seize and patent genetic resources.

Financial support for ecologically-based agricultural research should be expanded as the dramatic effects of rotations and intercropping organic production systems and general agro ecological techniques on crop health and productivity, as well as of the use of biological control agents on pest regulation, have been confirmed repeatedly by scientific research.

Yield increases are being achieved by using technological approaches, based on agro-ecological principles that emphasise genetic conservation, diversity, synergy, recycling and integration; and social processes that emphasise community participation and empowerment. When such features are optimised, yield enhancement and stability of production are achieved, as well as a series of ecological services such as conservation of biodiversity, soil and water restoration and conservation, improved natural pest regulation mechanisms, etc. leading to increased ecological security, are promoted.

The issues of technology transfer and appropriate technologies for the resource poor are critical in our quest for food security. We take them up in the next section. But before that you may like to attempt an SAQ.

SAQ 4

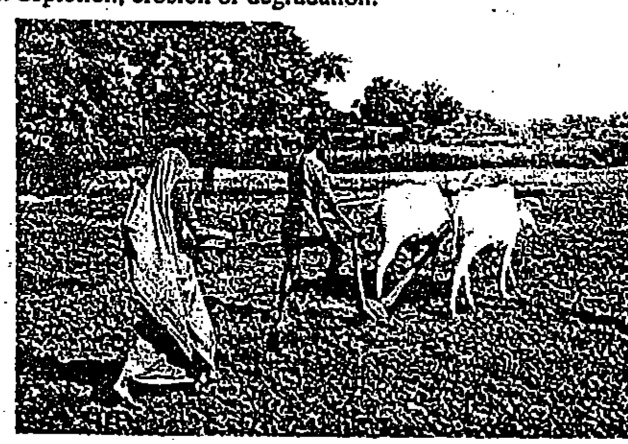
What do you understand by ecological security? Outline the factors that threaten ecological security.

15.4 TECHNOLOGY TRANSFER AND TECHNOLOGIES FOR RESOURCE POOR FARMERS

You have learnt that the sustainable development of rural economy and advances in agriculture are intertwined with the goals of poverty eradication and reduction of social and economic inequalities in the developing countries. While the world has witnessed tremendous advancement in the fields of science and technology, the results unfortunately have benefited a small portion of the rural population in the developing nations. The major hurdles for the large proportion of poor have been the lack of access to latest technologies and a lack of awareness regarding resource management techniques. The main factors responsible for such a state of affairs may be attributed to the lack of technology transfer and the communication divide between the farmer, the scientists and other sectors involved in agriculture. The technology options appropriate to farmers include, for example:

- improved soil usage through drainage, terracing and intercropping of food crops so as not to exhaust the soil;
- conservation, management and development of 'agricultural biodiversity', to make use of the vast range of plant genetic resources which farmers themselves have developed over centuries, such as thousands of indigenous varieties of staple food crops that are adapted to particular local conditions;
- sustainable use of wild foods and medicinal plants; and
- irrigation, water harvesting and other appropriate technologies.

The most appropriate technology will be one that builds on the use of local resources and is also sustainable. In terms of sustainability, the key issues are that the technology should be affordable, culturally acceptable, and the soil should not suffer from nutrient depletion, erosion or degradation.



Use of various technologies is involved in different aspects of farming, viz. seed preservation, planting, sowing, applying fertilizer, crop protection, harvesting, animal husbandry, livestock production, processing, transporting, storing, and marketing of food as well as use of tools and implements suitable for on-farm and off-farm activities. Appropriate technologies also include products to aid in fuel and water collection, food harvesting and crop processing, such as pumps, crop storage systems, efficient or smokeless stoves, water hauling devices, food driers, grinding mills, dehuskers, butter churners, beehives and honey extractors, transport vehicles such as trailers and carts, wheelbarrows, animal harnesses, hand-operated oil presses, biogas digesters, etc.

Access to and training in the use of appropriate small-scale technology has the potential to greatly enhance the quality of life and work of especially the poor farmers. However, information on the types of technologies developed for poor farmers is sorely lacking, as is the evidence of their appropriateness or success. Even in countries like India that have a comparatively stronger R & D base in rural technologies, the dissemination of these technologies to the poor farmers has a tremendous scope.

Thus, while the development of appropriate technologies per se may not be an insurmountable problem, but their transfer from the lab to the land is not that easy. Many of the technologies promoted to the farmers have been rejected, or partially and half-heartedly adopted with the result that the poor farmers have failed to benefit from them. Let us try to examine the reasons for this state of affairs.

Traditionally, appropriate technologies for the farmers are developed at special research centres. Here, researchers try out different species, cultivation practices, cropping patterns, and develop various techniques, tools and machines. Based on these studies, an appropriate technology is identified which is then extended to farmers. Even though in many cases the technologies developed are truly appropriate, as proven by their widespread adoption by farmers, in many more cases the technologies have failed miserably. Many reasons can be identified.

The primary reasons for low usage of appropriate technologies include limited distribution systems, insufficient awareness among farmers of the technologies, high cost, and lack of coordination, training and attention to the specific needs of farmers. Quite often farmers fail to understand the technology developed by the scientists. But more often, it is because the researchers fail to understand the background of the farmers for whom the technology is supposedly intended. In some cases, the problem may not be correctly identified, since only the technological aspects may be taken into consideration and the farmers' perspective ignored. In other cases, the technology recommended may be inappropriate: too costly, conflicting with social and cultural norms, ignoring farmers' preferences, not adapted to the local agro ecosystem, etc. In some other cases, technologies may be rejected, not because of the technology itself, but because those promoting it may be perceived as outsiders with no credibility as farmers.

The majority of farmers who are supposed to use these technologies are most of the time poor and illiterate. More often than not, technology development is not driven primarily by their knowledge or their perceived needs, but rather by imported prototypes and the views of technology developers and promoters are more theory based. Technology development is also biased in terms of socioeconomic class, with more attention given to those who can afford the technologies.

For example, improved water lifting technologies are currently limited to motorized pumps. While these pumps may be appropriate for larger-scale farmers, they are unaffordable and uneconomical for the majority of poor farmers who irrigate relatively small plots of land.

How can this situation be remedied? Firstly, farmers must participate in all stages of the technology development cycle: from the very first step of problem identification and planning to the implementation, monitoring and evaluation of the technology that may be termed as Farmer participatory approach. Farmers' input into the technology development is essential. It is necessary to create an honest, open, and equal two-way communication with farmers through appropriate programme approaches and extension methods.

Communication here does not only mean researchers and extension workers *telling* the farmers what they should and could do, but also the other way around; researchers and extension workers *being told* what to do by the farmers. What is needed is communication in the truest sense of the word; a mutual exchange and sharing of opinions between equal partners.

Farmer acceptance and his assessment of the value of technology may not need controlled experimentation many a times. The farmer draws on his own experience to make decisions about application. Acceptance of a previously unused technology by a lead farmer usually means that many farmers "looking over the fence" will pick up the technology. However, following farmer acceptance, controlled farmers' field experimentation may be needed to fine tune the technology and overcome major local and unpredicted constraints.

Innovations carried out by the farmers themselves with proven results need to be given due recognition and disseminated amongst other farmers. For example, in India, the National Innovation Foundation supported by the Government of India maintains a database on the technologies innovated at the grassroots level by farmers across the country. It was set up with the main goal of providing institutional support in scouting, spawning, sustaining and scaling up grassroots green innovations and helping their transition to self supporting activities. It also helps in faster dissemination of information.

To sum up, there is a clear-cut need to forge strong linkages between research scientists, technology transfer agencies and farmers. Farmers' involvement at present is limited to on-farm trials but it is absolutely essential that the farmer must be the focus in all technological interventions. It is vital that the farmers are able to articulate their needs and views in all aspects of technology generation and application, including patent rights and access to genetic resources that has significant consequences for them in the short and long term. Moreover, their own innovations in technology need to be recognized and combined with the frontier technology, if needed, and disseminated. Farmers' participation at all levels is one of the key elements of technology development, transfer and the effective use of appropriate technologies to ensure food and ecological security of the current and future generations.

With this we end the discussion on the imperatives for a greener future. We now summarize the contents of this unit.

15.5 SUMMARY

- **Sustainable food and nutritional security** may be defined as a condition in which every individual at all times, has physical, economic, social and environmental access to safe, **nutritionally adequate and personally acceptable foods in a manner that maintains human dignity.** Along with availability, access to food, cultural acceptability and appropriate policies and processes are needed to achieve food security.

- Clean air, safe and reliable water supplies, nutritious and safe food, healthy housing and workplaces, civic services and protection against disease and disasters for all people form the cornerstones of **ecological security**. Its ambit may be expanded to include ecological sanitation, i.e., efficient, cost-effective eco-engineering for treating and recycling human excreta, waste water, and other wastes.

Genetic conservation involves all activities aimed at ensuring the continued existence, evolution and availability of genetic resources, in situ and ex situ.

While the world has witnessed tremendous advancement in the fields of science and technology, the results unfortunately have benefited a small portion of the rural population in the developing nations. This brings forth the importance of the issues of **technology development, transfer** and **appropriate technologies for the poor farmers**. There is a clear-cut need to forge strong linkages between research scientists, technology transfer agencies and farmers. Farmers' participation at all levels is one of the key elements to ensure food and ecological security of the current and future generations.

15.6 TERMINAL QUESTIONS

1. Discuss the social, economic, cultural and environmental aspects of the issue of food security.
2. What do you understand by genetic conservation? Explain in what ways it influences food and ecological security.
3. Analyse the factors that inhibit the transfer of technology from the lab to farmers. List the technologies needed by the resource poor farmers to improve productivity. Suggest measures that can be taken to enable farmers to benefit from new technologies.

UNIT 16 NEW TECHNOLOGIES

Structure

16.1 INTRODUCTION

In Unit 15, you have studied about the various issues pertaining to food security, ecological and genetic conservation and technology transfer. You know that we are faced with an increasing pressure on the existing land. We need to enhance agricultural productivity with the optimal use of resources that are facing the twin threats of depletion and degradation, particularly in the South Asian countries.

In such a scenario, our societies have to learn to take advantage of new technologies such as biotechnology, space information and communication technologies for improving the productivity of land as well as for profitable marketing of the produce. We also need to know about post harvest technology to prevent losses and encourage value addition to the produce. These new technologies are also eco-friendly and if adopted will be useful in ensuring healthy food and environment for our future generations. Therefore, we discuss these technologies in this unit. In the next unit, you will learn about agricultural waste management which is an equally important area for ensuring a better future.

Objectives

After studying this unit, you should be able to:

16.2 BIOTECHNOLOGY IN AGRICULTURE

5.3 INFORMATION AND COMMUNICATION TECHNOLOGY

ecent developments in the space, communication and information technologies (IT) fer uncommon opportunities to our agricultural research, development and farming stitutions for **weather-proofing** our farming, sustaining its productivity and oviding in-time advice on **markets** and on yield-reducing biotic and abiotic stresses. ' tools are convergent and therefore these can effectively solve the complex iallenges posed by technological, ecological, economic and equity issues on an tegrative platform. Further, with the increased availability of ever-faster computers, e application of IT tools can speedily answer many intricate questions on:

- the rational use of non-renewable natural resources,
- maintenance of the quality of our environment,
- the magnitude of the impacts of various options of farming on the land quality, its degradation (and desertification) and
- the carrying capacity of land for human, cattle and diverse biotic populations.

hus the use of IT, communication, and space technical tools can speed up the pace of ie processes of development to meet the needs of our farm families both during roduction and post-production phases of their farming. Let us learn about the role of pace, communication and information technologies in agricultural R&D and transfer f new methods of farming.

here are three broad ways by which space, communication and information chnology tools can benefit our farming communities. **First**, space technologies (in articular, the remote sensing satellites installed in space) provide a unique set of data f the land cover and its natural resources through various sensors placed in the itellites. There are a number satellites girdling the globe. They are observing the 'eather and natural resources and are sending digital data on a regular interval. These itellites are equipped with multispectral and multi-temporal space-borne sensors. The ata received can be mapped to give information on vegetal cover, its quality and xtent and the changes that have occurred over-time.

'he data can be processed give us information on vegetal cover, its quality and extent nd the changes that have occurred over time. For example, the UNEP, FAO and JNDP recently completed a pioneering study on the **quality of the land resources** of outh Asia. It is estimated that 40% of the region's agricultural land (140 million ha) as suffered from one form of land degradation or the other. The intensive food roduction areas here have been largely eroded of their floral and faunal diversity, the round water acquifers have been seriously reduced, forest resources have dwindled to much less than the required 33% of the geographical space), multiple deficiencies f plant nutrients are a common occurrence, and biotic stresses are on the increase.

space, communication and information technological tools can help reconstruct and estore these degraded agro-ecologies, maintain their vigour in good health so that vergreen revolution is sustained to feed our increasing population.

The space observed data when analysed together with other (geologic, edaphic, iydrologic, weather and socio-economic) in a geographical information systems (GIS) nvironment, can provide a firm basis to land use planners to devise alternate options or sustaining productivity of

a) different farming systems and their impacts on ecological, natural and environmental resources, and
b) on their economic implications together with the costs of reversing any losses to productivity due to land degradation.

Second, space, communication and ITs have almost revolutionized the systems of data collection, its warehousing and transfer from one site to another. Through inter-networking, the data can now be shared nationally and internationally, almost in real time. Thus interpretation of data into useful information by inter-and cross disciplinary teams of science and development workers can be made at a rather fast pace. The ecologies threatened with temporary or permanent lowering of productive capacity of land can now be easily delineated and mapped, and action programs initiated to stall the damage and repair it in the shortest period of time, and

Third, space, communication and IT enabled services can be of great assistance to our farming communities for progressively adopting precision farming, which is a management strategy that employs detailed site specific information to precisely manage production inputs. The application of precision farming techniques can improve the productivity of our agriculture and its economic and environmental sustainability. The chemical pollution can also be minimized by the adoption of precision agriculture methods as it uses integrated pest, nutrient and crop management.

Thus, we are entering the knowledge based century dominated by an increased use of space and information technologies which will reduce the developmental gap on the one hand and access to innovative farming systems options on the other. However, the benefits of digital technologies can only be reaped when our research and development systems will create a strong compelling environment and vision permeated by the best representations of science and scientific values which according to Bruce Alberts, the President of U.S. National Academy of Sciences shall include, a) honesty, generosity, a respect for evidence, and openness to all ideas and opinions irrespective of their source; b) knowledge sharing and capacity building, c) building networks of trust by connecting scientists to each other and to their local farming communities; and d) providing impartial scientific advice. There is thus a challenge here for the South Asian agricultural research and development institutions to revamp their R and D framework for embedding knowledge based space, communication and information technologies for upgradation of farm output both during its production and post-production phases. The time is not on our side. The earlier we take the gauntlet, the better. Agriculture [and food processing] and information technology are important areas where some countries in the SAARC region have a core competence for integrated action to remove poverty and usher in sustainable rural livelihoods. Let us assess where we stand today and see what can be done to meet these goals.

Progress made and some suggested initiatives

- In some SAARC countries like India, agricultural research and development agencies have invested large resources in establishing electronic communication network facilities; the staff have been trained, and computer software are in day-to-day operational use. It is time that the available data sets are computerized, geo-referenced and cleaned. The data should be placed in a common format, so that it is easily accessible. Further, all new research and development data collected from now-on should be formatted to undergrid the decision support system for agrotechnology development and transfer. Comprehensive minimum data sets on crop (commodity), management, location, weather and geocoordinates should be collected on a unified basis, digitised and made available on the internet to all interested parties. This one step would give a boost to our research productivity and its quality.

- Agricultural research and development agencies of countries in the South Asian region should adopt knowledge-based rural development villages (at least two in each of the agroecological zones) patterned after the very successful information village research project launched in the union territory of Pondicherry in India by the M.S. Swaminathan Research Foundation (MSSRF). Empowerment of farming communities with information and communication technologies has been shown to play a major role in environmentally sustainable rural development. MSSRF believes that such an effort allows not only reaching the poor but also helps them to achieve food security and social justice. A multi-year program of work should be undertaken so that the entire region is covered by the year 2025.

- Agriculture research and development organizations of various countries should join hands in actively promoting the use of new information and communication technologies. Regional networking to achieve integrated sustainable development should be encouraged. In this connection, advantage could be taken of the experience of the Integrated Mission for Sustainable Development (IMSD) launched by the Department of Space, India through inter-governmental efforts. The objectives of IMSD are to generate plans at 1:50,000 scale for land and water resources development for use by district-level natural resources managers. Spatial databases on natural resource themes (in GIS environment) including land use, soil, slope, hydromorphology, groundwater prospects, rainfall and climate, drainage watershed and surface water bodies, road network and settlement locations and village boundaries have been generated using satellite remote sensing data and conventional information for some selected districts. GIS technology is used to integrate and analyse resource themes for arriving at plans for land & water development, alternative land uses based on resource potential, optimal use of ground water and soil conservation. Agricultural research and development agencies could provide the required interface between the farmers, stake-holders at the watershed or community level and in the process of the development of action plans. Such activities could be undertaken in all developing countries of the SAARC region.

- The Department of Space in India has three other programs: these are, CAPE (Crop Acreage and Production Estimates) and FASAL (Forecasting Agricultural Output using Space, Agrometeorology and Land based observations) in which ICAR (Indian Council of Agricultural Research) and similar agencies from other countries should be encouraged to take a deep interest. Some agricultural research and development workers may be placed with the CAPE and FASAL groups to provide the required linkages between the agricultural R and D and space agencies. ISRO (Indian Space Research Organisation) and ICAR are already working together in an experiment called Agricultural Resource Inventory and Survey Experiment (ARISE). The scope of these works may be enlarged into well-focussed programs to cover all the agro-ecologies in the South Asian region in a time-framed fashion so that the entire region is covered within a given time frame, say, by 2025.

- To quote Professor M.S. Swaminathan, an eminent agricultural scientist from India, modern ecological agriculture offers great opportunities. We have a very large untapped yield reservoir in our country (true for all South Asian countries). We can take advantage of the tools provided by the space, communication and information technologies to usher in an era of intensified, diversified and value added farming. All the technical bits and pieces are available on the shelf, we need to put them together. Let's make the unique experiments universal by putting the space, communication and information tools and precision agricultural technologies together on an operational basis. The state of Andhra Pradesh in India has already launched its first 'cyber Grameen' to harness the power of internet broad band for providing one-stop destination e-services including the development of agriculture and horticulture. Let's get our priorities right and let's get moving to usher an era of greener future.

16.4 POST-HARVEST TECHNOLOGY

In India, some 60 million tons of food grains are held as 'buffer' stocks. This very large quantity of food needs to be sustained as wholesome edible commodity suitable for human consumption under varied agro-environments across the country. Any loss in weight or deterioration in quality due to infestation with insects, fungi or other grain pests or due to wetting of the grain can end in serious economic loss. Often-times the result is: the food becomes unsuitable for consumption.

In the case of fruits and vegetables or fish products which are highly sensitive to post-harvest handling, the deterioration in quality occurs rapidly if such foods are not properly handled. Because of their high moisture content, which typically ranges between 70% to 95% and soft texture, the losses are usually caused by rotting (due to bacteria, fungi). The shelf life of these perishable agricultural foods is fairly short compared with cereal, pulses and oilseeds. Thus, steps need to be taken to prevent this loss. Post harvest technology helps us meet this goal.

Let us begin by understanding what is post-harvest technology.

What is post-harvest technology:

In its broadest sense, the term post-harvest technology means the conservation, protection (of quality), processing, transport, packaging, distribution, marketing and utilisation of the agricultural products upon their harvest or at the moment of separation of the edible commodity from the plant (as in the case of agricultural crops and fruits including vegetables) or from water (as in the case of fish and aquatic edible species) or products obtained from the animals (e.g. meat, eggs, poultry, milk etc.). In this section we will mainly focus our discussion on post-harvest technology as it relates to agricultural crops.

Importance of post-harvest technology: The post-harvest technology of agricultural crops is important for the food security, on the one hand, and has economic dimensions on the other.

The application of the tenets and the adoption of post-harvest technical practices could potentially prevent,

- losses of weight of food, fruits and vegetables during their harvest and in the course of transportation of these products to storage, sale and consumption points;
- loss of quality by conserving their appearance and nutritional value; and
- any reduction in value addition.

Thus, on both these counts – economic and nutritional, the preservation of food, its acceptability and access is basic for food and nutritional security. So there is a strong justification for the large-scale adoption of post-harvest technologies.

The post-harvest technology is a highly diverse and inter-disciplinary subject of study. It includes

- selection and planting of appropriate varieties of crops, vegetables and fruits suited to the agro-environment and their end-use;
- the method/s of harvesting and field transportation to on-farm handling and storage;
- processing of the harvested food, vegetables, or fruits on the venue of production; and finally
- methods of packing, mode of transport from the farm to the various points of the marketing-chain and processing prior to sale.

It is estimated that about 10% the yield-loss occurs during harvest and field drying oi crops, and a somewhat similar loss is sustained during field processing (primarily threshing), transport and storage of food-grain and oilseed crops. The weight and quality losses in the case of fruits and vegetables are much higher. It is estimated that 10-20% of the horticultural crops and vegetables perish due to poor methods of harvest and on-farm processing. Lack of appropriate packaging and transport facilities particularly available with the small-holders add to loss of quality and food value. The monitory post-harvest losses, most conservatively are estimated at Rs. 20-30 crores annually for India. However, a more important point for the countries in this region is that we are all food-deficit nations. Food that deteriorates due to wrong post-harvest handling is the food wasted. Therefore due attention must be given both to the scientific aspects of post-harvest and its technical aspects. To be effective, the post-harvest technological measures will have to be adopted by the growers of food – the farmers and farm cooperatives, marketing institutions at the various levels, wholesalers and the retailers. For this, we need to understand what kinds of losses take place at the post-harvest stages.

Both quantitative and qualitative losses of agricultural produce occur at various stages of their post-production, i.e. at post-ripening stage. These losses, as explained earlier, refer to loss of weight, diminished food value, loss of quality and non-acceptance of the food by the consumer. These, thus result in its decreased price leading to economic losses. A case in point is the recent rejection of wheat produced in India by Iraq and Afghanistan. Our wheat has been purported to be contaminated with Karnal bunt (a fungus).

Weight-loss usually occurs due to wrong timing or methods of harvest of crops or both. Sometimes crops are left in the field, after full ripening. In the field the produce may be infested with insect/pests or if the humidity is high it can become moldy, or the grains may even germinate, if the seeds have no dormancy.

In the following two sections post-harvest losses of food crops (e.g. cereals, pulses, oilseeds) and of the perishable crops (e.g. vegetables, fruits etc.) are discussed in some detail.

Post-harvest losses in cereals, pulses & oilseeds

These food crops are characterised by a low (10-20%) moisture content at the time of their harvest, small unit size (seed weight is typically less than 1g), very low respiration rate having a very small generation of heat during storage. Heat production is typically 0.05 mega joule/ton/day for air-dry grains. These crops are generally hard textured, have a stable shelf-life, and if stored in dry, well ventilated storage, these crops can maintain their quality for several years. However, in most SAARC countries, majority of the food grain is produced by small farmers having limited means. In order to appreciate and understand the post-harvest losses that can potentially occur in food grain crops, the prime example of post-harvest loss that can potentially occur in rice crop is discussed here in some detail. Rice is a major food crop and is grown in most countries.

The various kinds of estimated losses in post-harvest of rice are summarised in Table 16.1 given below.

This information has been gleaned from P.H. Pandey's book: Principles and practices of post-harvest technology (Kalyani publishers. First Edition. Reprint 2001, 453pp).

Table 16.1: Estimated post-harvest losses of rice in south & south-east Asia

Post-harvest Operation	Range of losses
Harvesting	1-3%
Threshing	2-6%
Drying	1-5%
Handling	2-7%
Milling	2-10%
Storage & Transportation	2-6%
Total	**10-37%**

It can be discerned from the table given above, that the post-harvest losses for rice crop are at best estimated at 10% and at worst these can be as high as 37% or about one-thirds of the crop producted. Through the use of appropriate post-harvest technologies, these losses can be substantially reduced. In Japan and in the United States of America where rice production is highly mechanized, the post-harvested losses in rice hardly exceed 2-3%. Even in Thailand these are estimated at less than 5%.

The question is, therefore, how to prevent such losses.

- The first step in the post-harvest technology is the harvest of the crop at an appropriate seed moisture. In rice, it has been found that the crop should be harvested when the seed moisture is at 20-22%. Traditionally, farmers harvest paddy at about 16% moisture content and then sun-dry it in the field. This practice results in drying of the seeds during the day, and their wetting during the night, when the relative humidity is high. Thus a dry-wet cycle of grains called 'sun-checks' sets-in which results in grain cracks during milling of rice. The percentage of broken rice grains is therefore much higher. The quality of rice thus seriously suffers. Such rice attracts a much lower price in the market.

  Researchers have now recommended an improved method of post-harvest technology for rice. It is suggested that the rice crop should be harvested when the moisture content of the paddy is 22 ± 2%, and it should be gradually dried to a moisture content of about 12%. The paddy thus should be dried on a dry, preferably cemented floor which is covered. The produce should be raked frequently. Generally small farmers do not have the necessary facilities. They are advised to join farmers-cooperatives or sell their produce to rice millers, who generally have adequate infrastructure for efficient handling of the paddy. This simple operation of the new post-harvest technology of rice has been shown to increase the yield of paddy by 10-20%.

- The second step in the production of rice involves its storage prior to parboiling and milling. Field drying of paddy, particularly in the farmers traditional method in Southern Indian states, exposes the crop to high temperatures. When paddy is rapidly dried, the loss of a vital vitamin called thiamine usually occurs. This reduces the nutritional quality of the rice. Also, if paddy is not stored in dry, well-aired storage bins or godowns, it may be infected with insect/pests, where it is estimated to suffer a potential loss of about 12% of available protein in the grains.

- The third post-harvest step in the production of rice involves its de-husking and polishing. Currently modern methods of paddy milling are available which cause minimum damage to the outer-seed coat thus retaining essential minerals and vitamins. In many ways the farmers traditional method of de-husking of paddy is superior than the modern methods of factory-based milling and polishing the rice. It preserves the essential vitamins and minerals in the seeds, however, such rice is not pearly white and it does not attract a better price.

- The final steps in post-harvest of rice are its packaging, storage, transport and marketing.

he post-harvest losses of grain crops like wheat, sorghum; millets and other small ain crops also range between 10-40%. All these crops suffer from extensive grain ality deterioration if these are exposed to high moisture at the time of their harvest during storage. The seeds of these crops are prone to the attack of molds, which akes them unsuitable for consumption by humans or animals or poultry. The loss of otein in pulses during post-harvest stage is particularly serious. It has been estimated at the cowpea and bean crops stored in bins under farmer's traditional systems, can iffer a potential loss of protein of upto 81%, in a year's time. This is an avoidable od-quality loss.

ost-harvest losses in perishable crop: The perishable crops are grouped as crops hich have a typical moisture content of 70-95%. Vegetables and fresh fruits are amples of perishable crops. These crops have a low level of natural protection gainst weather, pests, bio-chemical deterioration and transportation. These onditions are aggravated in the tropical climatic regions where required storage and itable transport conditions are generally lacking. The shelf life of the perishable ops ranges between a few days to a few weeks. The causes of spoilage, the rate at hich it occurs, the degree of loss in weight and quality, are substantially different in erishable agricultural produce. Because of these vital differences, it is necessary to lentify the causes of loss in each case and design appropriate set of interventions to eck post-harvest losses in perishable crops.

auses of loss of perishable agricultural produce

Primary: These are those causes that directly affect the food and its quality. These may be;

a) **microbiological**, where damage is generally caused by infection of the produce with fungi and bacteria. These micro-organisms consume only small amount of food or colonize the outer coat of the vegetables and fruits, but they damage the produce to a point that it becomes unacceptable for consumption. The molds produce mycotoxins which are oftentimes poisons. The best known example of mycotoxins is *aflotoxin*, which is produced by the mold *Aspergillus flavus*. It is a liver carcinogen. It is commonly found in groundnuts. Another mycotoxin which is found in apples and pear products, is *patulin*. It is caused by *Penicillium expansum* and infects fresh fruit;

b) **chemical**, which cause loss of colour, flavour texture and nutritional value of the agriculture produce. As an example Maillard reaction in fruits and vegetables causes browning and discolouration. Some pesticides and harmful chemicals which are not biodegradable also persist in fruits and vegetables (e.g. DDT can persist for a long time and is carcinogenic);

c) **biochemical**, which are enzyme activated reactions which mainly occur during storage. These give rise to off-flavours, dis-colouration and softening of fruits and vegetables. The biochemical and microbiological reactions can be slowed down considerably by freezing or refrigerating the fruits and vegetables; and

d) there are number of biological (e.g. rodents, birds, large animals), mechanical (e.g. bruising of produce during handling and transportation), physical (e.g. excessive heat or cold) or premature ripening of fruits by chemicals (e.g. ethylene) factors which primarily cause loss of quantity or quality of horticultural or vegetable produce.

Secondary: These causes of post-harvest loss of perishable agricultural commodities are mainly inadequate harvesting, packaging and handling skills; lack of appropriate containers for handling of perishables; inadequate storage facilities to protect the deterioration of food; long time-lags between harvest and marketing; inadequate refrigerated storage capacity; lack of appropriate drying facilities and finally lack of marketing infrastructure which is efficient, equitable and transparent. The sites of secondary post-harvest loss occurrences of perishable agricultural commodities are: harvest, preparation, preservation, processing, storage, transportation, and marketing.

Controlling post-harvest losses of agricultural perishable

Few accurate and reliable data are available on the magnitude of post-harvest losses of fruits and vegetables. As a general guide, the FAO believes that 25-35% of production losses occur in the case of fruits and about 40% losses take place in vegetable production in south and south-east Asia. These losses can be controlled or reduced by:

- Harmonizing the harvesting techniques with the kind and type of fruit and vegetables.
- Careful handling and storage of the produce.
- Use of minimal cost cooling techniques; where appropriate, use evaporative cooling. Harvest crops early in the morning and store in well ventilated areas, cool promptly after harvest.
- The produce should be stored at optimum storage temperature. For most tropical horticultural crops is between 7° and 10°C.
- Store vegetables in an appropriate humidity environment (if not refrigerated) in order to maintain the product in a better condition.
- Maintain high-class sanitation in all storage areas.
- A number of chemical product specific growth retardant sprays are available. These may be used, in consultation with advisory services of the Department of Agriculture with advantage.

Post-harvest handling of agricultural produce is an important area of agricultural research and development. Adoption of 'good practices' of post-harvest technology could result in substantial savings of agricultural produce from deterioration and waste; it would thus add to the 'food security' of the country. Post-harvest technology also preserves and enhances the quality of the food; it would thus provide 'nutritional security'. The progressive implementation of post-harvest technological programmes are economically viable, environment-friendly, and highly needed for sustaining a greener future for the country.

In terms of R and D in India, at the national level, Central Institute of Post-Harvest Engineering and Technology (CIPHET) is the nodal organisation. It is leading research and development in agricultural production catchments on agro-processing industries. It is equipped with pilot plants, industrial liaison, technology transfer facilities. It has a department of international cooperation. CIPHET was established first in Ludhiana (at the campus of the Punjab Agriculture University) in 1989 and has a campus at Abohar in Punjab (established in 1993). An All India Co-ordinated Research Project on Post-Harvest Technology (established in 1972) is operational in 18 centers across the country. It coordinates research and development efforts on post-harvest technology in the various eco-regions.

In sum, most farmers in the SAARC countries currently sell their farm production without any grading or processing. If they carry out primary processing at the village level, it will generate value addition to the food produce, conserve and enhance food quality, and will thus generate additional income and employment in the rural sector.

With this we would like to end the unit and summarise its contents.

6.5 SUMMARY

Three new cutting edge technologies which can facilitate leading our agriculture towards a greener future are: **Biotechnology; Space, information and communication technologies;** and **Post harvest technologies** to preserve the food and its quality while avoiding losses.

Biotechnology is the new cutting-edge arm of life sciences which applies biological organisms, tissue culture techniques, cloning of DNA, including its recombinant manipulations, monocolononal antibodies, protein engineering, protoplast fusion, immobolized enzyme, cell catalysis, sensing with the aid of biological markers. It aims to provide goods and services for human welfare by an integrated use of biochemical, microbiological, and engineering sciences, which impact almost all aspects of living organisms including crop plants. In agriculture, the major use of biotechnological tools is to produce genetically engineered transgenic crop plants, which are hoped to perform better in stressed environments. Such plants can ward-off insect/pest attacks, give better and quality produce which have a higher nutritional value and shelf-life.

The use of the products of space, information and communication technologies has already revolutionized the use of visual and voice media. Today, we can receive TV signals in the most remote places and talk to any one across the world by pressing a few buttons on a cellular phone system. Thus a farmer or farmer's cooperative situated in any remote corner of the country can be in touch, on a real time basis, with the markets, on the one hand, and with the technical advisory services, on the other.

The remotely observed data when read in conjunction with geologic, weather and socio-economic data in a geographical information system (GIS) environment, can provide a firm basis to land use planners to devise alternate options for sustaining productivity of various land uses and their impacts on ecological, natural and environmental resources together with their economic implications. MS Swaminathan Research Foundation in India has already established a research program of empowering farming communities with information and communication technologies. The Department of Space in India has also undertaken several missions for sustainable development using space, communication, and information technologies aimed at a greener future of our agriculture and to achieve food security and social justice.

The third set of new technologies for ensuring a greener future for our agriculture is related to post-harvest technology. It aim at saving food losses that take place during the harvesting of crops – both agricultural and horticultural, and during processing until these reach the ultimate consumer. The kinds and extent of harvest and post-harvest losses of cereals, pulses and oilseeds (agricultural crops) on the one hand and of perishables (fruits and vegetables) on the other have been described. The post-harvest losses in the case of agricultural crops are estimated to range between 10 and 40%, while in the case of perishable these could be as high as 60% or even a total loss of the crop.

The losses of quality due to in-appropriate post-harvest handling are identified. This is another area of concern. In the case of rice losses of protein, vitamins & minerals occur due to wrong milling techniques. If the drying cycle of paddy is not well managed, the content of the broken rice has been shown to increase considerably, which results in economic losses. Similarly losses in the protein content in pulses can be considerable, if these crops are not properly stored. A number of steps for controlling post-harvest losses of agricultural crops have been suggested. Food saved is the food available for ensuring food and nutritional security of our people. Also, the quality of food has assumed a special importance in view of the globalisation of agriculture in the post-WTO regime. Post-harvest technology saves both quantity and quality of food.

16.6 TERMINAL QUESTIONS

Biotechnology in Agriculture

1. What is biotechnology? Name some areas of study which are of direct relevance to agriculture.
2. Discuss scope and limitations of biotechnology in sustaining agricultural production.
3. What are GM crops? How are they useful in avoidance of biotic and abiotic stresses in crop plants.
4. Name some important centres where human resource development and, research and development efforts on biotechnology in agriculture are underway in India & Abroad.

- **Space, Communication, and Information Technologies**

   1. What are the inter-relationships between space, communication and information technologies?
   2. What elements of space technologies are useful for agricultural development?
   3. Name some programmes undertaken by Department of space for sustaining a greener agriculture.
   4. How modern communication technologies can improve extension of new technologies on real-time basis in agricultural research & development and farmer's economic situation.

- **Post-harvest Technology**

   1. What is post-harvest technology. What relevance it has for food and nutritional security of India?
   2. How post-harvest technologies differ for storage of food crops and fruits and vegetables?
   3. Taking rice as an example crop, what are the estimated losses due to its various post-harvest operations?
   4. At what moisture content should paddy be harvested and how should it be dried to reduce shedding, shattering and losses due to broken rice.
   5. How perishable crops differ from the food grains in terms of post-harvest losses? What are some of the essential elements of the post-harvest technology for fruits and vegetables to minimise losses.

REFERENCES

1. Symposium on Resource and Environmental Monitoring – ISRS Annual Convention held at Hyderabad 3-6 December 2002. Source : Indian Space Research Organisation and National Remote Sensing Agency
2. Science and the World's Future. Lecture delivered on 26 April 1999 at the 136th annual meeting of the National Academy of Science, USA, Washington, DC by Bruce Alberts, President, NAS. Source : Bruce Alberts.html

. Sustainable Development: Agriculture and Rural Development. Source : Untied Nations, UN.org/esa/sustden/agri.htm

. Information Village Research Project (IVRP). Source : MSSRF

. Success stories of rural ICTs in a developing country. Report of the Panasia Learning and Evaluation Group's Mission in India. Source: MSSRF

. Information and knowledge in the age of Electronic Communication: A developing country perspective. Talk given at the Volkswagen Foundation 7 May, 1999 by Subbiah Arunachalam. Source : MSSRF

. Connecting Rural India to the World. Celia Dugger. The New York Times, 28 May 2000

. Information Technology (IT) in Developing Nations. M. Shanmugavelan. Sustainable Development Department. FAO. Source : MSSRF

. Towards a knowledge system for sustainable food security: The information village in Pondicherry. Source : MSSRF

0. How to eradicate hunger. An editorial based on an interview given by Professor MS Swaminathan to Mr. Parshuram Ray. Humanscape. 2001. Source : MSSRF

1. Ignited Minds: Unleashing the power within India. A.P.J. Abdul Kalam. 2001 Source: Viking Publishers.

2. Precision Agriculture: Information technology for improved resource use. Agricultural Outlook, 1998. Source: Economic Research Service, USDA.

3. Pandey. P.H. (2001). Principles and practices of post-harvest technology. First edition. Reprint 2001. Kalyani Publishers. Ludhiana (India) 141 008. 453 pages.

4. INSA-US-NAS (1979) Post-harvest food conservation. Report of the joint workshop. Indian National Science Academy, New Delhi, India.

5. FAO (1988) Food loss prevention in perishable crops. FAO agricultural services bulletin #43. Food and agriculture organisation of the United Nations, Rome. 72 pages.

UNIT 17 AGRICULTURAL WASTE MANAGEMENT

Structure

17.1 INTRODUCTION

Agricultural wastes are the excesses and the residues generated from diverse agricultural activities such as farm operation, planting and harvesting of field crops, food processing, dairy and animal husbandry. The wastes are available in the form of wheat straw, paddy straw, maize straw, sugarcane trash, maize cobs, animal wastes, left over ration from the feed lots, and agro-industrial wastes. Intensive cropping, use of high analysis fertilizers and improved management practices have not only resulted in increased crop production but also increased generation of crop residues and the allied wastes. Animal dung is one of the major solid wastes available in country side.

The large amount of organic wastes produced in agriculture is a serious and increasing problem. It has been estimated that 70 % of total expenditure involved in waste management goes to meet the collection and transport charges and the remaining 30 % is spent towards treatment and disposal. Methods of handling, treating or disposing off agricultural wastes may also affect air, water and soil quality. There has been an increasing attention on agricultural waste management with the objective of continued food production while minimizing the environmental pollution. The residual wastes are national resources of large economic value and hold considerable promise for innovations in nutrient cycling in addition to their own utilization. During recent years a good deal of information has been generated for the maximum and efficient utilization and recycling of agricultural wastes and harnessing energy in relation to environment. Composting, vermicomposting, traditional indigenous nutrient management practices, biomethanation, processing, etc., are some of the technologies for utilization and recycling of the agricultural wastes for improving soil health, producing fuel and manure, processing into value added products and retard the possible deterioration of environmental quality.

This unit deals with the availability and usage of crop residues and their effects on soil properties and crop yields along with different plant products. The practice of composting and vermicomposting as a route for recycling a variety of wastes in agriculture has been dealt. A special emphasis has been made on biogas technology for the economic recycling of animal wastes. The application of less intensive traditional agricultural practices to restore soil fertility and sustain productivity are also enumerated.

Objectives

After studying this unit, you should be able to:

- enumerate the quantities and the nutritive values of the agricultural wastes for processing and utilization;
- compare the different abilities of agricultural wastes in improving soil health;
- explain the process of composting and vermicomposting for conversion of agricultural wastes into eco-friendly valuable agricultural inputs; and
- describe indigenous and traditional methods of application and conservation of plant nutrients contained in agricultural wastes.

17.2 USE OF CROP RESIDUES

Annual production of wheat and rice in India during 1999-2000 was 71.78 and 88.55 million tonnes respectively, amounting to generation of 258 million tonnes of straw. This accounts for about 70% of total crop residues available in India. About 45 million tonnes of fruit and vegetables wastes accumulate each year and an estimated 25 million rupees are lost annually.

Crop residues are the part of the plants left in the field after crops have been harvested, threshed, pruned or processed. Though they have been regarded as waste materials that require disposal but it is now increasingly being realized that these are a tremendous natural resource and not a waste. Following traditional practices, farmers of South Asian Countries remove the major portion of crop residues from the fields for use as cattle feed, livestock bedding, thatching material for houses and fuel. Recently because of advent of mechanized harvesting, farmers prefer to burn large quantities of crop residues left in the field in sites as these interfere with tillage and seeding operations for the next crop. Burning of residues causes a serious waste of precious nutrient resource and contributes to intense air pollution.

India, having a large bovine population of 282 million heads, houses 50% of world's buffaloes and 15% of all goats and cattle in the world. Availability of dung from a total livestock population of 459 million is about 354 million tonnes per year. Cattle and buffalo alone make up 60% of total livestock population and are the source of 91% of total dung produced.

Proper use of crop residues provides a highly effective means for

- controlling soil erosion and sediment transport,
- reducing nutrient losses through runoff to streams, and
- supplying organic matter to maintain good soil tilth.

When incorporated into the soil or placed on its surface, crop residues and the resulting soil humus

- improve infiltration rates,
- reduce soil crusting,
- enhance soil aggregation, and
- increase the soil's water holding capacity.

Renewable organic matter from farm wastes can be novel closed systems efficiency utilized as a raw material for:

- the recovery of renewable energy as methane in biogas;
- the production of soil amendments/bio-fertilizers that contain energy plant nutrients and beneficial micro-organisms;
- the production of the environment as each yearly addition will increase the carbon sequestering abilities of soils.

So it may be said that we need a residue management system which will be ecologically favourable economically profitable, environment friendly, holistic and resource efficient. No small feat, but not impossible if you consider the research and technology already available today.

Availability and Usage

With the increase in food grains production, the production of crop residues has also proportionately increased. The use of mechanical harvesting in big farms leaves more residues for *in situ* utilization. Of the various considerations it is assumed that about one third of total crop residues can be made available for land application thus providing a gross annual nutrient potential of the order of million of tonnes in these countries.

Table 17.1: Estimates of the availability of some crop residues in India and their plant nutrient potential

Crop	*Residue to economic yield ratio*	*Residue yield* ('000t)*	*Nutrient (%)*			*Nutrient potential, '000 tonnes*		
			N	*P_2O_5*	*K_2O*	*Total*	*Utilizable***	*Fertilizer Equivalent****
Rice	1.5	110,495	0.61	0.18	1.38	2,398	799	399
Wheat	1.5	82,631	0.48	0.16	1.18	1,504	501	250
Sorghum	1.5	12,535	0.52	0.23	1.34	262	87	43
Maize	1.5	11,974	0.52	0.18	1.35	252	84	42
Pear millet	1.5	6,967	0.45	0.16	1.14	121	40	20
Barley	1.5	2,475	0.52	0.18	1.30	51	17	8
Finger millet	2.0	5,351	1.00	0.20	1.00	118	39	19
Sugarcane (stripped cane)	0.1	22,736	0.40	0.18	1.28	423	423	211
Potato tuber	0.5	7,867	0.52	0.21	1.06	141	141	70
Groundnut (pods)	1.5	10,598	1.60	0.23	1.37	339	339	169
Total		273,629				5,609	2,470	1,231

* *Arrived at by multiplying the economic yield by the given residue: economic yield ratio.*
** One- third of the total NPK potential assuming that two third of the total residue is used as animal feed on national basis.
*** *50 % of the utilizable NPK assuming 50 % mineralisation of NPK per season.*
Source: Bhardwaj (1995)

Thus, the crop residues returned to the soil can potentially supply a substantial portion of the nutrient requirements for the succeeding crops. Besides, crop residues offer many benefits to soil fertility productivity.

17.2.1 Improvement in Soil Properties and Crop Yields

Freshly added crop residues play a significant role in improving the physical condition of soil, making it more favourable for optimum plant growth. The observed beneficial effects of residues incorporated may, therefore, be attributed mainly to improvements in the overall physical, chemical and biological properties of soils. We discuss some of these here.

Biological properties: Nitrogen immobilization

After the crop residues are incorporated into soil, a host of micro-organisms bring about mineralisation of carbon and other elements contained in the residues. This is accompanied by a large increase in soil microbial populations and evolution of carbon dioxide from the residues-treated soils. The microbiological activity is maximum during the first one to two weeks. During the active decomposition period, tremendous amount of mineral N (native or added) is immobilized by the micro-organisms into their body cells. This results in a temporary depletion of N during the initial stages of plant growth. Besides being a handicap from immediate plant nutrition point of view, immobilization is a means of conserving N. The mobile forms of N subject to leaching and denitrification are covered and subsequently re-mineralized.

The process of nitrogen immobilization has great practical significance in the management of crop residues in cropping systems. Therefore, sufficient time should be allowed for the decomposition of residues before the crop is sown. Alternatively, immobilization effect can be overcome by adding some fertilizer N to the residues.

[T]he adverse effect can also be overcome by allowing adequate time for the [d]ecomposition of organic residues before the sowing of crops.

[P]hysical Properties: Erosion control

[A]s you have learnt in Units 6 and 10, sediments from erosion is our nation's greatest [w]ater pollutant. Returning crop residues to the land as surface mulch is a very [e]ffective and economical practice for reducing runoff, wind and water erosion, and [w]ater transport of sediments to streams. Prudent use of crop residues can reduce [e]rosion over a wide range of soil and cropping conditions, from losses of 25 to 62 [t]onnes / hectare per year, or more, to 12.5 tonnes/ hectare per year, or less.

[S]oil moisture conservation

[C]rop residues cover plays a key role in moisture conservation for better crop yields in [d]ry land areas. Surface residues trap snow and reduce evaporation. The residues [i]ncrease infiltration by slowing the flow of water over the soil surface and increase [s]oil moisture holding capacity. **Farmers in drought prone areas should always [r]etain crop residues.**

[S]oil organic matter maintenance

[S]oil organic matter is a critical component of the soil and serves many purposes. Soil [o]rganic matter contributes to the soil structure stability and resistance to erosion. It is [a] storehouse of food for soil microbes. It stores carbon thereby opposing any build up [o]f atmospheric carbon dioxide (a green house gas) and global warming. The addition [o]f plant materials or other organic substances build or maintain soil organic matter. [A]n often-asked important question is how much crop residues should be retained to [h]ave a sufficient level of soil organic matter? There is however no definite rule for the [l]evel of organic matter to be recommended for each soil type or zone. It may vary [a]ccording to soil texture, initial organic matter content, management system and [c]limate especially moisture and temperature.

[F]or low organic matter soils, retaining crop residues is very important to maintain [s]ufficient soil organic matter. For soils with high level of organic matter, the annual [a]ddition of straw may not always be critical; adequate fertilizer or use of zero tillage is [o]ften as important as straw retention for building soil organic matter levels.

[D]etrimental effects

[I]t is generally agreed that crop residues returned to the land produces beneficial [e]ffects. However, problems crop up where crop residues are excessive and they are [a]pplied at loading rates that exceed the soil's capacity to decompose them within a [r]easonable time. In such cases, residues tend to accumulate because of slow rates of [d]ecomposition. This situation could lead to the microbiological production of [c]hemicals and toxins that may adversely affect plant growth. Moreover, since many [m]ature crop residues have a high carbon: nitrogen (C:N) ratio, excessive residues [l]oading rates on soils can lead to immobilization of plant available nitrogen, resulting [i]n nitrogen deficiencies in crops, a problem which can be offset only by application of [a]dditional fertilizer nitrogen.

[T]he presence of excessive amount of residues, particularly of surface residues, can [a]lso cause physical obstructions that interfere with normal tilling and planting [o]perations. This can often result in poor seed germination, stand reduction, [p]hytotoxic effects, non-uniform moisture distribution, immobilization of nitrogen in a [f]orm unavailable to plants, and increased insect, disease and weed problems. [C]urrently, excess residues are often burned, causing air pollution and other [e]nvironmental problems.

Crop yields

In general, the residue incorporation may bring about an overall improvement in physical, chemical and biological properties of the soils. Many short and long-term experiments in India and elsewhere have shown mixed effects of crop residues incorporation on crop yields. The incorporation of wheat residues in general, increased the yield of rice and also had a positive residual effect on the yield of subsequent wheat in rotation. However, the incorporation of rice straw in wheat and wheat straw in rice caused yield reduction. High crop yields were obtained from the combined long-term use of fertilizers and crop residues. It has been realized that if sufficient time (25-30 days) is allowed for residue decomposition in the soil, the immobilization effect is greatly reduced. Control of weeds, diseases and pests is important for the success of residue management practices.

17.2.2 Application of Farm Refuge and Crop Residues

The higher level of crop production through the increased use of fertilizers and pesticides has created ecological imbalance and affected sustainability of crop production. It is now being realized that the yields are declining year after year with the same level of inputs use. Since exploitative agriculture with an immediate profit motive will lead to shrinking of natural resource base (land) for crop production, there will be no option but to produce more food and other agricultural commodities from its limited available land. The need for more food has to be met through higher yields per until of land, water, nutrient, energy and time.

It has thus become imperative to adopt appropriate blend of the traditional agricultural practices of the pre-green revolution era and the modern technology to restore soil fertility and sustain productivity. Traditional indigenous nutrient management practices popularly followed in most regions are:

- Application of farm yard manure (FYM) to the field.
- Use of rice straw/husk, wheat bhusa as bedding materials in the cattle shed.
- Storage of cow/buffalo dung in the ground surface for 6-8 month and its subsequent broadcast in the field during summer.
- Browsing of residues of harvested crops during summer by herds of goats and sheep
- Burying weeds and wild rice in rice field, which eventually decompose and augment plant available nutrient supply.
- Mulching: crop residues such as sorghum straw, soybean trash, dried weeds are used for this purpose. Mulching reduces runoff, reduced losses of soil and plant nutrients from cultivated lands.
- Polas (*Butea monosperma*) leaves are commonly used as mulch in vegetables for controlling weeds and conserving soil moisture. Subsequently, dried leaves are incorporated into the soil with a view to enrich soil which results in higher yield and nutrient use efficiency.
- Coating of urea with neem, mahua, karanj, sal cakes by physically mixing before application.

We cite below some practices specific to particular states in India:

- Khadin cultivation in Western Rajasthan.
- Permanent set furrow system for groundnut cultivation in Gujarat.
- Vermiculture through rishi-krishi method of Maharastra.

- Haveli and bundh cultivation in Madhya Pradesh.
- Collection and dropping of sheeps and goats followed by organic farming in Himachal Pradesh.
- Use of jute leaves as potential source of manure in West Bengal and Orissa.
- Recycling of nutrient through pond excavation, animal hey bed compost technology in Punjab.
- Application of sudumannh (burnt soil) in coastal Karnataka.
- Use of fresh dung for vegetable cultivation in Kerala.

These are the appropriate technologies innovated, tested/improved and implemented y the local peasants. These indigenous practices aim at adding organic matter to the oil, utilization of locally available waste materials and rational use of natural esources.

17.2.3 Competitive Uses of Crop Residues

here are two major competitive uses for crop residues as:

) animal feed
) energy source.

n addition, there is also some potential for industrial use.

. Animal feed

rop residues have considerable potential as feed for livestock and provide a portion f the roughage requirements of ruminants and horses. The nutritional value of the ifferent types of crop residues varies widely. Low digestibility, however, is ssociated with the high lignin content in some crop residues. Transportation and rocessing cost are the chief limitations to wide scale utilization.

. Energy source

rop residues are used as an energy source for agriculture and industries. echnologies to convert crop residues into energy falls into two categories: **iological** and **thermo-chemical**.

iological processes like **anaerobic digestion** and **alcoholic fermentation**, involve nzymatic break down of biomass by micro-organisms at low pressure and low emperature. The anaerobic digestion for the conversion of agricultural residues into uel (biogas) and manure is considered one of the most feasible technologies to meet e challenges of depleting reserves of fossil fuels and escalating deforestation.

he utilization of agro-residues for the production of ethanol, the biofuel has been onsidered as a source to meet the partial energy demand. Rice straw in North west ndia is neither currently utilized as livestock feed nor for any other purpose. Farmers order to vacate the fields for timely wheat planting generally burn much of it. This traw could be an ideal and cheap substrate for ethanol production. To give you some lea, a rough estimate indicates that such rice straw is more than 5 million tonnes in unjab and Haryana alone. Based on this, it is estimated that assuming the ethanol otential of crop residues is about 250 litres/tonne of the straw, the ethanol potential f the straw alone would be 1250 million litres. This is sufficient to meet 10 % lending requirement for gasohol of India at present (Sushil Kumar, *et. al.*, 2002).

hermo-chemical processes use high temperatures to convert residues into energy by irect combustion, pyrolysis, gasification and liquefaction. Briquetting of agricultural residues helps in direct burning of biomass effectively. Briquetting is the conversion of solid fuel in the form of small pellets. It can be produced by compacting crop residues either directly or after pyrolysis.

Gasification implies the extraction of combustible gas (producer gas) from residues by burning them under conditions of limited air supply. In the presence of oxygen, carbon and moisture, agricultural residue is converted into a mixture of CO and H_2 gas, which is combustible in nature. Collection, transportation, and conversion costs are currently limiting the use of crop residues for energy. Nevertheless, the use of residues for energy seems feasible in areas where large volumes of residues are available in excess of the demands for other uses.

Industrial uses

Crop residues are now being used as raw materials in various chemical industries. For example, the plastics and pharmaceuticals industries use substantial amounts of certain crop residues. Corncobs are used to prepare mild abrasive and polishes, to absorb oil spills, and to make some cosmetic powders. Limited amounts of crop residues are used in the production of particle board, insulation, and paper. An additional potential use is in the production of single cell protein (SCP) by micro-organisms. Crude protein produced by this process may eventually become a major source of food for animals and people as well.

Cost of collection, processing, transportation and application

The cost of collection, transportation, and application of crop residues are minimal or zero when crop residues are returned to the land on which they are produced. Even where crop residues are available for land application, problems of their collection and transportations to the fields exist. Their manual handling is also laborious due to the bulk involved. In addition, most residues need some type of pre-incorporation, physical processing or shredding to facilitate their rapid decomposition in the soil. This needs suitable machinery, which is not available in most areas. Turning under by tractor discing is the common mode of incorporation by the farmers who own or rent tractors.

Large cultivated areas in South Asian countries are rainfed where the fallow periods generally fall under the dry months of the year. Hence, provision of adequate moisture for optimum decomposition of the incorporated residues is another limitation that restricts gainful recycling of these materials. Faced by these constraints, many cultivators generally prefer to burn the residues to clear the fields for tilling and planting. If the volume is small, the residues are converted into compost by natural decomposition.

Since crop residues are such a rich source of nutrients, fodder and fuel, we should ensure that these are judiciously recycled and reused. You will learn about these aspects in the next section. But you may like to first consolidate the ideas presented so far.

SAQ 1

a) How can crop residues control soil erosion due to wind and water?
b) Why and when should we incorporate crop residues in the soil?

17.3 ECONOMY THROUGH RECYCLING

Recycling of wastes for meeting the shortages of raw materials for industry and inputs for agriculture is an important aspect of national economy. Serious efforts in this direction could reduce the cost of production and ensure rich dividends as well as solve the disposal problem and minimize pollution effects.

The greatest benefit from cycling and recycling organic material in soils is the overall improvement in soil productivity/fertility, which is the key component. Our soils being in tropical zone are poor in organic matter due to high rate of decomposition and intensive cultivation. The organic carbon content is less than 1% in most of the soils in the plains. They are very low to low in N, low to medium in P and medium to high in K.

Since most of the recycles are organic, they directly add organic matter and plant nutrients, which improve the soil bio-physico properties and fertility, thus improving soil productivity. The old practice of fallow cultivation if combined with paddy straw incorporation will have many economic benefits such as

- increase in the return per unit land area,
- increase in the carbon content of the soil,
- enhancement in soil fertility,
- conservation of water resources,
- saving in the use of chemicals for weed control, and
- reduction in environmental pollution by not burning the straw.

Studies show that the recycling of different crop residues in soil by way of mulching (6t/ha) resulted in saving of irrigation water, induced reduction in maximum soil temperature and increase in the crop yield (Table. 17.2).

Table 17. 2: Effect of straw mulching on different crops

Crop	Mulch induced reduction in max. soil temp. (^{0}C)	Saving irrigation water (cm)	Increased in crop yield (%)	Saving in fertilizer N (kg/ha)
Maize (forage)	1.1-7.9	15	26	50
Maize (grain)	1.4-6.8	-	20	-
Sugarcane	1.0-9.5	40	13	-
Sorghum (forage)	0.5-7.0	23	20	50
Japanese mint	0.6-9.4	32	9	25
Mung bean	0.8-9.1	7	17	-
Winter maize (grain)	2.0-5.5	23	20	-
Autum potato	1.0-5.7	12	15	-

In a recent survey it has been estimated that the quantities of rice straw burnt in Punjab annually is about 12 million tonnes and through this, significant amounts of nutrients are being lost. Calculated in economic terms, the Punjab farmers are losing Rs. 684 million annually through N alone in the form of fertilizer. Moreover burning of rice straw is posing serious threat of air pollution and increasing respiratory problem to local population. However, application of 8 tonnes of rice straw compost per hectare to both rice and wheat increased the yield by 51% and 40%, respectively.

The process of composting and vermicomposting converts a wide variety of wastes into valuable agricultural inputs, which are an excellent source of humus and plant nutrients. Composting of organic residues and using them on farms can reduce the fertilizer dependence by about 25 %, besides improving the soil physical properties and health. It has been reported that the continuous application of 15 t FYM/ha could save 30 kg N and 20 kg P_2O_5 in rice-wheat cropping system. Vermicomposting is an efficient and inexpensive method of composting. On an average, the vermicompost makes up 63% of total benefits, the worms and the waste disposal brings out the saving of 29% and 8%, respectively.

Recycling of animal dung through the biogas plant can save enormous amount of firewood and produce the enriched manure. We now discuss the process of composting and vermicomposting as a route of recycling agricultural wastes.

17.4.1 Composting

Composting is an age-old process that simulates nature's method of recycling. It is the microbial decomposition of piled organic materials into partially decomposed residues, called as **compost or humus**. It occurs in the presence of air (aerobic) or in a closed container or underground (anaerobic).

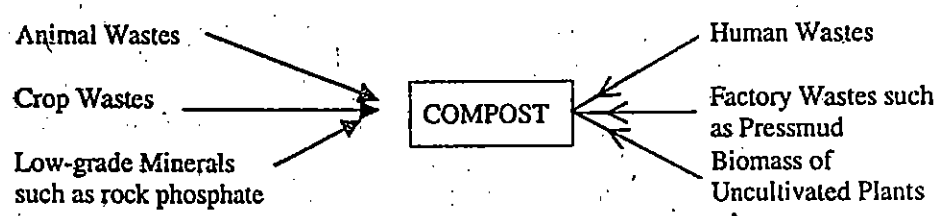
Why composting?

Application of organic materials or crop residues to the soil if not treated properly may pose certain consequences. Materials low in nitrogen (sawdust, straws) may cause a lack of available nitrogen to growing plants in the first few weeks of rapid decomposition because nitrogen in the soil and that released by decomposition are preferentially used by soil bacteria. The decomposition of some materials may release substances that are toxic to plants or contain seeds of noxious weeds, diseased organisms, viruses, or certain parasitic worm eggs and have unpleasant odors.

Composting can alleviate most of these problems and make organic matter suitable for later disposition onto soil. Phytotoxins and bad odors produced during early stages of decomposition of some organic materials are dissipated by evaporation of the substances at the elevated temperatures while in the composting bed. By the time the compost is added to the soil, most toxins and undesirable odors are gone or appreciably reduced.

Materials suitable for composting

A wide variety of by products and wastes can be used for composting. There exists an enormous potential of agricultural, rural and urban wastes in all these countries. The materials of compost from farm refuge include weeds, stubbles, straw, crop residues, remnants of fodder, hedge clippings, animal wastes, etc.



Process of Composting

Composting is a fermentation process, which involves the break down of organic materials aided by an array of micro-organisms, earthworms and other insects in the presence of aerial moisture. This process yields compost (residual organic material often referred to as humus), ammonia, carbon dioxide, sulphur compounds, volatile organic acids, water vapour and heat. Typically the compost produced is 40-60 % of the volume of original wastes. The microbiological nature of composting requires several environmental parameters for the growth and proper functioning of numerous organisms which have an access to and synthesis compounds such as C, N, O_2, H_2, inorganic salts, sulphur, P and trace substances of micronutrients.

Optimum Parameters

1. **C:N ratio:** The key to initiate and maintain the composting process is to keep the C:N ratio between 25:1 and 30:1. When C:N ratio is in excess of 30:1, the decomposition process is suppressed due to inadequate N limiting the evolution of bacteria, that is essential for breaking strong C bonds. A C:N ratio of less than 25:1 will produce rapid localized decomposition with excess N given off as NH_3 which is source of offensive odours. Attaining such balance of ratio and range is possible because all organic materials have a fixed C:N ratio, e.g. food waste has a C:N ratio of 15:1, grass clippings have a C:N ratio of 19:1, leaves have a C:N ratio of 60:1. When these and other materials are mixed in the right proportion, they provide optimum C:N ratio for composting. Typically N is the limiting component, that is encountered in waste materials and when insufficient N is present, the composting mixture can be augmented with fertilizers such as urea or ammonium nitrate.

2. **Particle size:** In addition to nutrients, the efficiency of composting process depends upon the size of the organic material and its surface characteristics. Small particles provide multifaceted surfaces for microbial action. Size also influences porosity (crevices and cracks which can hold H_2O) and permeability (circulation or movement of gases and moisture).

3. **Moisture content:** Moisture is an essential component in the biological degradation process. A moisture level of 55-60 % by weight is required for optimal microbial nutrient and air circulation. Below 50 % moisture, the nutrients to sustain microbial activity become limited, above 70 % moisture, air circulation is inhibited.

4. **Air flow (Aeration):** Air circulation controls the class of micro-organisms that will predominate in the composting process. Air breathing micro-organisms are collectively termed as **aerobic**, while those that can exist in the absence of air are called **anaerobic**. When anaerobic micro-organisms prevail, the composting process is slow and unpleasant, smelling NH_3, or H_2S which is frequently generated. Aerobic micro-organisms quickly decompose organic material into its principal components of CO_2, heat and water vapour.

5. **pH control:** The role of acidity and alkalinity in the composting process depends upon the source of organic material and predominant organisms. Anaerobic organisms generate acidic conditions, which can be neutralized with the addition of lime. Organic material with a balanced C:N ratio will initially produce acidic condition of 6.0 on pH scale., However, at the end of the process, mature compost is slightly alkaline with a pH >7.0 and <8.0.

6. **Temperature:** The regulation and measurement of temperature is fundamental to achieving satisfactory process of organic material decomposition. However, the effect of ambient temperature or surface temperature on the process is limited to periods of intense cold when biological growth is dormant. Expeditious processing and reduction of herbicides, pathogens and pesticides is achieved where internal temperature in the compost pits are maintained (55-60 ^{0}C). If the internal temperature is allowed to reach or exceed (65 ^{0}C), biological activity is inhibited due to heat stress.

7. **Activator:** The use of compost inoculants is known to speed up the process. These are cellulolytic and lignolytic microorganisms like *Trichurus spiralis*, *Paecilomyces funisporus*, *Trichoderma* and *Asperigillus* spp. Inoculation with mesophilic cellulolytic fungi are known to reduce the time needed for completion of the process and improve the quality of final product.

Methods of composting

There are several methods of composting:

Indore method (Heap method): The waste materials are chopped into small pieces of 5-10 cm size and are dried to 40-50% moisture before stacking. Then, they are spread in layers of 10-15 cm thickness either in pits or in heaps of 1m width, 4-6 m length and 1 m depth. The heap is properly moistened with dung, using earth or night soil. Sufficient quantity of water is sprinkled over the heap to wet the composting materials to the level of 50% moisture. Periodical turnings, usually three times at 15, 30 and 60 days after filling, are given to aerate and the material is covered with a thin layer of soil about 2-3 cm thickness. The compost obtained by the Indore method would have a composition of 0.8 % N, 0.3% P and 1.5% K_2O.

Bangalore method (pit method): The composting of the vegetative waste is done in the pits. The size of pit ($9 \times 2.1 \times 0.9$ m) varies with the quantity of material available for composting. A 22 cm thick layer of waste material is first laid in the pit. On each layer is spread a slurry made of dung, urine and earth. A sufficient quantity of water is sprinkled over the material in the pit to make it moist but not too wet. The pot is filled in this way, layer by layer till it rises 2 ft above ground level. At the end dome shaped heap is plastered over with wet mud. It is left undisturbed. The compost is ready in about 4 to 5 months. This method overcomes many of disadvantages of the Indore-method like turning etc. After the initial aerobic decomposition during the first eight to ten days (i.e, filling of pit is going on) the material undergoes semi-anaerobic decomposition. Under these conditions, the decomposition is more gradual and slow. The process ensures less loss of organic matter and nitrogen. Therefore, this method is known as developed or superior method. The compost obtained by this method would contain 1.5% N, 1.0% P and 1.5% K_2O.

Fig.17.1: Various methods of Composting

NADEP compost: In this method, plant wastes, dung slurry and clay soil are used as raw materials for composting. The process is similar to heap method of composting, but is done in brick lined enclosures provided with air holes in all sides.

Coimbatore method: It is anaerobic degradation followed by the aerobic process. In a pit of 4 m length, 2 m width and 1 m depth, crop residues are filled to a thickness of about 15 cm. Over this layer, cow dung slurry to enhance the rate of biodegradation, is applied to a thickness of 5 cm. Above this layer, 1 kg of bone meal, or rock phosphate to minimize the nitrogen loss and to add phosphorous is applied. Alternate layers in this fashion are filled till the height reaches 0.5 m above the ground level. Then the above ground portion is covered with red earth or mud to prevent the rainwater entry and it becomes an anaerobic process. After 30-35 days, the material is turned and it becomes an aerobic process. The compost will be ready within five months.

Windrow composting: Windrowing is a method in which long narrow piles of organic matter are periodically turned and moistened as necessary to allow sufficient ygen to penetrate all the parts of the pile or, alternatively, air can be blown into the ies. Windrows are usually about 3 m wide at the base and 1.5 m high. Temperature thin a windrow approach is 140°F, entirely because of biological activity. The pH ll approach neutrality after an initial drop. Windrowing composting requires large ıd surfaces and a month to several months time to produce satisfactory results.

echanized composting: On a community scale, composting may be a mechanized eration, using anaerobic digesters or a low-technology operation using long rows of redded refuse known as windrows. The machinery used varies according to the kind d quality of the materials to be treated. Digesters are usually enclosed composting stems where moisture, temperature, nutrients and mixing are carefully controlled. me refuse digesters take only a few days for processing, but equipments costs are gh compared with other composting practices.

ıaracteristics of mature compost

e matured compost should have an earthy smell, similar to peat moss and a dark ›wn color. Typical final compost will have composition in the following range:

Organic matter	25-50 %
Carbon	8.40 %
Nitrogen	0.5-3.5 %
Phosphorous (as P_2O_5)	0.5-3.5 %
Potassium (as K_2O)	0.5-2.0 %
Calcium (as CaO)	2-7 %
Incombustible matter	20-60 %

: average nutrient contents of some common composts are given in Table 17.3.

ble 17.3: Average nutrient content of some common composts of animal and plant origin

ınures/Composts	Nutrient Content (%)		
	N	P_2O_5	K_2O
m Yard Manure	0.80	0.41	0.74
ıltry Manure	2.87	2.93	2.35
:al compost	1.22	1.08	1.47
›an compost	1.24	1.92	1.07
‹ed farm wastes	0.87	0.59	2.22
‹ed dry residues	0.90	0.45	1.95
ton stalks	1.61	0.48	3.38
ter hyacinth compost	2.00	1.00	2.30
ldy straw	1.59	1.34	3.37
grass/ weeds	1.90	0.55	1.09
ton wastes and groundnut husk	1.62	1.04	1.26
ıtana stalks and leaves	1.55	0.52	1.07
eat straw	2.90	2.05	0.90
ize stalks	1.99	1.30	1.01
;arcane tarsh	2.73	1.81	1.31
micompost	1.60	2.20	0.67

:ce: Mishra and Hesse, 1983. Handbook of Manures and Fertilisers, ICAR, New Delhi

Enrichment of compost

Compost is bulky and low in major plant nutrients such as N, P and K. Hence there is a need to improve its quality. The missing ingredients can be added to the compost, assuming that the nutrients are tested for and determined to be deficient. Nitrogen, phosphates, and lime are the most frequently added. Fertilizers, legumes, seed meals, manures, and animal slaughter wastes (dried blood, fish carps, tankage) are commonly recommended materials that can improve composts. Presently these materials are more often used for animals feed rather than having their energy wasted on microbial growth in composts. Some examples of the enriched compost are:

- Phosphocompost made from organic refuge (crop residues, leaves, grasses, weeds, etc.), cattle dung or biogas slurry, soil, well decomposed FYM and Mussoorie rock phosphate. It contains 68 % P_2O_5.
- Granulated compost (15-15-5) consisting of 44 % conventional compost, 25 % DAP, 22 % SSP, 1 % urea and 8 % MOP (Pillai and Krishnamurthy, 1983).

SAQ 2

What are the essential conditions for the production of a good quality compost? Enumerate various changes that take place during composting.

17.3.2 Vermicomposting

Vermicompost refers to organic manure produced by earthworms. It is a mixture of worm castings (faecal excretions or excretions or excreta), organic material including humus, live earthworms, their cocoons and other organisms. Vermicomposting is the most appropriate technique for disposal of nontoxic solid and liquid organic wastes. It helps in cost effective and efficient recycling of animal wastes, agricultural residues and industrial wastes. **Vermiculture** is the process of culturing earthworms in various kinds of wastes material and using the excretion of the earthworms as manure.

Vermicomposting process

Earthworms accelerate the process of breakdown of wastes greatly by fragmenting the organic matter, thereby increasing the surface area available for growth of micro organisms and thus promoting further breakdown.

A number of steps are involved in the **preparation of good quality vermicompost.** We describe them below.

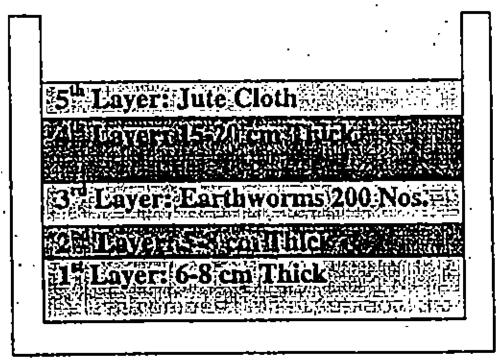
- **Selection of earthworm:** Earthworm which is native to the local soil may be used for vermicomposting.
- **Size of pit:** Any convenient dimension such as 2 m × 1 m × 1 m may be prepared. This can hold 10-40 thousand worms giving one tonne manure per month.
- **Preparation of vermin bed:** A layer 15-20 cm thick of good loamy soil above a thin layer (5 cm) of broken bricks and sand should be made. This layer is inhabited by earthworms.
- **Inoculation of earthworms:** About one hundred earthworms are introduced as an optimum inoculating into a compost pit of about 2 m × 1 m × 1 m. provided with a vermibed.
- **Organic layering:** It is done on the vermibed with fresh cattle dung. The compost pit is then layered to about 5 cm with dry leaves or hay. Moisture content of the pit without flooding is maintained through the addition of water.

Wet organic layering: It is done after four weeks with moist/green organic wastes which can be spread over it to a thickness of 5 cms. This practice can be repeated every 3-4 days. Mixing of wastes periodically without disturbing the vermibed ensures proper vermicomposting. Wet layering with organic wastes can be repeated till the compost pit is nearly full.

Harvesting of Vermicompost: At maturation, the moisture content is brought down by stopping the addition of water for 3-4 days. This ensures drying of compost and migration of worms into the Vermibed. The mature compost, a fine loose granular masses is removed out from the pit, sieved, dried and packed.

Rate of application: Mature Vermicompost is recommended @ 5t/ha.

ıe successive layers to be made for vermicomposting are shown in Fig. 17.2.



Wooden Box
(50 × 50 × 60 cm)

Fig.17.2: Layers in a wooden box for the preparation of Vermicompost
(Source: Jnana Prabodhini, Pune)

lutrient content of Vermicompost

'ermicompost is an excellent soil additive made up of digested and undigested ompost. The digested part is known as worm castings. Worm castings are much igher in nutrients and microbial life and are of higher value product. Worm castings ontain up to 5 times the plant available nutrients found in average potting soil mixes. 'he nutrients are readily available to the plant. There is abundant evidence to show ıat concentration of exchangeable Ca, Na, Mg, K and available P and Mo are higher ı earthworm casts than in the surrounding soil (Table 17.4).

ıpplication of vermicompost

:astings should be spread liberally around plants to a minimum depth of ıpproximately 2-3mm. They should be lightly covered over with soil and watered in o encourage growth of bacteria and hatching of baby worms. Castings may be used afely on all plants, including indoor plants. In orchards the dose depends on the age ›f the tree. A deep ring of 15-30 cm should be formed around the tree. A thin layer ›f dry cow dung and bone meal with 2-5 kg of vermicompost is then applied. This is :overed with thin layer of soil and is mulched with organic matter and a light spray of vater is given. For general use in agriculture, Vermicompost should be applied @ 5 /ha. Vermicompost is mixed with equal quantity of dried cow dung and broadcast vhen seedlings are 12-15 cm high and water should be sprinkled.

Table 17.4: Comparison of the available mineral elements in the cast of earth worms and in the upper layer of ploughed soil

Particulars	Earthworm cast	Depth of soil layer	
		0-15 cm	20-40 cm
Loss of ignition (%)	13.1	9.8	4.9
C:N ratio	14.7	13.8	13.8
NO_3–Nitrogen (ppm)	130.0	20.8	8.3
Available P (ppm)	130.0	20.8	8.3
Available K (ppm)	335.0	32.0	27.0
Exchangeable Ca (ppm)	2.7	1.9	1.8
Total Ca (%)	1.1	0.8	0.8
Total Mg (%)	0.5	0.5	0.5
Exchangeable Mg (ppm)	49.2	162.0	69.0
PH	7.0	6.3	6.0

Source: Palaniappan and Annadurai, (1999)

Advantages

Vermicompost is a "live" product. It contains soil benevolent bacteria. Vermicompost may contain up to 1000 times more soil benevolent bacteria than the original organic material consumed by the worms. Soils treated with vermicompost produce stronger, healthier and more disease resistant plants. Vermicompost is a rich sourge of phosphorous, nitrogen, potassium, calcium and magnesium. The unique action of worms digestive systems on organic matter has made these minerals more readily available to the plants. Vermicompost is formed of aggregates, which are mineral granules bonded together in such a way that they are resistant to wind and water erosion and compaction.

Economic Benefits

The potential economic benefits of vermiculture are the (i) worms, (ii) worm-worked wastes (vermicompost) and (iii) reduction in waste disposal costs. It is estimated that the earthworms numbering 1000 fed on 300 kg FYM, 350 kg garbage in an area of 100 ft^2 give a recovery of at least 400 kg compost and about 25,000-30,000 earthworms, thus making substantial monetary profits. In comparison with other feedstuffs, earthworms are high in protein and essential amino acids. Assuming that the dried earthworms can substitute for existing protein sources in animal feed rations, their values per tonne would be high. Vermicompost is an odourless compost, similar to peat, which is potentially valuable in agriculture. Vermicompost is 5 times richer in N, 7 times richer in P, 11 times richer in K, 2 times richer in Mg and Ca and 7 times richer in actinomycetes than the ordinary soil. Besides it contains valuable vitamins, enzymes and hormones like gibberline.

The third area of benefit which could result from vermiculture is reduction of waste management costs. The cost of handling, storage and reduction of wastes are substantially greater than their manurial value. The reduction in volume that occurs when worms are grown on it brings about reduction in waste disposal costs. On the average, the compost makes 63 % of total benefits, the worms 29 % and waste disposal savings 8 %. While the figures vary accordingly to the assumed values of the worm and compost, they are more or less the same for all sizes of unit.

SAQ 3

Do you agree that vermicomposting should be promoted on a large scale in developing countries. Justify your answer.

17.4 RECYCLING OF ANIMAL WASTES

Wastes of animal origin are one of the major underutilized resources in many countries. These wastes are available either in dairies, slaughterhouses, near the cities or in the backyards in rural houses. Their presence is a source of nuisance and pollution since they contain pathogenic organisms and produce unbearable smell. The scattered and bulky nature of these wastes and their smell pose collection and transportation problems although many of these are valuable sources of organic matter and plant nutrients. In the past, these wastes were mainly used as manures and were important in sustaining sustenance agriculture. Recently, research efforts have identified several uses of these wastes for fuel and manure, as substrates for microbial protein synthesis and as ingredients for animals feed.

Availability

Availability of dung from animals varies with the type of the animal. It has been estimated that cattle on an average produce 10-15 kg of fresh dung/day whereas the buffaloes give 15-25 kg fresh dung/day. Cattle and buffaloes make up a large proportion of total livestock population in South Asian countries.

Composition

The composition and characteristics of excreta are a function of the composition of the feed ration, its digestibility, species of animals and their physiology. The wastes from ruminants such as cattle, buffalo, goat and sheep have a different composition than the wastes of pigs and poultry, which are highly digestible. The chemical composition and the nutrients in different classes of animal excreta are given in Table 17.5.

Disposal and Utilization pattern

There exists a good deal of variation in the disposal pattern of dung from one area to another. The pattern depends upon climate, local customs and the availability of firewood. In Himachal Pradesh in India where plenty of firewood is available from forests, 8 % of the total dung collection was thrown into manure pits and 2 % was used for preparing dung cakes. In Kerala, Andhra Pradesh, Karnataka, Maharastra and Tamil Nadu which have coastal areas and where the climate is warm and humid, the percentage of dung thrown into manure pits was high. In Madhya Pradesh, where firewood is available in abundance, about three-fourth of the total dung collected was thrown into manure pits and the use of dung for fuel was comparatively less. In Punjab, Haryana, Eastern U.P., and Bihar, a fairly high percentage of the total dung collected was converted into cakes for fuel purpose and the proportion of dung thrown into manure pits was comparatively less. This may be due to the non-availability of alternate cheap domestic fuel and cold weather for over five months of the year.

Table17. 5: Nutrient content in excreta of different animals

Material	Nutrients (% on dry basis)				
	N	P_2O_5	K_2O	Ca	Mg
Pig dung	2.27	3.1	1.8	0.21	0.54
Cow dung	1.74	1.7	0.6	0.37	0.53
Horse dung	1.07	2.1	3.6	0.26	0.49
Camel dung	1.51	0.35	1.8	0.7	0.69
Poultry excreta	2.17	2.0	4.2	2.28	1.39
Goat and sheep excreta	0.65	0.5	0.03	-	-
Material	**Micronutrients (ppm)**				
	Fe	Zn	Mn	Cu	B
Pig excreta	1200	50	70	8.9	-
Poultry excreta	1400	90	210	7.1	5.0
Goat and sheep excreta	-	2570	150	6.1	4600

Sources: Gaur. et.al; (1984) Sushil Kumar and Biswas (1982)

Utilisation as Soil Conditioner and Manure

There are various methods for handling and treating animals wastes. The aim is to process and recycle these in one or more ways so as to be utilized efficiently in an environment-friendly manner. The simplest and most effective method is to utilize them as a soil nutrient by recycling it back to the soil. Methods that are available for applying the animal excreta to the soil include

i) direct surface application followed by immediate ploughing
ii) application after processing as FYM
iii) conversion into compost, and
iv) as feed stock in biogas plants to produce gas and slurry manure.

Direct Surface Application

The run off (both liquid and solid wastes) from the paid and unpaid areas is directly spread on the open fields and is subjected to sun drying under natural conditions. This practice is the oldest and easiest method of recycling the animal wastes and is commonly adopted in case of poultry excreta.

Farmyard Manure (FYM)

Farmyard manure (FYM) is the decomposed mixture of dung and urine of the farm animals along with litter (bedding material) and left over material from roughage or fodder fed to the cattle. The FYM occupies a prominent place among the bulky organic manures. A well-decomposed FYM contains 0.7-1.3 % N, 0.3-0.8 % P_2O_5 and 0.4-1.0 % K_2O on dry weight basis. However, the composition depends upon the kind of the animal, its ration intake, age, species and condition. Sheep, pig and poultry excreta are richer in nutrients than the dung from cow and horse.

Utilisation for fuel and manure

Animal excreta can be recycled for fuel and manure by two different processes:

- one involves the physical and chemical processes at high temperature and/or pressure viz., direct combustion, gasification and liquification and
- the other involves the use of microorganisms at ambient temperature and atmospheric pressure in the absence of air, i.e., anaerobic fermentation.

For the purpose of recycling, only the second process is of interest, as it not only provides clean fuel but also manure.

Recycling through biogas technology

Anaerobic fermentation is the process of biological conversion of animal wastes into fuel without sacrificing their manurial potential value (Fig. 17.3).

Fig.17.3: Plant nutrients are recycled of and bioenergy is reused

his technology about which you have read in unit 9 has generated a worldwide iterest because it is amongst the most feasible ones as renewable sources of energy to ieet the challenges for depleting reserves of fossil fuels and escalating deforestation.

Ianurial value of the biogas slurry: One of the major advantages of biogas :chnology, besides cooking, lighting and electricity generation, is the utilization of :sidual slurry obtained after digestion as manure for crop production. It has been)und that the biogas spent slurry is far better than FYM, since it is well digested and as higher nutrient contents for soil micro organisms and for plants. It increases arbon content in cultivated soils and improves physical, biological and chemical roperties of the crop-land on long term basis. A Comparative analysis of biogas lurry and FYM is given in Table 17.5.

Table 17.5: Composting of biogas slurry and FYM (% on dry weight basis)

Constituent	Biogas slurry	FYM
Nitrogen (N)	1.41	0.78
Phosphorous (P_2O_5)	0.92	0.72
Potash (K_2O)	0.84	0.65
Organic Carbon	27.32	24.40
C/N ratio	19.37	31.28

;ocio Economic Benefits: The viability and potential benefits of the biogas echnology have been established beyond doubt. Biogas technology is cheap, simple ınd site specific. It can be easily adopted by the farmers in the rural areas.

Aoreover, biogas is a clean and time saving cooking fuel. There is a reduction in the 'amily fuel budget, saving in fuel wood, reduction in the drudgery of rural women's ives and improvement in rural sanitation. In addition, the residual slurry obtained ıfter gasification is an excellent manure. It not only improves the soil structure and vater holding capacity but is ideal for mushroom cultivation, feed for the fish and can)e used for vermicomposting. The combined use of biogas spent slurry with fertilizer ıave increased the yields of different crops by 35 % accompanied by a discount in 'ertilizer costs.

n this section you have studied how different kinds of plant and animal wastes can be 'ecycled and reused. We now discuss how post harvest waste can be reduced. But you nay like to attempt an exercise before you study the next section.

SAQ 4

Outline the various ways in which animal wastes can be recycled and reused.

17.5 REDUCING POST HARVEST WASTAGE

A grain saved is a grain produced. Ample evidence and statistics are available on losses, which occur from harvest until it reaches customers. It has been estimated that the post harvest losses may range from 8-25% in case of cereals such as rice, wheat, barley, millet, sorghum, etc. The estimate of perishable fruits and vegetables may be as high as 20-30%. Quantitatively this means a lot, since a minimum of 10% lost of over 196 million tonnes of food grains production in would amount to over 19.6 million tones. Post harvest technology and agro-processing are recognized as major instruments in minimizing losses of agricultural produce.

Harvest and post harvest loss

Losses to agricultural produce and by products both quantitative as well as qualitative, take place at various stages of harvest and post-harvest operations. Efforts to increase production should minimize losses that occur during the harvest and post harvest operations like threshing, transport, drying, and storage. It is estimated that 10 % of food grain produced in India are lost due to improper and inefficient methods of storage, transport and handling. If better methods of processing and storage are adopted, the losses could be reduced to 2 to 3% and more food grain could be available to the people. Table 17.6 presents the estimates of percentage losses of paddy in various stages of post harvest operation. Proper methods of processing storage, packaging, transport and marketing are required for export of crops such as jute, tea, cashew nuts, tobacco, mango, litchi, nut and spices.

Table 17.6: Estimated post harvest losses of rice in South and South eastern Asia

Operation	Range of losses (% of production)
Harvesting	1-3
Threshing	2-6
Drying	1-5
Handling	2-7
Milling	2-10
Storing	2-6
Total	10-37

Harvesting loss: Most serious factor that contribute to harvesting loss is shattering. Inability to harvest the crop at the optimum stage allows the crop to get over dry, become brittle and prone to shattering. Timely harvest minimizes undue exposure to weather hazards.

Threshing loss: It is usually due to incomplete threshing or poor separation. Threshing losses can be reduced though threshing at proper crop moisture and implement adjustment.

Cleansing loss: It is usually due to spillage, incomplete separation, and sieve/winnowing loss. Spillage is avoided by using a ground spread.

Drying loss: Drying is done to remove the excess moisture by evaporation to reduce the biological activity to negligible levels thus improving shelf life of the produce. To keep storage losses low, grain must be dried to safe moisture levels: 12-14% (wb) cereals, 10-12% pulses and 8-10% oilseeds. Improper drying can cause cracking of the kernels, high initial moisture or slow drying may cause discoloration due to microbial growth and over heating. Use of mechanical dryers can avoid most of the defects of sun drying.

Storage loss: Storage at improper moisture content, loss occurs due to quantitative and qualitative damage caused by insect, mites, molds, rodents, birds, heat, spillage etc. High storage moisture and high temperature cause loss of germination to seed lots. Rat proof structures, rodent repellants, predators, traps and rodenticides are essential to keep the produce rat free.

Horticulture crops

As far as fruits and vegetables are concerned, nearly 20-30% are wasted during harvesting, packaging, transport and storage. Preservation of fruits and vegetables by sophisticated methods like canning, freezing or dehydration raise the raw material cost many folds. Alternate cheaper processing technologies based on solar dehydration, chemical preservation and use of recyclables need to be developed. Further development of 'Intermediate technology' in fruit growing areas to preserve fruits as ılp, juice or their concentrates would help for their subsequent use by processing dustries. Converting large scale factory wastes into useful value added products like ıultry and cattle feed, oil, pectin, vinegar etc., would reduce losses.

owers and ornamentals

ıe high perishability of flowers and foliage plants render them vulnerable to large ıst harvest losses. Owing to their delicacy and tenderness, flowers and ornamental ants are more susceptible to mechanical and physical damage and infection by seases and pests during and after harvest. Even after detaching from the mother ant, the cut flowers are metabolically active and carry on all life processes at the pense of stored reserve food in the forms of carbohydrates, proteins and fats. Proper ındling, packaging, storage conditions (light, temperature, environment), watering, eservatives and control of diseases and pest and cushioning influence the longevity flowers and foliage plants. Lower temperature protects flower quality by reducing oduction of ethylene. High relative humidity of the storage environment maintains eshness by conserving water loss.

tilization of the Post Harvest Wastes

order to cope with the challenge of minimizing post harvest wastage, producing due added products, better utilization of wastes and by products and appropriate arketing need to be considered. A brief account of the wastes generated from some ajor crops and their possible utilization is given below:

ice: The rice milling industry produces rice husk (20% of paddy) and rice bran (5%) by products. It is possible to use rice husk, though high in silica content and latively impervious to bio degradation after alkali treatment as cattle feed. Besides it used in chicken litter, fruit pressing and production of activated carbon, hard boards acoustic boards, etc. The rice bran itself is a source of edible oil containing 15-20% rice bran oil and has been traditionally used as a feed for poultry and livestock. ice straw is traditionally used as feed, fuel, manure, packaging material. However, it suitable for preparation of quality pulp and paper in combination with wood rag in ınd made paper sector. Besides it is used for generation of electricity and a source of ɔmestic/ industrial fuel.

/heat: Wheat is seldom used whole. Primary processed products of wheat are flour, ıaida, suji/rawa and dalia. Wheat straw is the major residue, which is mainly used as ıttle feed and partly in straw board production, as cheap fuel or manure. It could be ilized for production of various types of paper, such as, cine bleached paper, garette paper, news prints etc.

Iaize: Maize is used as food. Maize stalk, husk, bran gern and gem oil cakes etc., e the by products. The maize stalks are fed to farm animals along with husk besides ıeir use as compost. They could be economically utilized in production of pulp and aper insulating boards/hardboards and domestic fuel. Industrially maize is milled by ry and wet process. Corn sleep liquor obtained in wet milling process is used for roduction of penicillin and other antibiotics.

'otton: Cotton waste includes stalks, stems, leaves, seed hull and dust; cotton waste ın be used for making a wide range of products, paper, boards, cattle feed, fertilizers, ɔod, acids, chemicals and fuel. Cotton stalks contain 71.2% hemi cellulose and fairly ɔw lignin and are therefore suitable raw material for paper making. Cotton seed hulls ɔntain 64.7% hemi cellulose and are used in the production of cheaper and improved re resistant particle board. Cotton textile mills, mainly in the blowing rooms, roduce a large quantity of waste, which is mainly used either as fuel in boiler or as heap filling in blankets. Willow dust, which is the residual trash from cotton rocessing textiles mills, can be used for biogas production.

Post Harvest Wastage Conservation Measures

The conservation of post-harvest produce should be a well co-ordinated effort. It requires a multi disciplinary approach involving agronomists, cereal chemists, food technologists, nutritionists and rural development personnel to accelerate progress in checking food losses. In general, the following aspects may be given priority:

- Popularization of methods and techniques to reduce post harvest losses of all types of crops,
- Simple and effective storage system for grain crops and vegetables,
- Development of post harvest techniques for special crop like makhana, litchi, mango, banana and other fruits and vegetables that are grown in abundance. Such a strategy would help the farmers to get remunerative price as well as consumers through prolonged availability of quality products.
- Centrifuge and rubber roll sheller be used in place of hullers. Extra cost incurred by the entrepreneurs be subsidized to give momentum to this programme,
- More emphasis on the use of power and mechanical (screw type) Ghani or expeller in place of kolhu for higher recovery,
- Popularization of low cost engineering storage structures,
- Use of crop residues for animal feeds,
- Food grain processing for developing new acceptable products and technology for oil extraction and by-products utilization.

With this discussion, we come to an end of this unit. Let us summarise its contents.

17.6 SUMMARY

- The **agricultural and farm waste problem** must be addressed from the point of view of their utilization as a resource. Agricultural and farm wastes are available in large quantities in all agriculture based economies. They contain valuable nutrients. Many reuse and recycling methods have been developed and are being effectively utilized to solve the problem.
- **Traditional agricultural practices** are being adopted by farmers to restore soil fertility and sustain productivity. Application of FYM, incorporation of rice straw/wheat straw into the soil before the next crop is planted, use of rice straw/husk or wheat straw/bhusa in the cattle shed, penning of cattle in the field and use of weeds like *Lantana camera*, Ipomea, water hyacinth in the soil are some of the most common indigenous nutrient management methods adopted by the local farmers.
- **Use of organic residues** in the soil surface decreases the raindrop impact on soil resulting in reduced depression of soil aggregates and enhance infiltration rates. The run off and sediments losses are considerably reduced.
- **Direct mixing of farm refuge and crop residues** leads to temporary immobilization of plant nutrients and the possible release of phytotoxic compounds. Hence, the crop residues must be modified to use as either mulch or as composted manures prior to their application to the soil.
- **Composting and vermicomposting** of these wastes gives a good solution as a waste disposal method, besides increasing the availability of plant nutrients, destruction of pathogens, elimination of unfavorable odours and easy handling. Vermicomposting is an efficient and inexpensive method of composting. The castings excreted by earthworms are rich source of available minerals and humus.

They have the potential to raise soil productivity by improving physical, chemical and biological properties of soil, thereby improving the plant growth. In the days of increasing fertilizer price and in view of necessity to improve the yield of rainfed agriculture, it is imperative to look for these agricultural wastes recycling by composting.

Lack of **post harvest management** and cold chain infrastructure, account for heavy economic losses in developing countries. There is an urgency to strengthen the network of post harvest management and cold chain infrastructures, grading/packaging centres, pre-cooling units, refrigerated vans, cold storage etc., both in the areas of production and at the retail outlets.

In rural development, there is an urgent need for **fuel with higher thermal efficiency** from the non-commercial local sources with lower thermal efficiency. Recycling of animal wastes through biomethanation is one such source, which deserves serious attention. This technology adoptable on a small scale is labour intensive, needs little skilled labour and uses locally available residues such as animal dung and crop residues. The technology provides an easy way of producing fuel gas known as biogas by anaerobic fermentation of wet dung and rich manure from the residual matter. The gas is a source of energy for lighting cooking and operating engines; the residual slurry provides energy and nutrients for agricultural production.

17.7 TERMINAL QUESTIONS

1. Can crop residues be managed without burning?
2. What possible measures could be taken to avoid burning of crop residues?
3. What are the possible options for managing crop residues in the present scenario?
4. How can various losses during harvest and post harvest operations of an agricultural produce be reduced?
5. **Activity: Vermicomposting**

   Take unused packing boxes (Khokha) or pots. Place them on roofs or the spare for kitchen garden wherever is available. Use the garbage of your house for vermicomposting.

   (i) Observe the smell of garbage after 48 hrs – You will notice that the foul smell has subsided.
   (ii) Use sieve to separate earthworms from the matured compost – You will observe that 40% garbage fed to the earthworm is converted into compost and the population of earthworms is doubled.

REFERENCES

1. Bhardwaj, K.K.R. (1995) Recycling of Crop Residues, Oilcakes and Other Plant Products in Agriculture. In: *Recycling of Crop, Animal, Human and Industrial Wastes in Agriculture.* (Ed. Tondon, H.L.S.), Fertiliser Development and Consultation Organisation. New Delhi. pp:.9-30.
2. Gaur, A.C., Neelakantan, S., and Dargan K.S. (1984) Organic Manures. ICAR, New Delhi. pp.159.
3. Mishra and Hesse (1982) Hand book of Manures and Fertilisers, ICAR, New Delhi
4. Palaniappan, S.P., and Annadurai, K. (1999) Organic Farming Theory and Practices. Scientific Publishers (India) Jodhpur.

5. Pillai, K.G.K., Krishnamurthy, K. (1983) Studies on new sources of N for its efficient use in rice. *Fert. News*, 28(6), 25-30.

6. Sushil, K., Aggarwal, P.K., Gupta, N. and Sujith. K. (2002) Agri-Resource for Ethanol Production in different Agroclimatic Regions of India- Current states and Future Prospects. Final Report submitted to MNES. Division of Environmental Sciences, IARI, New Delhi,

7. Sushil, K., and Biswas, T.D. (1982) Biogas production from different animal excreta. Indian J. Agric. Sci. 52, 513-520.

8. Svedelius, R. and Watkin S.J. (2003) Your body renewable organic waste and the environment rsvedelius@hotmail.com (Sweden).

UNIT 18 ALTERNATIVE AGRICULTURE

Structure

18.1 INTRODUCTION

It has been realized that income through arable farming alone is insufficient for marginal farmers. Activities such as livestock management, poultry, aquaculture, beekeeping, sericulture, agroforestry etc. assume significant importance in supplementing their farm income. The concept of 'Alternative agriculture' is a broad range of agricultural systems that are alternatives to present common practices and provides an opportunity to increase economic gains per unit area per unit time by virtue of intensification and allied enterprises. Alternative agriculture fits well with farm level infrastructure and ensures judicious utilisation of available resources and the byproducts and will reduce the drawback of present day agriculture. Its main objective is to make agriculture ecologically and economically sustainable. The emphasis is on two dimensions i.e. time and space. This minimizes the risk and increases the production with better utilisation of resources like waste and residues. In this unit we will discuss the various components of alternate agriculture and how their integrated use can enhance the income of the marginal farmer and contribute towards sustaining agricultural production.

Objectives

After reading this unit, you will be able to:

- define alternative agriculture;
- List the various components of alternative agriculture;
- explain the importance of livestock, bee keeping, poultry, aquaculture, sericulture and lac cultivation;
- describe agroforestry and social forestry;
- understand the importance of various plantation crops; and
- gain knowledge about herbal and medicinal plants.

18.2 COMPONENTS OF ALTERNATIVE AGRICULTURE

Alternative agriculture is being practiced now to improve the economy of Indian agriculture and standard of living of the farmers of the region. Farmers and land holders need information about alternative agricultural practices which may provide them with a profitable alternative to what they are currently practicing. Some may wish to diversify their crop or livestock to deal with the risks inherent in agriculture yet others may look for some alternative for supplementing their family income. The different components for alternative agriculture can be: agroforestry, sericulture, apiculture, plantation of cash crops and medicinal crops, livestock, poultry, aquaculture etc. But all depend upon their requirement and available resources of the farmers and their ability to judicially incorporate the alternative components.

18.2.1 Livestock

The interdependency of crop enterprise and livestock production systems is an age old practice. The productivity of livestock is controlled by 3 principal factors, *viz.*, (i) genetic make-up, (ii) environment including nutrition and diseases, and (iii) their interactions. If livestock production is to be made sustainable, it should have 4 major qualities, *viz.*, economic viability, technical feasibility, social acceptability and relevant resource base.

The breeding, weeding, feeding and heeding are universally recognized essential aspects for livestock management. Management of animals involves a certain degree of control of these parameters. The present trend is to give greater emphasis to the study of their behaviour and apply control through intelligent manipulation of their behaviour rather than through the application of brute force or through inflicting pain. Domestication is the process whereby man has structurally, physiologically and behaviorally modified certain species of animals by maintaining them in or near human habitation and by breeding them for various human objectives like docility, efficient maternal care, high fertility, longevity, production and ornamentation. In breeding, animals both the male and female selected for breeding should be of superior genetic merit, of known potentialities and possess desirable qualities. The production characteristics of livestock are not entirely because of heredity, but it is influenced by environment also. Heredity provides the ability to exhibit certain characters and environment provides the opportunity to express them. The capacity of animals to cope with the climate and disease environment of a region and to maintain the health status, is of profound importance to livestock production systems. Healthy stock makes use of genetic potential under good nutrition. Although indigenous livestock are equipped with better climatic adaptation, ability to withstand stress, disease resistance and ability to thrive on poor feeding regimen, they are also poor producers. Major reasons for poor performance may be poor genetic constitution, inadequate availability of nutrients and large number of unproductive animals. The genetic superiority of the indigenous stock for the ability to adapt to thermally adverse environments may result in better survivability of these animals in these environments, but need not necessarily result in better productivity.

Land use pattern for livestock: The status of land use pattern envisages that the total reported area is 395 million ha which is almost constant from 1950-51 onwards. Out of total geographical area, 22.26% comes under forest area, 3.87% under pasture-cum -grazing lands, 1.21 % under miscellaneous tree crops and groves, 4.92% under cultivable wastelands, 7.67% under fallow lands and 6.96% under barren-cum-uncultivable land. The wastelands constituting about 33% (129.76 million ha) of the total area and the development of the wastelands into land for feed and fodder resources can solve the most critical constraint that stands in the way of livestock improvement.

'eed and fodder resources: According to "National Wasteland Development Board" ne deficiency of dry and green fodder for livestock has been estimated recently as to e 43.46 and 73.18 per cent respectively. The deficiency is likely to increase in oming years if no efforts are made to meet the supply of fodder. Various approaches o enhance feed and fodder productivity on existing land is desirable.

Areas of integration: The integrated approach becomes more acceptable by the eople if it is well designed on need based principles, for which, a systematic analysis of the various inputs like conservation methods, selection of suitable biomass species, se of quality planting stocks, watch and birds protection along with available dequate waste land and its suitability for growing fodder is needed to make them vailable for livestock development programme. This will enhance extra income to he rural masses. It is evident that both livestock rearing and wasteland development programme should be taken up in an integrated manner. The agencies concerned with he wasteland development and livestock development must act in close co-ordination by ensuring active involvement of financial institutions.

Livestock Management

Livestock management involves the integrated application of the principles of breeding, feeding, housing, organization and disease control in a manner suitable for a particular situation. These principles are often modified based on different trends in livestock management. Renewable rural energy utilization, draught animal power, animal waste management and use of non-conventional animal resources are now receiving greater attention in the livestock field. Greater stress is given to the sustainability so that the farming system may not destabilize or contaminate the environment; or degrade natural ecosystems. Emphasis is also given to the social aspects in that it should provide optimum employment opportunity and promote self reliance.

All the managerial systems should be designed and executed in such a way that livestock remains healthy and attains optimum production. In modern livestock production systems where large number of animals are concentrated in limited space, ventilation, prompt and efficient removal of excreta like urine and dung assumes great significance in hygiene, and prompt cleaning and disinfections of sheds, premises and surroundings are of paramount importance.

South Asian Countries have vast livestock resource, which includes cattle, buffalo, sheep and goat. Livestock rearing provides employment and supplementary income to majority of rural households, particularly landless and marginal farmers. **On an average 100 ha. of cropped area sustains 151 bovine stock comprising 111 cattle and 40 buffaloes.** It is a well-accepted fact that the productivity of livestock in these countries is very poor. Typically, the milk yield per animal per day in case of crossbred cows ranges from about 3 litres to 9 litres. In comparison, the milk yield from cows in Western countries ranges from 15 to 20 litres and that of murrah buffaloes is 8 litres per day per animal. The reason for such low productivity can be attributed to poor health coverage and insufficient capital for rearing livestock on scientific lines. Besides these factors, the most critical factor is inadequate supply of feed and fodders, which depends on availability of the land resources. However the situation regarding the availability of milk changed after "Operation flood" which covers 9 million farmer families in 170 milk-sheds in 22 states and union territories under the cooperative umbrella. Operation flood provides animal health, marketing facilities and new technologies for improved cattle and buffalo productivity.

India had approximately 204 million cattle and 84 million buffalos and the gross value of output from livestock sector alone at current price is Rs. 1.114 billion which is above 25% of the value of output of Rs. 4,495 billion from agriculture sector (1997-98). There are about 70.6 million drought animals comprising mainly cattle and buffalo, contributing 20% of energy input into crop farming.

The advances in animal husbandry have greatly helped in improving the economic status of rural masses of the country. To obtain maximum profit it is advisable to rear Jersey crossbred cows (FI crosses) since they come up very well in all climatic conditions, consume less feed and fodder, give more milk with high fat content and possesses comparatively better disease resistance. However, Holstein Friesian crosses could be reared for higher milk yield in places of cooler climate as they lack heat tolerance. Buffaloes breeds like Murrah crosses and even non-descript types could be reared for milk production. Buffaloes can digest more percentage of roughage than cows and thrive well on dry fodder. Buffaloes contribute nearly 60% of milk to the national milk grid. More profit could be accomplished through utilisation of improved breeds.

Box 18.1: The important breeds of livestock in India

Cattle: Kankrej, kangwariya, Kherigarh,Malvi, Tharparkar,, Bachaur, Gaolao, Hariana, Krishna velley, Mewati, Nagauri, Ongole, Rathi,Dangi,Deoni, Gir, Nimari, Red Sindhi, Sahiwal, Hallikar, Amritmahal, Khillari, Kangayam, Alambadi, Ponwar, Siri,

Buffalo: Murrah,Bhadawari, Jaffarabadi, Surti, Mehsana, Nagpuri, Nili Ravi, Godavari, Toda, Parlakhemundi, Tarai, Sambalpuri

Sheep: Nilgiri, Hissardale, Kasmir merino,Pugal,Patanwadi, Tibetia, Bonpala, Gaddi, Rampur Bushir, Poochi, Karnah, Gurez,Ramboullet, Suffolk,Corriedale, Karakul etc.

Goat: Jamunapuri, Beetle, Sirohi, Surti, Kutchi, Barbari, Ganjam, Changthangi, Gaddi, Marwari,, Bakharwal, Mehsana, Osmanabadi, Malabari, Zalawadi,Gohilwadi, Sangamneri, Kannaiadu etc.

There are certain areas, which can be strengthen for livestock improvement and rural masses.

18.2.2 Bee-keeping

Honeybee and the fruits of its toils have been familiar to man since pre-historic times. It is one of the few insects that are directly beneficial to man. One comes across a number of folk-lore's praising the honeybee's diligence, usefulness and sacrifice. These winged creatures and the honey they produce find mention in many religious epics. Figures and carvings of the honeybee, its combs and hives are found in tombs, coffins, crowns, maces of kings and coins of ancient and modem empires. Honey is prized as food and medicine and the uses of beeswax are many and varied. Bee keeping is an important art which provides additional income with little effort (Fig. 18.1).

Fig.18.1: Bee keeping in orchards

cial life and division of labour

e honeybees live in a colony and adopt highly organized system for their own ›tection and production of honey and also provide unique example of social life :luding division of labour like human community. A normal honeybee colony ıtains one queen, 10000- 80000 workers and 100 to 400 drones.

ıeen: Queen is considered as the mother of the colony and all others work under her wardship. The main function of the queen is to lay eggs and most often she lays gs is large number even twice her body weight.

orker bees: These are females; unable to reproduce but possess all the maternal :tincts and each bee is assigned a definite amount of work. The main functions are:

- nest building for the queen for laying egg,
- preparing feed by mixing pollen and honey for the young larvae,
- maintaining the temperature inside colony,
- guarding the nest against the attack of enemies
- collect nectar and pollen from different species of flowers and
- synthesizing honey in their body and confining honey in the cells.

e worker bee starts her work by doing comb cleaning during first 3 days after birth d provides feed to the developing larvae for the next 4 days. In the meantime, royal ly is formed in the head region of the worker-bees, which is fed for 2 days to the .all worker larvae and for 6 days to the queen larvae. The jelly formation continues 10-13 days. After about 12 days, wax glands are formed on the lower side of the :'s stomach and produce wax which is used for the formation of combs/cells. The : starts taking flight after 7 days of her emergence but starts collecting water and :d after attaining the age of 21 days.

'one bees: Drones are male bees and the bee species can not multiply without them.

›neybee as Universal Pollinator

›ney bees are excellent pollinators particularly in grain or vegetables crops having ›arate male and female flower/plants owing to their adaptation for carrying the llen such as:

- dense cover of hairs on its body,
- habit to visit flowers frequently to collect nectar and pollen,
- consistent visit on the same flora for many days,
- ability to cover a large area up to 2 km radius,
- reproducibility at a faster-rate, with respect to time and space.

oducts of Honeybee

›ney: "Liquid Gold of Nature" has its immense use on account of nourishment and healing properties. It contains large amount of glucose and fructose and is readily sorbed into the blood stream. The raw use is preferred because cooking removes the :cial aromatic compound and cause the sugar to caramelize. It has a long keeping ality and requires no refrigeration. Honey is supposed to work as miracle in the atment of aliments, gastric and intestinal disorder, respiratory troubles etc. and has rmicidal properties and used in surgical dressing. Its nutritional value per 100g is scribed as, calories (319K cal), moisture (20g), protein (0.3g), carbohydrate (79.5g), lcium (5g), phosphorous (16mg), iron (0.9mg), vitamin C (4mg).

.e-wax: It is a complex substance containing complex esters of monatomic alcohols d fatty acids constituting 70.4 to 74.7% of wax. The other components are, free acids 13.5 to 15.0% and saturated hydrocarbons 12.5 to 15.5%. it is rich in vitamin A and 100g of wax contain 4096 I.U of vit A. it is mainly consumed by candle industry and bee industry or preparing comb foundation sheets. Wax is also an important constituent of cosmetics like cold creams, lipsticks and rouges because it adheres better to skin. Pharmaceutical and perfume industries are also major users of wax. It is also used in ointments, capsules, pill coatings and deodorants. Wax is used in preparation of shoe polish, furniture etc.

Bee venom: A bee, when two weeks old has maximum venom in her poison sac and there is no more addition to this quality. Composition of bee venom is complex and it consists of many active substances such as stamina, apamine, calcium etc., Bee venom has been reported to be useful for curing many diseases and disorders. It has also given positive results in curing neurosis, endoarteriosis, endoarthritis and neuralgia.

Propolis: It is gathered by bees from resinous exudes of trees. In the bee colony propolis used by bees for sticking frames, sealing cracks and crevices. It has quality of healing wounds effectively and is commonly used in preparing ointments for treating cuts: wounds and abscesses in cattle.

Economics of beekeeping

The beekeeping is the only enterprise, which requires less initial investment and can be started from a small to large unit according to the capacity of the farmers. From ten colonies one can earn a net profit of Rs. 8500. (Table 18.1)

Table 18.1: Economics of beekeeping

Particulars	Rate (Rs)	Quantity (No.)	Total Expenditure (Rs.)
(A) Non Recurring Double chamber bee Hives (Kailwood)	1000	10	10, 000
Nucleous colonies (4 frames bee each)	480	10	4, 800
Iron stands	50	10	500
Honey extractor	1000	1	1, 000
Bee-veil, bee gloves, Hive tool, smoker, bee brush, uncapping knife, etc.	500	1 set	500
Queen excluder	60	10	600
Honey tins	25	6	150
Sub-total			17, 550
(B) Recurring			
Comb foundation sheets	7/sheet	160	1,120
Sugar (2kg/colony)	16/kg	20	320
Winter packing	10/colony	10	100
Sulphur (100g/box)	30/kg	1	30
Sub-total			1,570
Grand total			19,120
(C) Gross income			
Honey (15kg/colony)	50/kg	150	7,500
Sale of multiplied colonies	480	5 (No)	2,400
Wax (300g/colony)	60/kg	3 kg	180
Total Gross Income			10,080

)) Net Profit	
Gross income	10,080
Less recurring Expenditure	1,570
Net profit	8,510

;AQ 1

Vhat are the main products of bee keeping?

\ctivity 1

f possible visit a bee keeping unit and wave out a report on its working.

18.2.3 Sericulture

\griculture and agro-based industries play a vital role in the improvement of rural :conomy. The limited availability of land, the limited cash returns, and agriculture)eing confined to one or two seasons in the year, have made villagers to look for upporting rural industries, such as sericulture. Agriculture and sericulture are adopted imultaneously by the agriculturists in regions where the ecological conditions are 'avourable.

Sericulture, with a high annual turnover of three to four crops in rainfed conditions and five to six crops under irrigated conditions, provide a means of regular and stable ncome. Division of the garden into plots with alternate harvest timings, could enable he household to carry on rearing silk worm throughout the year on a continuous basis. A regular and relatively steady income from sericulture provides a very strong ground 'or improving the living conditions of the poor.

Cocoon: The silken shell spun by the silkworm larva that serves as a protective covering during its pupal stage of existence. The cocoon needs to be processed through reeling for taking out the silk fibre in the form of silk yarn.

Sericulture being a cottage industry, provides the maximum opportunity for the participation of women. In fact, it is estimated that more than 60% of work in sericulture is carried out by women. Thus sericulture provides a unique scope for the direct participation of women in the process of production and decision making, for mproving their economic conditions, and for giving them a greater recognition and status in the family and society.

Sericulture is the sector where nothing goes waste. There is a hundred percent utilization and recycling of all that goes into or comes out of the production system, be it rearing or reeling. While the left-over mulberry stems along with the worm droppings form an excellent cattle fodder on the one side, there are reelers to reel the worst of the cocoons, the dirtiest flimsy and jelly cocoons rejected at the cottage basins. Finally, even the stifled and much maligned pupae are used up for preparation of dog biscuits, oil etc.

Sericulture, the technique of silk production, is an agro-industry that can play an eminent role in the rural economy of the SAARC region. Silk-fibre is a protein produced from the silk-glands of silkworms. Mulberry silk constitutes nearly 95% of **total silk production. Silk in popular terms may refer only to mulberry silk and sericulture only to the rearing of mulberry silk worm, *Bombyx mori*.** Although there are several commercial species of silkworms but, *Bombyx mori* is the most widely used and intensively studied, and techniques for its rearing are the most improved.

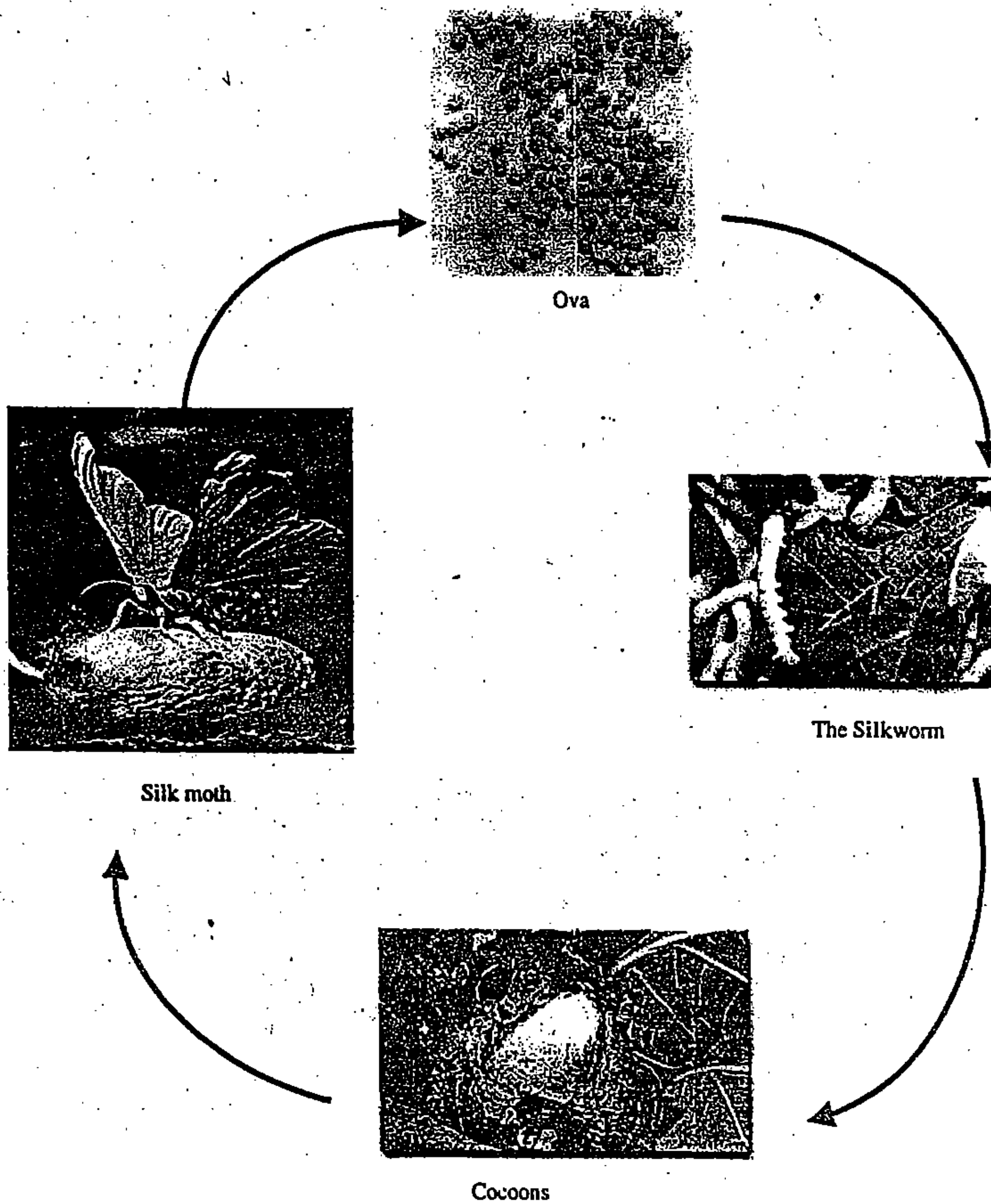


Fig.18.3: Life cycle of *Bombyx mori*

Sericulture in India – A Case Study

Among the developing countries, India enjoys a very favourable position for doubling the present status of silk production of 2,969 tonnes owing to the low cost of labour. sericulture is ideally suited for improving the rural economy of the country, as it is practised as a subsidiary industry to agriculture. Recent research has also shown that

Five varieties of silk worms are reared in India for producing this natural fibre. *Bombyx mori,* the silk worm, feeds on the leaves of Morus to produce the best quality of fibre among the different varieties of silk produced in the country (Fig. 18.3). *Antherea assama* is confined only to the Brahmaputra Valley of India. It produces the

ıous mugasilk.Tasar silk is a product *of Antherea mylitta*, which feeds on *rminalia tomentosa* grown in the thick jungles of Bihar, Madhya Pradesh and issa. The recent introduction of *Antherea royeli* and *Antherea perniyi* has enabled : country to produce the oak tasar silk, *Phylosamia ricini*, the eri silkworm, which ›ds on *Ricinus communis*, is raised in Assam and Orissa commercially.
the total production of 2,969 tonnes of silk in India, as much as 2,445 tonnes is ›duced by the mulberry silkworms, *Bombyx mori*. Silk worm has **univoltine**, **voltine** and **multivoltine** species.

Uni,Bi,and Multi Voltine: Silkworms are classified based on the number of generations (life cycles) per year under natural conditions. If it is one it is Univoltine. if it is two then it is called Bivoltine, and for more than two it is called Multivoltine. In the rest of the period they undergo diapause during the egg stage. Multivoltines produce many generations without any rest period throughout the year.

ıe life cycle of the silk worm ranges from 25 to 30 days through which the eggs ıch the stage of cocoons. In between, the worms, being voracious eaters, expand ›re than 10,000 times consuming a lot of mulberry leaves, labour and care. The ulberry yield of half an acre of irrigated land could be used to rear about 100DFLs r batch with the family labour of a small household of five members.
ulberry silk is produced extensively in the states of Karnataka, West Bengal and mmu and Kashmir. About 85 per cent of the country's production is contributed by e Karnataka state by rearing multivoltine hybrids of silkworm and this activity ıables the sericulturists to harvest five to six crops a year. Jammu and Kashmir, ving to its salubrious climate during autumn and spring, is producing silk by rearing ıivoltine silkworms. Other states, namely, Andhra pradesh, Assam, Tamil Nadu, ttar Pradesh,Himachal Pradesh and Punjab, contribute roughly 1.8 percent to the ›tal production of mulberry silk in India.

DFL (Disease Free Laying): A silkworm laying which is produced under controlled breeding conditions in a grainage (silk worm seed production centre). Each laying contains about 250 to 500 eggs depending on the silkworm race and breed. Usually, the eggs are allowed to be laid on sheets of paper called 'egg sheets'—each sheet having a place for 20 layings.

ericulture has progressed under the leadership of Central silk Board which is opularising the new technology of silkworm rearing which gives specific attention to 'howki rearing, quality of mulberry to be used as food, proper spacing and bed leaning method to reduce the mortality of silkworm. This technology has increased ıe harvest from 15-20 kg/100 DFLs to 40 kg/100DFLs.The development of hybrids ke "Nandi" and "Chamundi" has opened up new frontiers in increased production in ilk.

ericulture plays a vital role in transferring wealth from richer sections of the society ilk is consumed mostly by the affluent and money so spent by them on purchase of ilk is distributed among the sericulturists, reelers, weavers and traders. Summary of ›ercentage distribution of money from sale of soft silk fabric of 40.5 to 60g/meter is ;iven in Fig. 18.4.

From the figure we can see that contrary to the traditional farmer the primary ericulture who grows the food plant raises the silkworm cocoon gets the maximum hare.

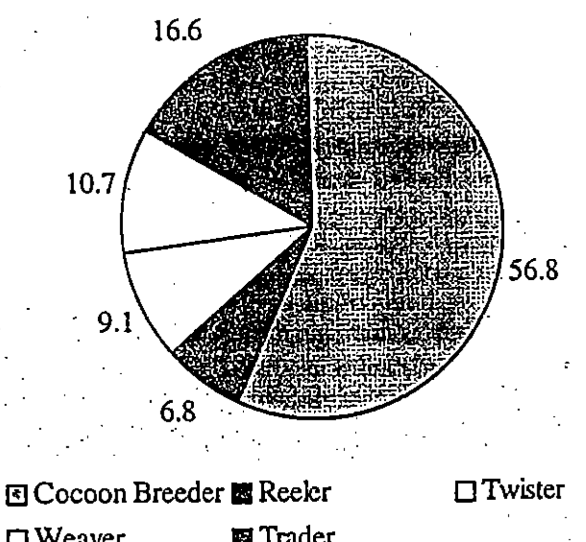


Fig.18.4: Distribution of gross income from sale of soft silk fabrics of 60gm/mtr.

Indian farmers are now increasingly prone to take up mulberry cultivation, as the returns from it are more than the other crops besides getting an additional income from silk worm rearing (Table 18.2).

Table 18.2: Annual revenue per hectare from different crops

Irrigated conditions		Rain-fed conditions	
Crop	**Net income per ha/year**	**Crop**	**Net income per ha/year**
Mulberry	15,000	Mulberry	5,000
Sugarcane	12,700	Jowar	550
Paddy	4,500	Ragi	750

SAQ 2

a) How many varieties of silk are produced in India?
b) How does sericulture help to supplement the income of marginal farmers?

18.2.4 Lac Cultivation

Lac is the hardened resin, secreted by the tiny lac insect belonging to an insect family. The indian lac insect is *Kerria lac* Kerr (Tachardiidae : Homoptera) and the lac insect of Thailand is *Kerria chinensis*. Lac insects settle closely on the twings of certain host trees. Sulk the plant sap and grow, all the while secreting lac resin from their bodies. Since the insects are closely spaced on twigs, the resin forms continuous encrustations over the twigs of the host trees.

Lac cultivation can be achieved by planting host plants of Lac insect as a component of agroforestry system, on waste and marginal lands; degraded forest areas, panchayat lands, field bunds, etc.

Sticks of lac encrustations (broodlac) which contain mature female(gravid) insects, about to give birth to young larvae, are placed on suitably prepared specific host plants. After emergence from the mother cells, the young larve settles on the fresh twigs of the host plants, suck the plant sap and grow to form encrustations. The twigs containing these encrustations are harvested after they are fully grown to extract the lac resin.

Lac cultivation is simple, does not need any large investment and requires only part – time attention. Sustained production and steady returns can be achieved by adopting improved methods of cultivation. Thus, lac cultivation can be extremely attractive avocation (See Box 18.2).

In Lac cultivation poor people of tribal areas get employment. Employment potential is generated in pit digging, planting, watering of seedlings, proper rearing of Lac insects, collection of stick Lac and brood Lac and their processing provides job to the people of weaker section in these areas. There are two strains of Lac crop grown in India: (i) Kusumi strain (grows on kusum trees).There are two maturity periods of kusumi strain: JETHWI (January- February to June-July) and AGHANI (June-July to January –February). (ii) Rangini strain (Grows well on palas and ber). There are two maturity periods of rangini strain: one is KATKI (June-July to October-November) and another is BAISAKHI (October-November to June-July).

Fig.18.5: Encrustation of Lac on twigs of host tree. This forms sticklac.

Harvesting of lac is done in two ways: Selection of brood lac for further inoculation, is done when a tiny yellowish spot appears at one end of encrustation indicating maturity of the brood lac and for collection of Lac from host plant, harvesting is done when Lac becomes mature. The encrusted shoots are cut and by scraping of the shoots Lac is collected. The product is known as stick Lac (Fig. 18.5).

he raw lac thus obtained is known as *scraped lac* or simply *sticklac*. Sticklac is rushed into small grains, seived, washed with mild alkaline water and dried. This emi-refined product, called *seedlac*, is further refined by a system of hot melting, ltration and stretching into thin sheets which are subsequently broken into brittle akes called *shellac*. Alternatively the purified lac resin can be in the form of circular iscs called *button lac*. If a solvent process is used to purify the raw lac, *dewaxed, ecolourised lac* can be obtained as the end product. The normally amber coloured esin can also be bleached with sodium hypochlorite to obtain *bleached lac*, which is hite in colour. Bleached lac has specialised demand for coating medicinal tablets, onfectioneries etc.

ndia is the principal lac producing country of the world producing approximately 3,000 metric tonnes of unrefined (raw) lac annually. About 85% of the country's roduction is exported to various countries. The USA, Germany and Egypt are some f the major lac importing countries of the world.

ac products are shellac and shellac based varnishes and insulating varnishes. he various applications of lac are as follows:

ac Resin

Food processing industry
Cosmetics and toiletries industry
Varnish and printing industry
Coating of fruits and vegetables
Electrical industry
Leather industry
Adhesive industry
Pharmaceutical industry
Perfumery industry
Miscellaneous applications

ac Dye

Food and beverages industry
Textile industry

ac Wax

Polishes (shoe, floor, car polishes etc.)
Food confectionery and tablet finishing
Lipsticks
Crayons etc.

ith increasing environment awareness, the importance of lac has assumed special levance, being an echo friendly, biodegradable and self-sustaining natural material. nce lac insects are cultured on host trees which are growing primarily in wasteland eas, promotion of lac and its culture can help in eco-system development as well s ve reasonably high economic returns.

any tribal men and women are already engaged in this trade. They earn Rs.25 to 40 r day and without being displaced from their village.

urce: Department of Public Relations Madhya Pradesh, Bhopal:
News: Friday – June 27, 2003

18.2.5 Aquaculture

Aquaculture constitutes an important ingredient of integrated rural development. It provides opportunities for self employment and income generation to the unemployed and under-employed people in rural areas. Aquaculture has provided protein rich aqua-food basket, which is more diversified, and consumers are getting both fresh water and seafood products.

In addition, the wasteland, unutilised water bodies, and animal, agricultural and agro-industrial wastes can be utilized extensively as environment-friendly tools in aquaculture. Aquaculture has a great role in human resource development by providing protein rich food to the people for good health and combat malnutrition among rural masses in the region. Blue revolution through aquaculture is possible and can largely be based on a two pronged approach: one is to extend the benefit of technology to rural poor by promoting low cost technology, and secondly to achieve the envisaged quantum jump in fish production for domestic supply as well as export earnings. Fish farming has established itself as a profitable venture as compared to traditional agriculture and animal husbandry because of high return per unit area, easy cultural practices, few risks and no marketing problems.

Aquaculture in India

The Fisheries sector with an annual growth of 4-6% is contributing 1.28 % to the total gross domestic product of the country and its share in agriculture sector is increasing. The innovation and adoption of technologies like polyculture, integrated fish farming, cage culture and pen culture of carps, cat fishes, masher, snow trouts, murrels, live fishes, fresh water prawns, mullets, milk fish, sea bass, shrimps, oysters, mussels, clams, lobster, crabs, sea cucumber and sea weeds have added new dimensions to the life of poor people by bringing prosperity. India's total fish production is 5.35 million tons out of which 1.6 million tons is contributed by aquaculture.

SAQ 3

How can aquaculture prove to be more profitable than traditional farming?

18.2.6 Poultry

India is the fifth largest producer of egg in the world and only next to China, USA, Japan and Russia. The per capita availability of egg and poultry meat was 33 eggs and 1,100 gm respectively.

"Poultry" includes a number of avian species such as chicken, turkey, geese, guineafowl, pea fowl, etc. domesticated for economic purposes. These species perform well under a variety of agro-climatic conditions, which help in raising them successfully almost anywhere provided certain minimum management, and nutritional requirements are met with. These birds are efficient converters of feed into animal protein of high biological value compared to other livestock species. While chicken and ducks are raised for commercial egg and meat production, turkeys, guineafowl, geese, etc. are maintained only for meat production.

Indian Council of Agricultural Research has played a vital role for poultry improvement by establishing two poultry institutes, *viz.*, Central Avian Research Institute, Izatnagar, U.P. and Project Directorate on Poultry, Hyderabad, (A.P.) These institutes provide necessary research, training and extension support to the growing poultry industry.

Box 18.2

Common poultry breeds are:

American breeds: Plymouth Rock, Rhode Island Red, New Hampshire.
Asiatic breed: Brahma, Cochin, Langshan
Mediterranean breeds: Leghorn, Minorca, English breeds: Cornish, Australorp
Indigenous breeds: Aseel, Busra, Chittagong, Karaknath;

In India poultry keeping is as old as its civilization. Poultry farming remained a disorganized "backyard venture" only to be patronised by poor and weaker sections of the society. Our poultry industry is primarily chicken oriented which accounts for more than 90% of the total poultry available in the country. Ducks next to chicken in the order of preference accounts for about 6% of poultry production. The quail egg and meat have recently become popular and commercial quail farms are being set up throughout the country, both in the government and private sectors.

Indigenous poultry breeds which are hardy but poor in productivity, continue to dominate Indian poultry scenario. There was strong prejudices against raising of poultry and consumption of poultry egg and meat by higher stratum of the society. Low productivity of indigenous birds, low prices for egg and meat, inadequate knowledge of poultry raising and lack of appreciation of poultry's special role in alleviating poverty and improving malnutrition through protein were the major drawbacks in development of poultry. However, during the last four decades, the entire scenario of poultry farming has changed. Poultry is recognized as an organized and agro based industry with tremendous employment potential. Both large and small farmers have come up all over the country with highly specialised hybrid layers and broilers. At present 500 hatcheries have been established throughout the length and breath of the country to produce and supply commercial hybrid chicks.

The policy of government to achieve self reliance has favoured the establishment of pure line breeding programmes both in public and private sectors for development of genetically improved layers and broilers. Our country has also achieved a respectable measure of self sufficiency in manufacture of compounded poultry feeds, equipment and machines, pharmaceuticals and biologicals, etc. This includes research and human resource development. Major emphasis is being given on processing of poultry egg and meat and manufacture of value added egg and meat products. In India the traditional system of poultry keeping although loosing its importance from day to day under the impact of modernisation and industrialisation, is still prevalent in rural and tribal areas of country. Near about one lakh poultry farms with flock size ranging from 25-250 birds exist in rural areas most of which follow backyard open range system of poultry keeping. This area needs to be strengthen by introducing modern hybrid birds in place of indigenous native fowl and their crosses.

18.3 AGROFORESTRY

Taungya

Agroforestry is a collective name for land management systems involving positive interactions between trees, crops and/or animals on the same unit of land. It actually involves cycling of nutrients and flow of energy through various trophic levels interacting positively at higher ecological efficiency. Conservation of natural resourses and optimisation of productivity could be considered vital to its functioning. Agroforestry has been an age old practice in India, since modern agriculture evolved in forests. From the early *taungya* systems to scattered trees on farm lands, agrisilviculture, silvipasture, agrihorticulture, hortipasture, energy farms, farm boundary planting, aquaforestry, home garden, slash and burn agriculture etc. are various forms of agroforestry practised throughout India. All these systems are the result of human need and support to their livelihood. Of course, variations are there according to the necessity and resources available with the farmers. Most of these practices are seen in small farm holding where there is a need of diverse requirements for the farm family.

Agroforestry is a holistic concept that involves various organisms sharing habitat and its abiotic and biotic components. It is acknowledged as a potential technology for arresting land degradation, restoring production waste and improving the environment besides enriching the wood products for rural use and industry. Agroforestry reduces the farmers' dependency on forests even as it provides them economic benefits.

Trees can provide many products such as timber, fodder, fuelwood, medicines, and oils. It also helps to conserve soil, enhance soil fertility, and provide shelter belts for crops and fruit trees. Queries have been raised on the efficiency of this type of agriculture, especially regarding soil nutrients, their requirements by both the groups, i.e. trees and crops, and how they help each other. All plants compete with their neighbours to some degree for these vital resources. But they can also be helpful to each other. For instance, some trees have a light, thin canopy, which allows adequate light to filter through to crops below. Crops growing under them save soil moisture as the protection of the tree cover reduces their rate of evaporation. Many leguminous trees can fix nitrogen, enriching the soil. This benefits subsequent non-leguminous crops, which do not have this capability. Trees also improve the soil in other ways. Leaf litter decomposes and adds nutrients. Even the root systems release nutrients and improve soil structure when they decompose. Some trees capture nutrients lying too deep in the soil, and bring them to the surface and later return them to the soil as litter, which the crops utilize when it decomposes. Trees use nutrients and regain them through their recycling system. However, if leaves and branches are left on the ground to decompose and their nutrients are lost, the tree will have to be nourished with externally nutrients added as fertilizer or organic manure.

18.3.1 Strategic Options

Viable agroforestry options for different agro-ecozones have been identified and specific technology packages as strategic options are now available, *viz.* silvipastoral systems on dry degraded lands, agrihorticul -tural systems on rainfed marginal agricultural lands, agrisilvicultural practices involving different tree species in different areas. Highly adapted tree species have been identified for each agro-ecozone to encourage high productivity and diversify the products for use. Most important multipurpose trees for meeting these demands have been identified, *viz.* *Eucalyptus* hybrid, *Populus delfodes, Acacia* sp., *Dalbergia* sp. *Morus alba, Anthocephalus cadamba, Casuarina equisefifolia, Prosopis* sp., bamboos, *Grevillea robusfa, Leucaena leucocephala* etc. The popular agroforestry systems are as follows:

1. **Agri-silviculture system:** Under this system agricultural crops are intercropped with tree crops in the inter-space between the trees and can be grown profitably up to two years in "protective irrigated conditions while in rainfed up to 4 years whereas fodder crops can be grown up to longer duration. The aim of this system is to increase the overall yield of the land and solve the problem of shortage of food, fodder, fuel wood and timber. Agri-silviculture includes boundary plantation with Tad palm, trees, shrubs; scattered trees like Babul, Khejri etc. and allay cropping shrubs or trees alternated with crops with fixed width.

2. **Silvipasture system:** This system include growing of improve pasture species along with tree species. Tree species would be either for timber or fuel cum fodder. Grasses or grass-legume mixtures are grown along with tree species simultaneously on same unit of land. The typical example of this system is Kangayam tract of Tamil Nadu where *Acacia leucopholea* is being raised as intercrop. The tree canopy gives a better shade to the cattle and the pods become palatable feed to the cattle and sheep.

3. **Agri Horticulture system:** This system refers to growing of agricultural crops along with fruit trees, which can be continued up to 5 to 6 years or till the canopy of fruit trees become fully enclosed. If fruit trees are planted at a wider spacing agriculture can continue simultaneously.

4. **Silvi Horticultural system:** This system is like agisilviculture system and is based on the sustained yield. Tree species are managed to get timber, fuel wood etc. and horticulture crops are grown in between the inter-space. Horticulture crops provide additional benefit in the form of fruits and vegetables. Thus dual benefit is available to the farmers. Silvi horticulture system may vary with the nature of horticultural crops like silvihorti pome (with apple, peas), silvihorti other fruits (orange, lime and other citrus), silvihorti vegetables (with vegetables), silvihorti garden (with ornamental plants) etc.

5. **Silvi-horti-pastural system:** Under this system trees are grown along with fruit trees while grass and legume mixtures are raised in inter-space between trees. The three combination are based on the principle that each of its component draw nutrients from different layers of soil. For instance in the state of Karnataka, *Casuarina* was intercropped with fruit tree like Mandarin orange and the performance of orange was excellent compared to other trees like *Eucalyptus* and *Leucaena*. The incidence of pest and disease was also negligible on orange when grown with *Casuarina*. Likewise when *Leucaena* was intercropped with fruit tree Sapota *(Archrus sapota)* encouraging results were achieved. Thus there is a need to identify profitable agro-forestry stem. This system can solve the problem of wood, food, fodder and restoration of ecological balance. Further by adopting this system the unemployment problem can be reduced to some extent and the socio economic conditions of the farming community will be improved.

6. **Silvi-agri sericulture system:** This is a very complex system where crops or vegetables are grown along with tree species(basically host plants of silk worm). If the tree species is *Terminalia arjuna*, tasar silk worms are reared and the larval excreta acts as a good manure for the crops and silk is obtained as the end product. The pruned branches of tree species are used as fuel.

7. **Silvi-agri-lac culture system:** Under this system crops or vegetables are grown along with host plants of lac insect. On maturity of host plants lac insets are reared. Woody shrubs *Moghania macrophylla* is ideal host for lac insect and is suitable for incorporation in this system. This is very popular in Chotanagpur plateau of Bihar where farmers also grow fodder along with lac host plant.

8. **Silvi-agri-apiculture/Horti-silvi-agri-apiculture system:** This is a complex system and the idea is to manage the land in such a way that the production of flowers, crops and honey is concurrent. The trees and crops are judiciously selected so that the worker bees in the course of ramblings never miss to collect nectar and pollen. There should not be any shortage of flowers in the system. Farmers in this system collect fuel wood, timber, honey and agricultural crops from the same unit of land. In several parts of the North-East, citrus trees are grown and citrus honey is a priced commodity.

SAQ 4

Distinguish between agri-silvicultural and silvi pasture systems.

18.4 SOCIAL FORESTRY

Social forestry is very important for the upliftment of living standard of rural masses. It has often been describe as forestry of the people, by the people and for the people. Social forestry is an answer to the unprecedented pressure on our traditional forest reserves, which have been steadily depleted due to the removal of large quantities of fuel, fodder, small timber, fruit and other forest produce. In practical social forestry, trees are grown along road sides, rail tracks, canals, banks, sides of drainage channel, compounds and around the buildings, cremation grounds etc. around or near the society or people's habitation for producing fuel, fodder, forage, food, fibre, medicines, raw materials of cottage industries. This creates develops and maintains a favourable microclimate around inhabitation of people; provides shelter for livestock; and shelterbelt for condensation of hot wind as well as for wind break.
Several forestry related integrated programmes are being sponsored by government agencies and non-government organisations. Various integrated projects based on forestry, aim to maintain the balance between man and nature. They strive for an overall development of the area without causing a strain on nature and natural resources.

The primary objectives of these projects are:

- to maintain the delicate balance between man, nature and natural resources;
- to provide a renewable resource of fuel, fodder, timber and fruit for meeting the needs of the local population; and
- to uplift the living standards of the rural masses by energy saving devices, and animal health services.

In India the various social forestry and integrated forestry programmes undertaken in Jammu and Kashmir, Madhya Pradesh, Himachal Pradesh Uttar Pradesh include plantation of fuel wood and fodder species in forest lands lying in the vicinity of the villages; plantation of fuel wood, fodder and fruit trees on Panchayat /Community lands and degraded lands; distribution of seedlings to local farmers at highly subsidised rates; encouraging school children to plant trees, motivating local organisations such as Panchayats and Mahila mandals to actively participate in social forestry programmes.

Strengthening village institutions holds the key for successful promotion, management and utilization of social-forestry applications. Creating rural opportunities for value-addition of products and establishing mechanisms for efficient marketing is yet another activity that is vital to social-forestry adoption.

It is also important to link the farmers and industry through development of village-level institutions. Value-addition facilities, *viz.*, seasoning, grading, conversion and product diversification like, bamboo mat boards, panels, medicinal plant products etc. need to be created at village level to create employment opportunities and attract higher prices for the products. To give more impetus to this activity, it may be required to stop subsidy on government supply of raw materials to industry and impose duty on the import of pulp. It will also be important to continuously strive to up- grade planting material and identify newer species of trees for higher production. When social-forestry is viewed in its totality it is realized that certain legal and procedural frameworks require improvement to encourage its adoption.

SAQ 5

What is the need of social forestry?

18.5 PLANTATION CROP

The SAARC region is rich in plantation crops and with proper scientific management it can provide extra income to the rural masses that are still following traditional technologies. With new technologies available to utilize byproducts of plantation crops, progress of rural masses is not far off. Various plantation crops are discussed in following paragraphs.

18.5.1 Coconut

The coconut crop has considerable significance in national economy in view of its vast opportunities for employment and income generation. Major share of coconut production is contributed by millions of small and marginal farmers mostly in the coastal areas (Fig. 18.6). The important coconut growing states in India are Kerala, Tamil Nadu, Karnataka, Andhra Pradesh, Orissa, Maharashtra, Goa, Assam, Pondicherry, Lakshadweep, A&N Islands. It is mainly cultivated for the nuts from which 2 important products 'copra' and fibre are obtained. Copra yields oil and oil cake. The trunk of the mature palm is used as timber for houses and the leaves are used for thatching houses, fencing etc. The unopened spathe is tapped for toddy called 'neera'. Sweet toddy can be converted into jaggery and sugar, fermented toddy is a mild alcoholic drink and vinegar can be made from it. Water from tender coconut is a refreshing drink. In kerela the extraction of coir from the husk of nuts and the manufacture of coir products provides employment for thousands of people. The coconut shell is largely used for fuel and for the production of charcoal. The shell flour is used as a filler for plastics. Thus every part of the crop is useful in one way or the other.

Fig.18.6: Products from the Coconut Tree

18.5.2 Arecanut or Betelnut

It is an extensively cultivated tropical palm and the nuts of which form a popular masticatory in India, Middle east, and Far East. India produces annually 150,000 tonnes of arecanut from an area of 18,34,000ha. It is a tall stemmed erect palm, reaching varied heights, depending upon the environmental conditions (Fig. 18.7). Palms attaining a height of 30 metres are not uncommon. Arecanut is consumed both as a raw/ripe nut (adaka or Kacha tamul) as dried ripe nut (chali supari) and as semi-mature cut and processed varieties 'Batoldike" or 'Kalipak'. There are over 150 trade types, differing in maturity, processing conditions and varying in their taste characteristics as per market conditions prevailing at different centres of the country. The drying of the whole fruits for making chali supari requires up to 40 to 45 days of good sunshine, so as to get a moisture level of about 10 per cent. Drying ripe nuts on cement floors reduce fungal infection of the nuts to a minimum level of about 5 per cent. A drier designed recently has been found to be most suitable to produce good quality chali supari. The cup shaped nuts are prepared by boiling tender arecanuts after husking and cutting into halves. An important by-product is the husk of the nuts which can be utilized for making boards, paper etc. The spathe covering the infloroscence and the leaf sheath can be used for making caps and for packing. The palm trunk is a useful building material.

Fig.18.7: Arecanut plantation

18.5.3 Cashewnut

India occupies a premier position contributing about 43% of the cashewnut production. India is the largest producer and exporter of cashewnut. The maximum production of raw cashewnut was 5.2 lakh tonnes obtained from an area of 6.86 lakh ha. during 1999-2000. This production is hardly sufficient to meet 50% of the demand of about 825 cashew-processing units in the country. The average demand growth rate for kernels for export and internal consumption is around 13% per annum. The demand of the industry is about one million tonnes of raw cashewnut. Cashewnut is grown over 0.635 million ha today with an average productivity 658 kg/ha.

18.5.4 Cacao

The cacao plant is a perennial dicotyledonous plant which has been under cultivation since pre-historic times. The centre of origin has been placed in the tropical forests of the Amazon Valley in South America. It is now extensively grown in the continents of Africa, Asia, South America and in parts of North America. The annual export earnings from cocoa is to the tune Rs. 9 crores. (Compared to the global production of 29 lakh MT, the Indian contribution is insignificant.) To fill the gap between the production and requirement, intensive programme for production need to be initiated. The fruit is a berry containing 20 to 40 seeds each surrounded by a pulp which is a transformation of the outer integument of the ovule (Fig. 18.8). The outer cells release a highly mucilaginous substance at full growth and are one reason for preventing fermentation of beans after harvesting.

In coconut plantations spaced at about 7.5 metres cacao may be planted either in a single row alternating with coconut or in double rows in triangular positions between the rows of coconut. This crop combination of cacao and coconut has synergistic effect on the yield of both the crops.

Fig. 18.8: Cacao pods

18.5.5 Rubber

Natural rubber is found in the latex of as many as 895 species of plants belonging to 311 genera of 79 families. Of these *Hevea brasiliensis* (Euphorbiacacae), the para rubber tree is the most important source of rubber. The tree is now grown in the tropical regions of Asia, Africa, America. It is a hardy, quick growing tree with a ight trunk producing branches 3-5 m above the ground and forming a spreading opy (Fig. 18. 9). The optimum ecological requirements consist of a fairly ributed rainfall not less than 200 cm, a warm humid climate (21 to 35°C) and a ll-drained deep loamy soil. It flourishes from the sea level up to altitudes of)-600 m. Others are glaziovii (Euphorbiacaeae), *Ficus elastica* (Moracaeae), *rthenium argentatum* and *taraxacum kok-saghyz* (Compositae). Many other species h as *Euphorbia intisy* (Euphorbiacaeae), *Cryptostegia grandiflora*, and *landolphia* have been tried as possible minor sources of natural rubber. *Hevea brasiliensis* is a ive of Brazil and was introduced in tropical Asia in 1876 through the Kew Gardens igland).

.5.6 Tea

ı (*Camellia* spp.) is made from the tender or young leaves and unopened buds of evergreen tea-plant, popular as a 'healthful herb'. The important tea growing ıntries are: India, Sri Lanka, East Africa, Japan, Indonesia, Bangladesh, China, orgia and Argentina. The leading tea growing states of India are: Assam, West ngal, Kerala, Karnataka and Tamil Nadu, and to some extent in Tripura and nachal Pradesh. In India tea is grown in about 3,58,000 hectares and over 468 llion kilograms of product is obtained annually. Over one million workers are ployed by the tea industries. Two distinct varieties of tea-plant are generally ognised, the small-leaved China (sinensis) and the large-leaved Assam (assamica). e tea-plant, in the natural state grows into a small or medium-sized tree, but in nmercial plantations it is pruned and trained to form a many-branched low bush l is encouraged to produce vigorous vegetative growth by adopting an appropriate ıedule of fertilizer applications (Fig. 18.9).

Fig.18.9: Tea gardens in Assam

offee: India earns considerable foreign exchange by producing 85,000 to 100,000 nnes of coffee. Arabica (*Coffee arabica*) and robusta (*Coffee canephora*) are the two incipal species of coffee which are extensively cultivated in our country. The major ffee growing states in India are Karnataka, Tamil Nadu, Kerala and Andhra adesh. While on a limited scale it is also grown in some part of Orissa, West engal, Assam and Madhya Pradesh.

The cultivation of coffee is mainly confined to the hilly areas of the Western and Eastern Ghats where annual rainfall ranges from 1250 to 3000mm.Coffee plant grows well at temperatures between 12 and 36 °C and the elevation above the sea level influences the quality of the coffee.

18.6 HERBAL AND MEDICINAL PLANTS

Problems arising out of rapid genetic loss of medicinal plants forced the need for international co-operation and co-ordination to undertake programmes for conservation of medicinal plants to ensure that adequate quantities are available for future generations. Cultivation of medicinal and aromatic species gives scope to continue the supply of quality drugs for future generation. Merits of commercial cultivation of medicinal and aromatic plants is the outcome of implementation of number of critical factors like location selection; good and genetically stable planting materials; good agro-technological practices; nutrient input; harvesting management and implementation of suitable post harvesting techniques to preserve the end product till smart and effective marketing arrangements are made. There is a growing demand today for plant-based medicines, health products, pharmaceuticals, food supplements, cosmetics etc. in the international market. The international market of medicinal plants is over 60 billion US dollar per year, which is growing at the rate of 7 percent per annum. WHO's forecast is that the global market for herbal products is expected to be US$ 5 Trillion by 2050. Herbal remedies would become increasingly important as people seek natural remedies and gentler, safer products to deal with the prevention of ill health and the promotion of good health. India, with its rich biodiversity has tremendous potential and a natural advantage in this emerging area.

The Indian Scenario

India is one of the world's 12 leading biodiversity centres, encompassing 16 different agro-climatic zones, 10 vegetation zones, 25 biotic provinces and about 426 habitats of specific species. It has been estimated that about 45,000 plant species (nearly 20 per cent of the global species) occur in the Indian Sub-continent. About 3,500 species of both higher and lower plant groups are of medicinal values. More than 80 per cent of medicinal and aromatic plants are collected from 17 million hectares of Indian forest land. However, many of these, due to over-exploitation have become rare (*Rheum emodi, Aconitum deinorrhizum*), threatened (*Rauvolfia serpentina, Berberis artistata*), or endangered ones (*Sassurea lappa, Dioscorea deltoidea*). The present export of herbal raw materials and medicines from India is approximately about US dollar 100-114 million per year. India is one of the major exporter of crude drugs mainly to six developed countries viz. USA, Germany, France, Switzerland, U.K. and Japan, who share amongst them 75-80 per cent of the total export market.

The scope of herbal industry in India is enormous. Although this is good but the lack of sustainable harvesting methods is raising concerns for the future of many valuable medicinal plant species. The medicinal properties of most medicinal plants exist in the root, which means that when they are harvested in the wild, the whole plant, including its root, is pulled out the ground and it cannot grow again the following year. It is because of this, and the growing demand for these herbs from both domestic and foreign markets, that many medicinal plants are being over-harvested and threatened in their natural habitat. The long-term availability of medicinal plants is of vital importance, not just for the herb-collectors who depend on it to earn a living, but also for the future of India's traditional system of medicine, ayurveda, which is rapidly growing in popularity both in India and abroad. Conservation of these plants is therefore of utmost importance.

Out of 45000 different plant species and 15000 medicinal plants, 7000 plants are used in Ayurveda, 700 in Unani medicine, 600 in Siddha medicine, 450 in Homoeopathy d 30 in modern medicine. The Indian Systems of Medicine have identified 1500 edicinal plants, of which 500 species are commonly used in the preparation of lian Systems of Medicine and herbal drugs. More than 150 plant species have been tegorised as endangered. The medicinal plants sector at present is not well organised d needs special attention. Although different Ministries and Departments in the overnment sector, NGOs and individuals in the private sector are making efforts in fferent directions, yet there is a need to co-ordinate and systematise these efforts. An propriate mechanism for coordination and implementation of policies relating to edicinal plants both at the National and State levels is necessary to facilitate inter-inistry, inter-state and inter-institutional collaboration to avoid duplication of efforts. ierefore, a need for the establishment of a national level nodal body was felt to rmulate policies for the medicinal plants sector and develop the potential of this ctor through schemes and projects that encourage investment in this sector.

dia is bestowed with a treasure of medicinal plants. The supply base of 90% herbal w drugs used in the manufacture of Ayurveda, Siddha, Unani & Homoeopathy stems of medicine is largely from the wild. Besides this, plants are also used in rious industries producing herbal items other than medicines (Table 3). This wild urce is speedily shrinking day-by-day. Therefore, there is a need for conservation id sustainable use of medicinal plants. Cultivation is clearly a sustainable alternative the present collection of medicinal plants from the wild. This can be a potential ovider of returns to the farmers/cultivators

Table 18.3: List of important medicinal plants along with their utilisation

S.No	Common name	Botanical name	Plant part and usage
1.	Amaltas	*Cassia fistula*	Fruit pulp- Purgative, laxative
2.	Amrita	*Tinospora cordifolia*	Stem- Dyspepsia, fever, urinary diseases, antipyretic
3.	Arni	*Premna latifolia*	Whole plant- Internally and externally dropsy, diuretic
4.	Ashwagandha	*Withania somnifera*	Roots- Cough, dropsy, rheumatism, tonic, astrigent, nerve sedative, gives glow to skin, removes excessive water from tissues rejuvenating
5.	Ati bala	*Abutilon indicum*	All parts- Urinary trouble, lumbago, diuretic, nervous tonic, anti-pyretic
6.	Bala	*Sida cordifolia*	Seed & root- Diuretic and tonic
7.	Bel	*Aegle marmelous*	fruit and all- Digestive and stomachic parts
8.	Gangeran	*Grewia tenax*	All parts- Heart diseases, diuretic, nervous diseases, tonic
9.	Ghrit kumari	*Aloe vera*	Leaves- Cosmetics, glycosides anti-irritant, anti-aging, soothings
10.	Gokhru-big	*Pedatum murex*	Fruit- Diuretic and tonic purpose and other diseases of urino-genital systems
11.	Gokhru - small	*Tribulus terrestris*	Fruit and all parts- Tonic, diuretic
12.	Gugulu	*Commiphora wightii*	Resin- Perfumery, muscular rheumatism
13.	Hingota	*Balanites roxburghii*	Fruit and bark - Whooping cough and skin trouble, bark anthelmintic, family planning

14.	Indrayan	*Citrullus colocinthis*	Fruit & root- Purgative, used in ascites, jaundice, rhematism & urinary troubles
15.	Isabgol	*Plantago ovata*	Seed & seed husk- Affections of kidney, bladder & urethra, ice-cream industries, substitute of Agar-Agar
16.	Jeevanti	*Leptidinea reticulata*	Whole plant- Tonic, increases milk yield
17.	Kasondhari	*Cassia occidentalis*	All parts- Purgative, for skin care
18.	Khari-Jal	*Salvadora persica*	Seed & root- Purgative, diuretic, cosmetic, dental care
19.	Kounch	*Mucuna pruriens*	Seeds- Disease of nervous system, sex power, dropsy
20.	Mehndi or Heena	*Lawsonia inermis*	Leaves & seeds- For colouring hands, antiseptic, sunscreen agent, astringent, improves skin hydration, hair conditioner
21.	Neel	*Indigofera tinctoria*	Leaves- Extract used in epilepsy and other nervous disorders
22.	Neem	*Azadirachta indica*	All parts- Skin trouble, antiseptic, laxative, insect killer, antiseptic
23.	Raasna	*Pluchea lanceolata*	Whole plant- Arthritis, constipation and respiratory diseases
24.	Safed-musli	*Chlorophytum borivillianum*	Roots - Tonic
25.	Sankhapushpi	*Evolvulus Asinoides*	Whole plant- Brain tonic, hair care
26.	Semul-musli	*Bombax malabaricum*	Roots- Tonic
27.	Senna or Sonamukhi	*Cassia angustifolia*	Leaves & pods- Laxative and purgative
28.	Sharpunkha	*Tephrosia purpurea*	Whole plant- Laxative, diuretic, bronchitis, liver diseases
29.	Shatavari	*Asparagus racemosus*	Root- Herbal tonic, diuretic used in nervous and rheumatic complaints
30.	Solai gugul	*Boswellia serata*	Resin- Diuretic, stomachic
31.	Utangan	*Blepharis edulis*	Seeds- Aphrodissiac, purgative, disorder of liver, asthama, diuretic

18.7 AGRI-PROCESSING

India is bestowed with a wide range of climate prevailing in its states, which enable the production of all sorts of fruits and vegetables. India stands second in vegetable and fruit production but consumers still feel its dearth because of inadequate availability throughout the year.

The total food production in India is likely to double in the next ten years and with the increase in agricultural produce in the region there is an opportunity for large investments in the areas of food processing. Specialty processing, packaging, frozen food/refrigeration and thermo-processing of fruits and vegetables, fish and fish products, milk and milk products, meat and poultry, alcoholic beverages and soft drinks, and grains are important sub-sectors of the food processing industry. Although there are a number of avenues in food processing sector, preservation of horticultural products like fruits and vegetables is highly emphasized.

In spite of abundant production the lack of infra-structural facilities results in the poor quality produce and heavy post-harvest losses and farmers are likely to get price even lower than the production cost in glut season. So, the only way to make profit and make available the products round the year there is a need of agri-processing or preserving the products with suitable methods. This will not only enable farmers to sweep extra good profit but the consumers will also get their required quality products irrespective of the crop season.

Horticulture has been identified as a thrust area for development from agri-processing point of view. A sturdy infrastructure for post-harvest facilities designed to minimize post-harvest losses and ensuring a steady supply of quality harvest produce is on the way. Special incentives are envisaged for export-oriented production with an eye not only on foreign-exchange earnings but also on a growing quality consciousness. Though the modern knowledge in food processing has advanced enormously incorporating extrusion technology, membrane processes, aseptic packaging, microwave heating, supercritical fluid extraction, biotechnology and rapid techniques of monitoring food quality and safety.

18.7.1 Food Preservation Methods

Food preservation methods are employed to check microbial, chemical and enzymic spoilage of fruits, vegetables and other food products.

Low temperature preservation: Cooling, freezing, chilling slows down the microbial growth. Cooling below ambient temperatures slows the rate of all chemical and biological reactions and helps in retaining the nutritional value of food products.

Chilling:

Chilling temperature in range of -1 to $+8^0$C is beneficial for preservation of various products. Some examples are:
Fresh meat and fish at -1 to $+1$°C
Milk at 0-5°C
Butter, margarine and cheeses at 5-8°C

Freezing:
Freezing in the range of -18 to -35°C is useful for:
Domestic freezer (-18°C)
Freezing of water into ice crystals
Food can be stored for more than one year with minimal loss of nutrients.

High temperature preservation: High ambient temperature predisposes food products by changing their biological value, contamination by micro-ogranisms, accelerating enzymetic activity and cooked flavour.

Various heating processes are:

Blanching inactivates enzymes in vegetables and fruits (prevent browning of peeled potatoes), reduces the level of surface micro-organism and leaching (loss) of water soluble vitamins (10-20% of Vit C), minerals and sugars.

Pasteurisation carried out by heating at 63-65°C for 30 mins. or 73-80°C for 5-16 Sec. kills all the pathogens and more than 99% of other micro-organisms and food remains safe to consume. It also extend shelf life to several days (milk), few weeks (fruit juices) or months (bottled fruit, canned beer) and nutrient losses are minimal (e.g. 25% vit C and 10% thiamine, vit B6, B12 and folacin losses in milk).

Sterilisation is carried out for canned food in temperature excess of 100°C (usually 115°C or above). It kills bacterial vegetative cells and spores including the most heat resistant spores of *Clostridium botulinum* and increases storage life for several years. However, under sterilisation hydrolysis of carbohydrates, lipids and proteins takes place. In addition losses of amino acids and thermal destruction of vitamins 20-50% losses of carotene in vegetables, 80% losses of vit C, 70% loss of thiamine, 100% loss of riboflavin, 6-9% lowering of protein biological value also takes place. Sterilisation improves keeping quality and convenience outweighs the losses.

Ultra High Temperature (135-140°C for few seconds) is carried out to produce commercially sterile milk and milk products. It facilitates storage life to several months without refrigeration.

Preservation by drying: Drying helps in removal of moisture from food and prevents the growth of microbes, long storage life, easy to handle and use. Various drying techniques include: Liquid drying (Spray drying, roller/drum drying, freeze drying) and Solid drying (Hot air drying, freeze drying, solar drying).

Preservation with salt, sugar, and other chemicals: Salt, sugar, sucrose, sodium metabisulphite create an environment unsuitable for microbial growth and other chemical changes such as browning. More than 70% sucrose is used in preserving fruits (jams, marmalade, sweetened condensed milk etc.). Different chemicals are used in preserving food stuffs are: *Sulphites-fruit* juices, dried fruits, raw prawns, dried vegetables, *Sorbic acid- fruit* juice, Benzoic acid- fruit juice, *Sodium nitrite-* cured/salted meat, Methylparaben- food colours, Propionic acid cakes etc. Chemical preservatives alone do not confer long storage, usually employed in conjunction with other methods such as pasteurisation, drying etc.

Fermentation and pickling checks the growth of bacteria, yeast and moulds, increase food diversity by changing product characteristics i.e. colour, nutrient content, composition, digestibility, taste and texture.

Technology development in agro-processing

In recent years some very important technologies have been developed in the field of agro-processing which are being exploited at the commercial level, for the following:

- Essential oils from citrus fruits
- Dehydrated products from grapes. pomegranate, mango, apricot etc
- fruit wines
- Various products of indigenous fruits such as *jamun. phalsa,* bael, aonla etc
- Baby foods
- Extraction of Pectin from citrus and mango waste.
- Corrugated fibre board boxes for fruits and vegetables packaging
- Tamarind juice concentrate
- Fruit toffees
- Instant pickles
- Papain form papaya.
- Reduction of losses by pre-harvest spray of $CaCl_2$, fungicides and growth regulators
- Standardization of maturity of many fruits and vegetables for better shelf - life and quality
- Zero energy cool chamber for on-farm storage of fruits and vegetables
- Development of whole tomato concentrate for culinary purpose
- Storage of pulps in flexible pouches
- Use of apple juice concentrate for canning of peach halves
- Techniques for preservation of vegetables and raw mango slices by steeping techniques using food additives

18.8 SUMMARY

In this unit you have studied:

- 'Alternative agriculture' is a broad range of agricultural systems that are alternatives to present common practices and provides an opportunity to increase