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 eco-compatible, have the potential to fulfill the social demands and are suitable for various agro-geo-climatic 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 eco-friendly 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 dassification 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.

11.2.2 Land Grading

Any land used for agriculture requires an even surface for crop production. Land grading refers to levelling the land to make it suitable for agricultural purposes. Not only that, this also helps in efficient use, and conservation of the various agri-resources in the long run.

Land grading is often done by equipments operated with either animal power or with mechanical power. This process removes humps and depressions so that water could flow evenly on the land surface. Low spots could cause concentration of water or waterlogging which affects the crop growth.

Land levelling need not necessarily mean to bring the surface to perfect level. Many a time a moderate grade or slight slope is created for surface drainage. Depending on the topography of the agricultural land, land levelling requires moving a lot of soil, sometimes over large distances.

Land grading in irrigated-agriculture helps in uniform application of water, better water regulation and saving in irrigation time. Under rainfed conditions, land grading helps in soil and water conservation. Both in irrigated and rainfed conditions, land grading provides the much-needed surface drainage, thus proving a valuable management tool.

SAQ 1

a) Identify a set of criteria for deciding about the best use that a piece of land can be put to.

b) What features/characteristics of a land/soil would you consider to use it for agricultural purposes?

c) What are the benefits of land grading in agriculture?

11.2.3 Salt-laden Soils and Water

High concentration of certain salts when present in the soil cause soil and water management problems, and ultimately affects the crop growth.

High concentration of soluble salts increases solute suction and thus reduces 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.

Most of the salt affected soils are found in the arid and subarid regions of the world. Some soils have salts as original deposits. In irrigated agriculture, even though to start with the water may be of satisfactory quality, salt build-up in the root profile invariably occurs over a period of time. This is because during crop growth water evaporates leaving behind the salts in the root zone. High water table in some agricultural lands bring the salts to or nearer the soils surface. The groundwater too in some agricultural lands contains large amounts of salts and the use of such waters for irrigation, accelerates salt build-up in the soil profiles. Salt could also be brought in through subsurface inflows of water. In irrigated areas, particularly if the irrigated water contains considerable amount of salts, its concentration in soils should be annually assessed and it should be ensured that the salts accumulated in the root zone are not beyond the permissible limits for the crop. The excessive salts in soil solution can be removed by leaching and subsequent drainage. And the salts held by clay as exchangeable 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.

Reclamation of Salt-affected Soils

You have learnt in Unit 6 that salt-affected soils are categorized as **saline**, **sodic** and **saline-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 **efflorescence 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, Sugar beet, Date palm, 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, and 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 sem iarid areas. The salient measures include:

i) Vegetation-based measures;
ii) Tillage practices; and
iii) Structural or mechanical methods.

Features considered for design and construction of wind breaks or shelter beds:
- direction,
- location,
- species selection,
- shape,
- protection measures, and
- casuality replacement.

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* consist 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

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 are 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.

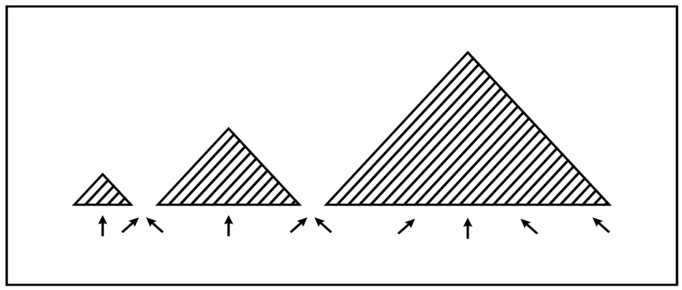

Fig.11.1: Cross section of different lengths of shelter-beds. Note the areas protected by each one of them. (Source: Murthy V.V.N., 1985)

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.

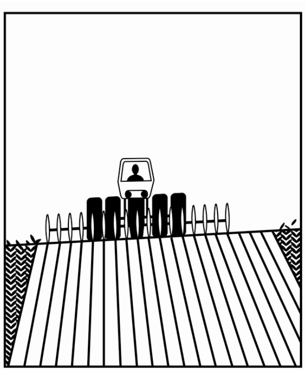

Fig.11.2: Diagrammatic representation of strip cropping

iii) Structural or mechanical methods – Barriers like fences, walls and stone packings also serve as wind breaks. These types 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 need to be looked at 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.

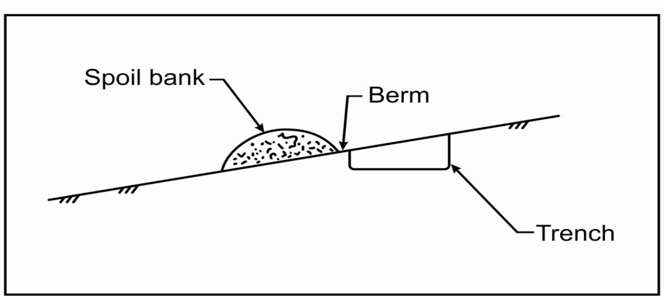

Fig.11.3: Cross section of a contour trench

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.

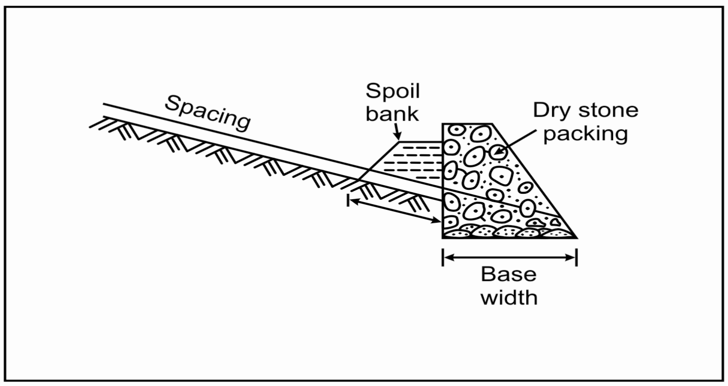

Fig.11.4: Stone terrace as seen in cross section

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 helps 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.

All the soil and water conservation measures dealt earlier in the unit, are applicable to dry farming as well. The most important factor in dry farming is conservation of moisture for proper and timely utilization by crops. In order to select suitable dry farming practices in an area, a thorough study of climatic conditions, adaptable crops, nature of soil, and topography of the area is essential. The recommended practices may be broadly grouped as : i) crop management; and ii) land management practices.

i) *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; sub soiling; 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 infiltrating 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 are 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.

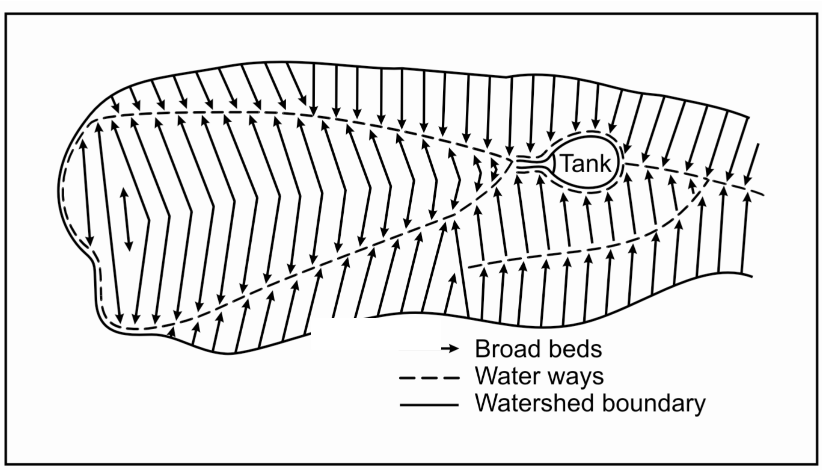

Fig.11.5: Layout of beds and collection system for soil and water conservation purposes.

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.

- 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 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:

Farm
storir
seaso
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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 requires 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.

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.

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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, is 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.

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.

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 are 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.

Application of irrigation water: Efficient utilization 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.

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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.

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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 has blocked the natural surface drainage in several places aggravating the drainage problem. Continued irrigation over a 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 ar e 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 pip es 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.

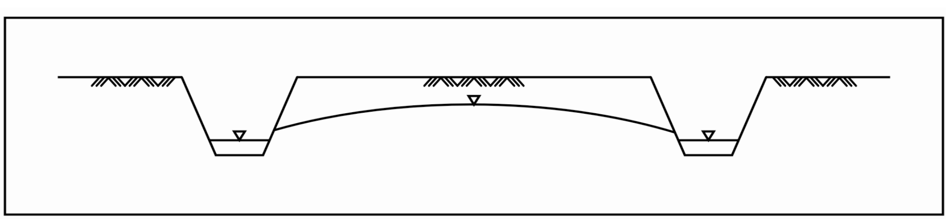
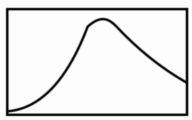
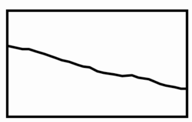
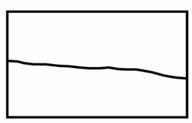
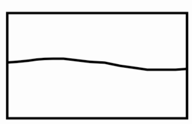
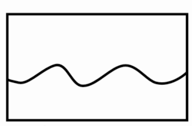
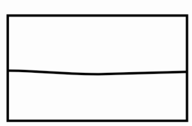
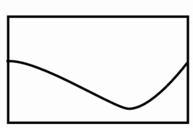
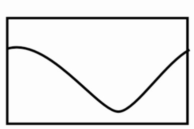


Fig.11.6: Deep drains of subsurface drainage and water table control.

v) *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.

With this we end our discussion on management of water resources. In Table 11.2, we summarize various land management practices suitable for different kinds of land with varying water management problems.

Table 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 have 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 has cut down considerably the amount of wood used.

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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.

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 types of equipment. Even electricity can be generated from biogas. The cost involved is

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.

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.

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.

One very important and practical aspect of energy conservation could be – a *change in consumption patterns*, i.e., to *consume less animal proteins*.This diet modification would reduce energy expenditures and increase food supplies because less edible grains would be fed to livestock to produce costly animal proteins. The average yield from 10 kg of plant proteins fed to animals is only 1 kg of animal proteins. Viewing this relationship on a large scale, say a hundred million tonnes of grains that are fed to livestock, are consumed directly as human food, about 400 million more people could be sustained on this grains-stock for one year. Bringing in such a change is a slow process, because people all over are accustomed to their social and religious beliefs and conditioning, as well as have developed personal preferences for food over the years. Nevertheless, it is an important dimension of feeding the ever increasing number of people in an energy efficient manner.

SAQ 4

a) What considerations are important for deciding about dry farming practices of an area?

b) Name the water sources that are tapped for meeting with the moisture requirements in an agricultural area familiar to you.

c) List, and write the main features of the common types of irrigation.

d) Differentiate between surface and subsurface drainage in a farm situation.

e) List the various ener gy conservation oppurtunities during crop production.

11.3 NUTRIENT MANAGEMENT

All agricultural systems whether crop-, or animal-based, involve removal or loss of nutrients from the land through their harvested produce. Grazing animals remove less than crops, for although their intake can be high, most of the nutrients are returned to the land through their faeces and urine. The removal in crops depends on the total yield, the part of the crop that is removed in the harvest, and the particular crop that is grown. Table 11.3 gives some such typical amounts.

Table 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
Wheat grain	5	100	20	28	8	3	8
Wheat straw	5	35	4	40	5	18	5
Maize grain	5	100	20	30	5	10	8
Maize straw	5	50	10	60	8	10	10
Rice grain	5	90	20	25	8	5	1
Rice straw	5	20	5	50	5	15	8
Ryegrass hay	10	160	30	180	12	40	12

Note: The values in the table, which are from various sources, give only the order of magnitude because nutrient removal varies with the crop variety, and depends on the amount of the nutrients supplied.

Nutrients are also lost by erosion, surface-run-off, leaching, gaseous loss, and by burning of vegetation. If there is no replacement of nutrients, the crop yields decrease. 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 nutrients 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 partic les (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.

11.3.3 Restoring Soil Fertility

Maintenance and improvement of soil fertility is the key to raising crop production. From the above discussion it is clear that factors like soil pH, nutrient status govern the health and fertility of soils. The declining soil fertility due to problems like soil acidity or nutrient impoverishment can be restored by application of lime and fertilizers. How much of lime and fertilizers would be necessary for the best plant growth can be determined accurately by soil testing.

Determining nutrient needs of soils – A soil test measures soil pH and the amounts of available nutrients the soil contains. By knowing the amounts of nutrients already present in the soil, it is much easier to determine the kinds of fertilizers to apply. Most of the fertilizer related problems are associated with the improper use of fertilizers. A crucial aspect of soil testing is the way the soil sample is collected. The sample should represent the total area in which fertilisers or other agro-inputs are to be applied. A large composite sample should be collected consisting of small portions of soil taken from different locations. These samples be placed in a clean container and thoroughly mixed before sending for analysis. In addition to soil testing, foliar symptoms of crops also indicate the nutrient status in soil. These two aspects, if used in conjunction can give an accurate nutrient picture of the field, for deciding – i) The appropriate method of supplying nutrients or taking any remedial measures, ii) the source, and iii) timing of application.

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- *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 mobilising organisms, and *Azolla.* These are low cost, effective and renewable sources of plant nutrients and are used to supplement the chemical fertilizers. Biofertilizers thus refer to biologically active products, and selective strains of microorganisms which can contribute nutrients to plants. The suitable strains of microorganisms may also be used for decomposition of organic wastes for use as organic manure in agriculture.

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:

Glomus deserticola was used. For more details you may log on to : http://www.hinduonnet.com, of September 5, 2003. Title of the article is -'Improving quality of grapevine with biofertilizers.'

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.

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 agro-biodiversity 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 imparts stability to the agrolandscape or the agroecosystem. Many local populations have historically managed biodiversity, and such 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 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 transgenic 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?

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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.