17.3 Soil conservation: prevention of water erosion

Previously, *soil conservation* referred mainly to the prevention and control of erosion. Today, however, the approach is broader, and includes the determination of proper land use, maintenance of soil fertility, conservation of cultivated land, rehabilitation of eroded land, and protection of land from all kinds of degradation. Bennett (1955:116) defines soil conservation as "the use of land within limits of economic practicability according to its capabilities and its needs in order to keep it permanently productive." All the measures required to achieve permanent productivity of the soil constitute the tools of conservation whether used singly or in various combinations. Soil conservation is thus a system of husbandry which aims at getting maximum production from the land on a sustained basis without damaging it in any way. The main difference between the approaches of agricultural husbandry and soil conservation is that the former aims at maximum production from the land for the present without regard to the future, whereas the latter aims at sustained production.

17.3.1 Principles of soil conservation

The following are some basic principles of soil conservation.

1. Use land according to its capability. This is the most important single factor for the success of soil conservation efforts, as misuse of land is the main cause of erosion. It is a common practice to bring even steeply sloping land under cultivation. The modern approach requires that after a survey of the soil a scientific inventory of the land be prepared. Conservation plans should then be prepared in which the appropriate use and treatment for each piece of land are specified.

Generally speaking, only level to nearly level (0–2% slope) and gently sloping lands (2–5% slope) should be cultivated. Marginal lands with steep slopes should be brought under range crops or forests. Gullied lands and those with even steeper slopes are more suitable for tree plantation.

2. Retain rainwater. Rainwater should be retained as close as possible to where it falls, so as to make the best use of precipitation and minimize potential runoff effects. However, it may not always be possible for all the rainwater to be absorbed into the soil. In high rainfall areas the amount of water usually exceeds the absorptive capacity of the soil, so that the excess must be disposed of safely.

Rainwater can best be retained in the soil in the following ways.

a. The soil surface can be kept covered by cultivated crops or vegetation, particularly during the rainy season.

b. Fields should be kept loose to allow maximum infiltration of rainwater when the fields are fallow.

c. The flow of surface water down a slope can be regulated by constructing field embankments and terraces or by reducing the size of the fields.

d. A proper system needs to be provided for the safe disposal of runoff water, since most of the rains during summer are erratic and of high intensity. This will reduce immediate damage by heavy rains.

3. Minimize runoff. The practices adopted on both arable and non-arable lands should be such as to minimize runoff and maximize retention of rainwater.

4. Store surplus water. Surplus water should be stored in dams or other reservoirs. This water can then be used later for supplemental irrigation, livestock, or other purposes.

5. Maintain soil fertility. Soil fertility should be maintained at a level which can support sustained crop production.

6. Use non-arable lands effectively. Non-cultivable lands, or those damaged by erosion should preferably be brought under forest.

17.3.2 Soil conservation practices

Specific applications of land and water management knowledge with the goal of protecting soil resources from exploitation, destruction, or neglect are called soil conservation **practices**. Soil conservation measures are highly site-specific and depend upon land use pattern, soil characteristics, topographic conditions, rainfall patterns, and potential erosion hazards. In order to determine proper land use and appropriate soil practices a land capability/erosion survey should be carried out.

Soil conservation practices can be classified into soil management, crop management, engineering, range management, and forestry operations. Land management refers to the proper use of land, and crop management pertains to selection of crops, tillage practices, and cultural operations. These two management approaches are complementary: land management is fundamental to crop management. For convenience in applying technology in the field, practices are grouped into those appropriate for arable lands and those appropriate for non-arable lands.

17.3.3 Conservation of arable lands

The cultivable area at our disposal is limited, as out of a total of 31.71 mha at present potentially cultivable land (cultivated land + culturable waste), 20.61 mha are already under cultivation (Government of Pakistan 1993:109). The ever increasing demand for food and raw materials for human and industrial consumption can be met only by increasing cropped area, improving crop yields, or both. It is, therefore, imperative that the cultivated area should be managed in such a way that it remains productive on a sustained basis. The conservation of cultivated area should aim at reduction in the quantity and velocity of runoff, and its safe disposal. This can be achieved by adopting the following practices.

1. Maintaining crop cover. Soil is the biggest storehouse of water. Soils vary widely in the degree to which they allow infiltration of water and the degree to which they retain it. Although these characteristics depend upon inherent soil properties, they can be improved by appropriate soil and crop management practices. Efforts should be made to maintain crop cover on the soil surface during the monsoon. If soils are to be left fallow, they should be ploughed across the slope before the onset of the rainy season and occasionally thereafter. This practice is especially important where the slope is more than 2 percent. Shafique et al. (1988) observed that runoff was highest under bare soil conditions, and that crop cover reduced the runoff significantly. Based on data for three years, it was found that the runoff under crop cover was reduced by 20, 22, and 25% with minimum precipitation and 19, 16, and 9 percent with maximum precipitation from that of bare soil conditions under 1, 5, and 10 percent surface gradients, respectively (Table 17.1).

Table 17.1 Mean annual rainfall, rainfall intensity, and runoff under different surface gradients and crop cover conditions, 1984–86.

			RUNOFF (%)					
			Slope 1%		*Slope 5%*		*Slope 10%*	
	Rainfall (mm)	Rainfall intensity (mm/h)	Fallow	Crop	Fallow	Crop	Fallow	Crop
Minimum	8.0	3.0	5.0	4.0	9.0	7.0	12.0	9.0
Maximum	141.0	85.0	62.0	50.0	64.0	54.0	71.0	65.0

Source: Shafique et al. (1988). Data collected at PARC Experiment Station near Fateh Jang.

2. Field embankments. The practice of constructing field embankments (Fig. 17.4) is called *wat bandi* in Panjabi. The boundaries of the fields are raised to a height of 15–50 cm depending upon the rainfall and the slope of the land. In low rainfall areas like Khushab, Mianwali, and Dera Ghazi Khan districts, the field boundaries may be raised as much as 50 cm in order to allow maximum absorption of rainwater into the soil.

3. Tillage to an appropriate depth. It is a common practice, unfortunately, to plough too shallowly and down the slope. Such incorrect ploughing practices reduce moisture retention and accelerate erosion. In the barani tracts of our country there are several different types of soils, which vary widely in their response to tillage operations. It is therefore essential that

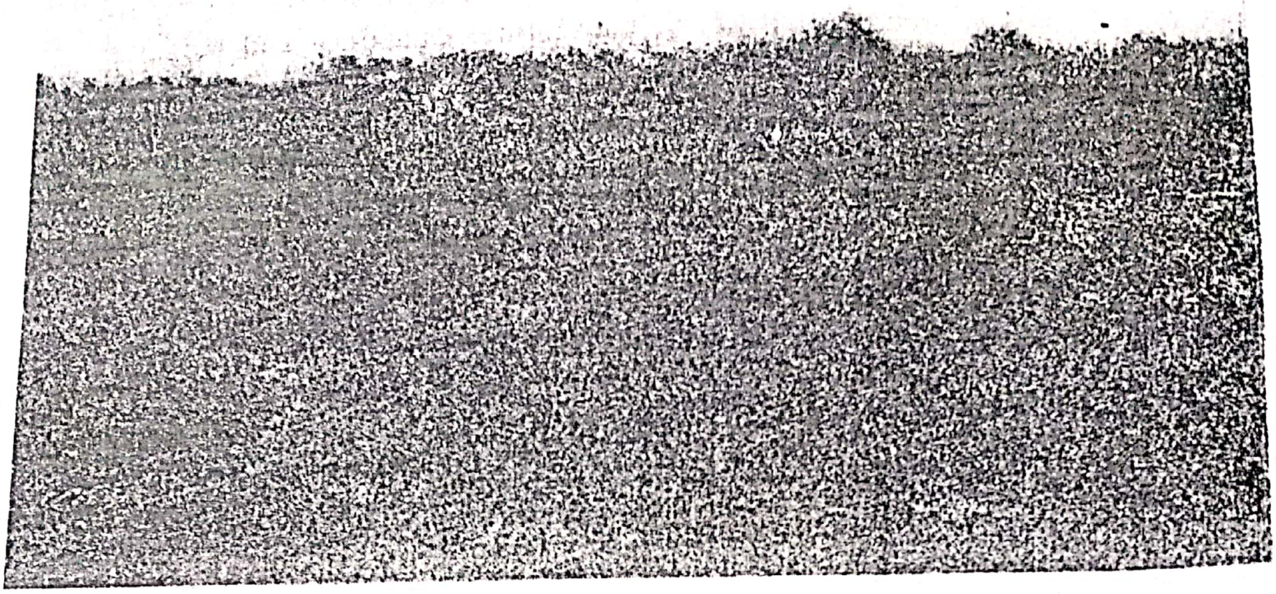


Figure 17.4 Field embankments on terraced fields help increase water retention.

tillage practices be suited to the particular type of soil and its depth. For example, experimental results on wheat at the Soil Conservation Research Station at Tarnol in 1972 showed that the yield of wheat was significantly higher at 12 in than at 6 in ploughing depth. However a comparison of two tillage operations—conventional tillage with bullocks, and deep tillage with a tractor—carried out in the research area of the Barani Agricultural College, Rawalpindi on a loam soil revealed no significant difference in the yield and yield parameters of wheat (Chaudhry and Ali 1987). It has been reported by various workers that heavy-textured soils show good response to deep tillage. Some recent studies with the mouldboard plough have shown encouraging results. Because the use of heavy machinery in our country is not yet widespread, there is no serious surface compaction problem; those soils which are underlain by a compact substratum, hardpan, or ploughpan respond well to deep tillage. Also, it has been observed that deep tillage operations need not be carried out every year and can be carried out beneficially every three or four years.

4. Effective mulching. The practice of spreading plant residue or any other material like straw or stone on the soil surface to reduce evaporation water losses is called **mulching**. Mulching has been found effective in conserving soil moisture, regulating soil temperature, preventing crust formation, and protecting soil against erosion. The mulching material absorbs the kinetic energy of raindrops, improves infiltration, and reduces the velocity of runoff water. Mulches can be used particularly effectively for soil and water conservation on moderately sloping arable lands. Chaudhry et al. (1988) observed the response of gram to the application of wheat straw, maize stover, and rice straw mulches. Their study showed that mulch treatment moderated soil temperature, improved moisture retention in the soil, increased biomass, and enhanced crop yield. In a study on mung (*Vigna radiata*) in which chopped wheat straw was top-dressed at 0, 2, 4, and 6 t/ha, Chaudhry and Faizullah (1989) found that mulch treatment produced a significant increase in moisture content, biomass, number of pods per plant, and crop yield. It was observed that mulch application @ 2, 4, and 6 t ha^{-1} caused 12.5, 26, and 42 percent increase in moisture content and 20.69, 44.83, and 44.83 percent increase, in grain yield, respectively, over unmulched treatments. However, mulch application at the rates of 4 and 6 t/ha delayed crop maturity.

5. Cropping systems and crop rotation. Selection of proper cropping systems and crop rotation are the key to success of conservation-oriented farming. The allocation of farm area to different crops depending upon the potential of the land is very important. In the Pothwar area the *dofasli dosala* ('two crops in two years') system of cropping is quite common. Wheat is the dominant rabi crop and is sown in about 60% of the area.

Millet, mung beans, and *mash* are important kharif crops. Gram is a dominant rabi crop in the low-rainfall areas. The Gujar Khan, Chakwal, Mianwali, and Attock areas are still the home of groundnut, but the area under this crop is declining. The issue of introducing change in the cropping pattern of the rainfed area is controversial. One school of thought believes that the existing cropping pattern is not suitable since a major portion of the area remains fallow during the summer. Most erosion takes place during the summer because about 60–75% of the precipitation falls in that season in the form of heavy downpours. These people believe that there should be more crop cover during the kharif season. The other school of thought is of the opinion that the present system is based on centuries of experience of the farming community, who have found that there are more chances of crop failure during summer than winter. Studies of relay cropping and intercropping are under way, which could be helpful in the readjustment of cropping systems, if the results are encouraging.

Cropping systems, cropping patterns, and crop rotation are site specific. Good information about the selection of crops in various ecological regions is contained in *Agro-ecological Zonation of Pothwar* (Beg et al. 1985). Much more research needs to be carried out in order to develop a comprehensive plan for cropping systems in Pakistan.

Cover crops are very important in cropping patterns and crop rotation in erosion affected areas because they provide good cover for the soil and have deep root systems. They protect the soil from the erosive effects of the beating action of rain, and they hold the soil against erosion. Groundnut, mung, and *mash* are good cover crops for medium-rainfall areas.

Figure 17.5 Water disposal outlets are helpful in disposing of excess rainwater.

6. Water disposal systems. Water disposal systems (Fig. 17.5) aim at the safe disposal of surplus rainwater that remains unabsorbed into the soil. These systems include **water disposal outlets** and **storm water channels.** There are different types of water disposal outlets — grassy, loose stone, and brick masonry. The selection of a particular outlet type for an area depends upon the soil characteristics, rainfall, slope of the land, availability of labour and construction materials, and the economic condition of the farmers.

Grassy outlets are very inexpensive. They are constructed in low-rainfall areas or where the volume of water to be disposed of is not great. The grasses should not be edible by animals, otherwise they will be destroyed by the cattle. Grassy outlets can be constructed satisfactorily in the Jauharabad, Khushab, and Mianwali areas.

Loose stone outlets are constructed in low-to-medium rainfall areas where the field-to-field fall is less than 2 feet. Because they are made with local material, loose stone outlets are also inexpensive . They are found in the Soan valley, Attock, and Jhelum areas where stones are available.

· Brick masonry water disposal outlets can be laid out where the field-to-field fall is more than 2 feet, where rainfall is more than 750 mm per annum, or in the lower reaches of a catchment.

In addition to the above types, prefabricated and specially designed structures like concrete pipes can also be used under certain conditions. These have been tried in the Gully Rehabilitation Project of PARC near Fateh Jang, but the farmers are still reluctant to adopt this technology.

The outlets are usually located at the lowest point of the field. The crest of an outlet is slightly higher (about 15 cm) than the ground level. Once surplus water has been safely conducted away from the cultivated land it should be carried through a storm water channel or watercourse which eventually leads to a natural drainage channel. The storm water channel should be designed keeping in view the peak flow during high intensity downpours.

7. Fertilizer use. Soil fertility is a very important factor in the conservation of soil and water. Fertile soils produce high crop yields and also have better physical properties than infertile soils. Organic matter improves the structure of the soil; a fertile soil with adequate amounts of organic matter (at least 1%) is resistant to erosion. Well-managed soils develop a granular structure which makes them porous and able to absorb more rainwater. It has been observed that 9.5% of rainfall water was lost as runoff from an unfertilized maize crop, while only 6.4% percent was lost where the maize crop was fertilized at the rate of 200 pounds/acre of 5–10–5 fertilizer (FAO 1965). However the best kind and amount of fertilizer to be used in each individual case depends on the soil type, crop, and rainfall.

8. Terrace farming. "The field terrace is an earthen embankment adjusted to soil and slope to control runoff. It is designed primarily for the control of runoff in high-rainfall areas and for the conservation of water in low-rainfall areas (Bennett 1955:193)." Terraces are constructed to decrease the length of a slope, reduce erosion, prevent formation of gullies, and retain runoff in areas of inadequate precipitation. There are two main types of field terraces: (1) broad-based terraces which remove or retain water on sloping lands, and (2) bench terraces which reduce land slope.

1. A **broad-based terrace** is a wide surface channel or embankment constructed across the slope of rolling land. From a functional point of view, there are two types of broad-based terraces: (a) channel terraces and (b) ridge terraces. The primary function of a **channel terrace** is to remove excess water in such a way as to minimize erosion (Fig. 17.6a). These are constructed by cutting a shallow channel on the uphill side and using the excavated soil for the construction of an embankment. The side slopes of both the channel and ridge are kept as flat as possible so as to facilitate farming operations. These are mainly constructed in medium to high rainfall areas and should not be built on soils that are too stony, steep, or shallow; or on deep sands.

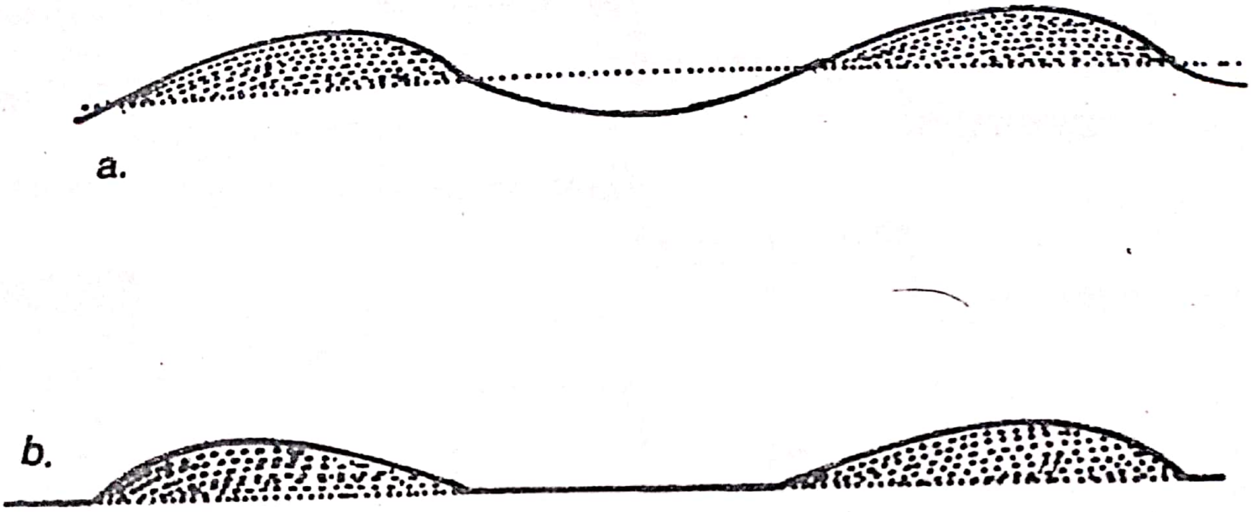


Figure 17.6 Types of terraces: (a) interception and diversion; (b) interception and retention. (Redrawn after Bennett 1955:194).

Ridge terraces are primarily constructed for moisture conservation, and erosion control is a secondary objective (Fig. 17.6b). They are helpful in trapping and retaining rainwater for infiltration into the soil in low-to-medium rainfall areas. They may also be used on permeable soils in high rainfall areas. The channel in this type is generally level to allow maximum retention.

2. **Bench terraces** with broad channels are commonly used around the world to reduce the length and steepness of land slope. Bench terrace farming is a centuries-old practice in the subcontinent. In Pakistan it is practised particularly in the Pothwar plateau and the northern hilly areas. There are four types of bench terraces: (a) Level bench terraces, (b) Sloping bench terraces, (c) Reverse slope bench terraces, (d) Irrigation bench terraces (Fig. 17.7).

Level bench terraces have an almost level field surface. They are suitable for medium-to-high rainfall areas. They are quite common in the Pothwar, Murree, Kahuta, and northern hilly areas. **Sloping bench terraces** can be adopted in high rainfall areas or where the purpose is to dispose of extra water. This type is not common in Pakistan. **Reverse slope bench terraces** are recommended for low-rainfall sloping areas so that the maximum possible rainwater can be retained in the soil. **Irrigation bench terraces** are suitable for sloping areas where fields are to be irrigated. In this case the field boundaries are raised above the level of the field, and the surface of the field is almost level (Fig. 17.7d).

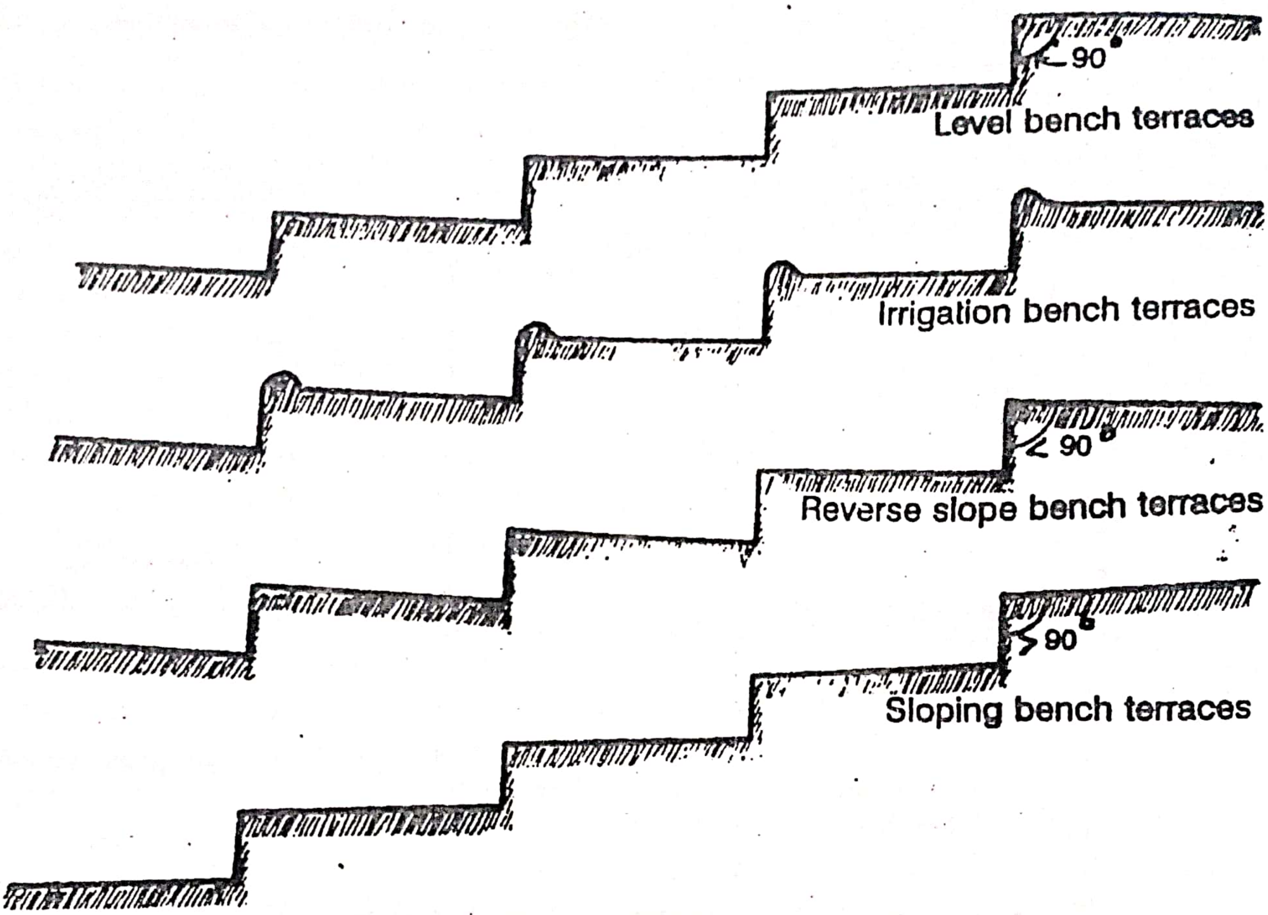


Figure 17.7 Types of bench terraces (Redrawn after Hudson 1981:88-89).

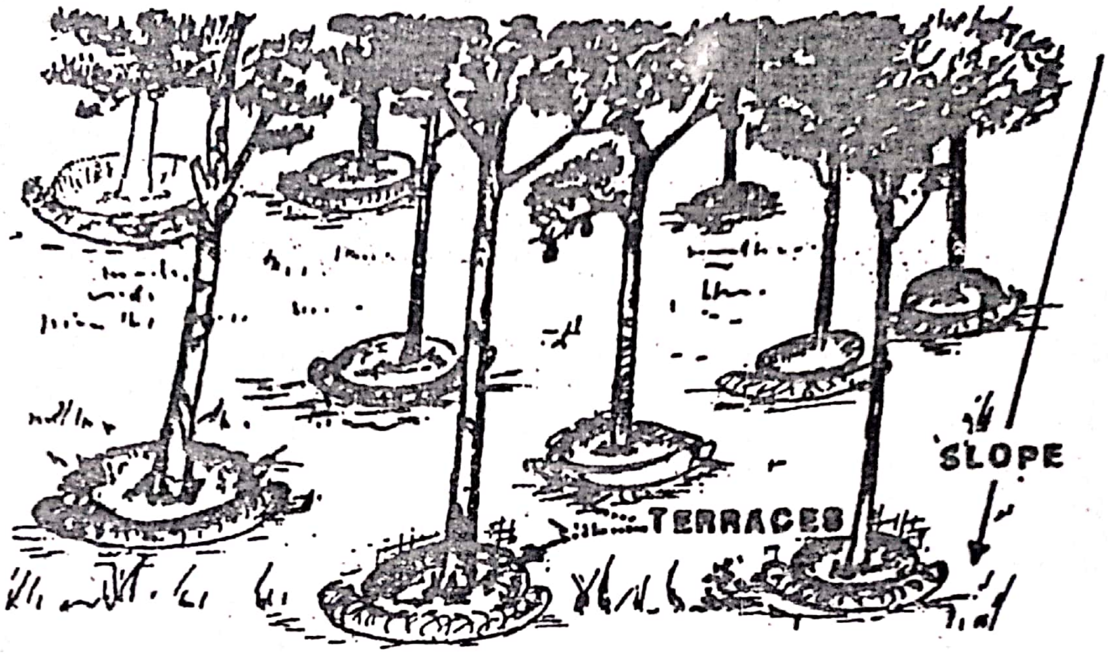
17.3.4 Conservation of non-arable lands

Land that is not suitable for the production of field crops because of severe erosion, steep slopes, shallow soil depth, or susceptibility to flooding is classified as non-arable land. This land should not, however, be treated carelessly, because adjacent arable lands can be damaged by excessive loss of water from eroded land and progressive moving back of the boundary between cultivated and eroded land. Also, such lands can be used profitably for raising grasses, shrubs, trees, or wildlife.

The following techniques will be helpful in protecting non-arable lands from erosion and in reclaiming already eroded lands.

1. Provision of permanent vegetative cover
2. Interception, retention, and diversion of rainwater
3. Reduction in the velocity of runoff in the gullies
4. Collection of surpius water in storage reservoirs

1. Provision of permanent vegetative cover. Vegetative cover is the most effective protection against soil erosion. The type of vegetative cover supportable depends on the soil characteristics, slope and ecological conditions. Usually non-arable lands are suitable for various kinds of grasses and trees (Fig. 17.8). In general, flora native to the area should be preferred. Bermuda grass, Sudan grasses, *bajra* × Napier grass hybrid, vetivar, *epil epil* (*Leucaena*), eucalyptus, and acacia have been found successful on a variety of soils and in low to medium-rainfall areas. After plantation it is important that the plants be provided continuing care, and protection from grazing and indiscriminate cutting of mature trees.



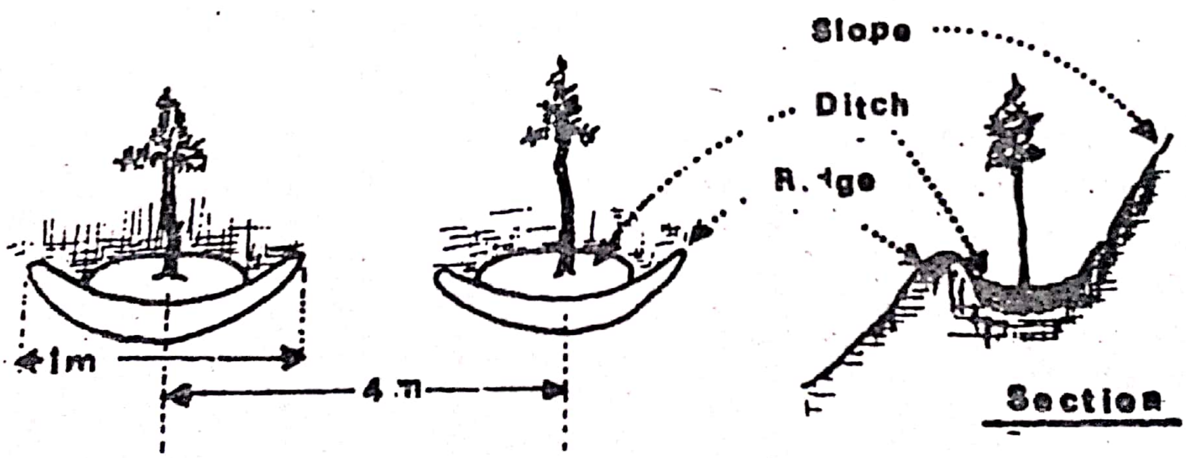


Figure 17.9 Interception and retention of rainwater on non-arable lands can be achieved by the construction of eyebrow terraces.

2. Interception and retention of rainwater. Non-arable lands with relatively steep slope should be terraced in order to cut down the length and steepness of the slope. Depending upon soil and ecological conditions, trees can be planted on eyebrow terraces, channel terraces, or basin ditches on non-arable lands. An eyebrow terrace is a series of oval-shaped ditches and ridges on a contour line of steep slopes for trapping and retaining maximum runoff water (Fig. 17.9). They are particularly effective for planting forest trees in hilly tracts. These terraces should be provided with diversion channels for the disposal of surplus water (Fig. 17.10).

Runoff water from the catchment or sub-catchment area can be carried through these ditches to a natural drainage channel (Fig. 17.11). The ditches must be specially designed to have a capacity sufficient to carry the water during peak flow periods. The lining of their beds with suitable grass species should provide enough resistance so as to carry it at non-erosive velocity, otherwise these waterways will themselves be converted into gullies. The surface can be lined with pebbles in the beginning but living material like grasses is more suitable in the long run.

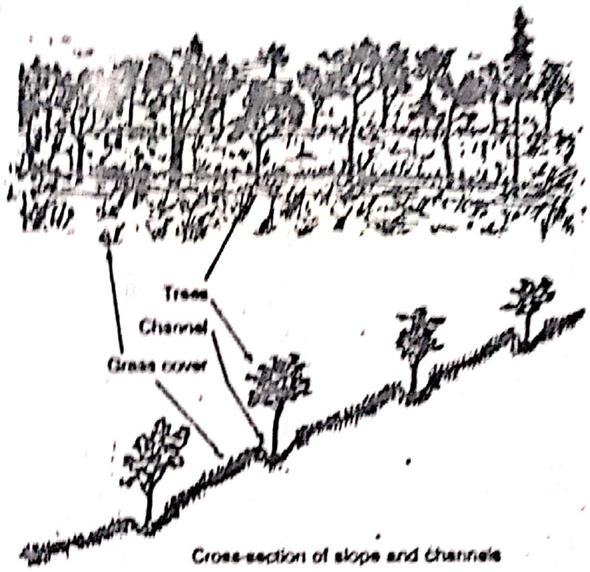


Figure 17.10 Channel terraces with trees and grass in the interchannel area.

3. Reduction in the velocity of runoff in gullies. Gullies are the last stage of erosion. They are the result of disturbance in the hydrostatic balance because of either increased runoff or reduction in the carrying capacity

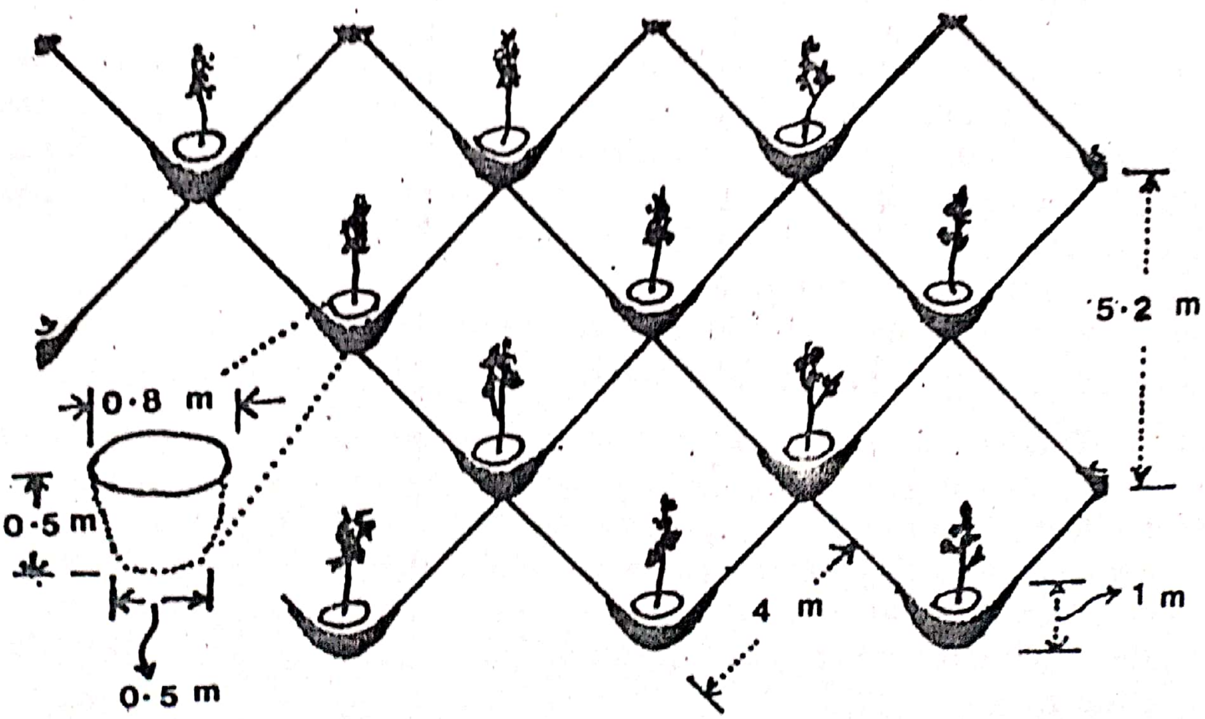


Figure 17.11 Basin ditches showing the plantation of trees and the arrows showing the direction

of a drainage channel. Management of gullies should begin from the top and proceed downslope with the object of re-establishing the hydrostatic balance. Check dams have been found useful in reducing the velocity of runoff water in gullies.

Figure 17.12 Check dams help to check erosion and to harvest water for later use.

Check dams. Structures of various materials which can check the flow of water flowing in streams or gullies and thus force it to deposit part of its sediment load in its upper reaches are called check dams (Fig. 17.12). Check dams allow the main volume of flood water to pass over them. The following types of check dams have been tried in Pakistan.

- Brushwood check dams
- Loose stone or wire-bound check dams
- Cement and stone check dams

Brushwood check dams are cheap to construct and maintain. They consist of two rows of wooden poles fixed firmly into the soil, spaced at a distance of 2–3 feet. The space between the two rows of poles is filled with as many tree branches as possible. These branches should be tied to the poles. Brushwood check dams can be installed in small gullies and where the volume of water flowing through the channel is relatively small and the section of the gully is narrow.

bed of a gully across the flow of water. If the volume of water flowing through the channel is not great, the check dams may be made of loose stone, otherwise they will have to be protected by a net of galvanized iron wire (Fig. 17.13).

Figure 17.14 Cement and stone structures are needed for larger volumes of water.

Cement and stone or cement and brick structures may be installed if the volume of water passing through the channel is too great for the former types to withstand.

Whatever structures are used, the sides of the gully should be provided with a vegetative cover of grasses, shrubs, or trees to stop further widening.

4. Collection of surplus water in storage reservoirs. Rainwater which remains unabsorbed into the soil flows away as runoff. It can be collected in different kinds of water reservoirs like ponds, mini-dams, and small dams, depending upon the volume of water passing through the stream. This stored water can then be used for domestic purposes, or supplemental irrigation. These water storage reservoirs not only help in harnessing the surface water but also add to the recreational wealth of the area (Fig. 17.14).

More than 50 mini-dams, about 40 water storage tanks/ponds, and 24 small dams have been constructed by the Soil Conservation Directorate and Small Dams Organization in the rainfed areas of Punjab, but because of socio-economic, institutional, and other problems the water from these reservoirs is not being utilized properly.

17.3.5 Erosion control efforts in Pakistan

The problem of soil erosion was officially recognized in the Indo-Pakistan subcontinent as early as 1880, and it was recommended that the uncontrolled felling and grazing of forests be restricted. Consequently the Punjab Land Preservation Act (Chos Act) was passed, which empowered the Forest Department to restrict and regulate the use of land. After that, the problem did not receive due attention till 1935. A Soil Conservation Circle was organized in the Forest Department in 1941, and the Punjab Land Preservation Act (Chos Act) was amended in 1944 and extended to almost all districts of undivided Punjab. Its main objectives were the protection and afforestation of hilly and sloping lands, conservation of soil and water on cultivated lands, and control and channelizing of hill torrents.

After Independence, the problem of erosion was given serious attention by the Government of Pakistan, and a number of soil conservation divisions were organized in the Forest Department. A Soil Conservation Organization was set up in 1950–51 in Quetta to assist the provinces in studying their problems and coordinating their activities. Later the headquarters was shifted to Rawalpindi. A Pilot Soil Conservation Project was established in 1954 with the help of the International Conservation Authority. Its aims were to make land capability surveys to find out the degree of erosion, to develop soil conservation practices, and to prepare farm plans. More demonstration units were opened in 1958, and in 1966 a soil conservation operational project was started in different parts of the country.

Several different agencies are operating in various parts of our country to combat the erosion problem. The province of Punjab has the most organized programme, with a full-fledged Soil Conservation Directorate; however its activities are limited to areas affected by water erosion. A few years ago, the Cholistan Development Authority was established to rehabilitate Cholistan, a vast sandy desert having a peculiar clay soil underlain by sand. Soil conservation activities in Sindh and Balochistan are being looked after by the Forest Department. For the management of the Tharparkar desert, the Sindh Arid Zone Development Authority (SAZDA) was founded about four years ago. There is no organized programme of soil and water conservation in the Northwest Frontier Province. It is being dealt with by the Agricultural Engineering Wing. In addition to these agencies, several federal government and other organizations like the Forest Department, the Watershed Management Projects of Tarbela and Mangla Dam, and other agencies of the Water and Power Development Authority (WAPDA) are dealing with the problem of erosion.

Soil conservation technology has usually been imported from abroad and adopted after slight modification. Hectic efforts have recently been made by different agencies and researchers like PARC and WAPDA to develop technology suitable to our own conditions. Realizing the importance of soil and water conservation research and the gravity of the erosion problem, in 1989 the Government of Punjab established a Soil and Water Conservation Research Institute. This institute is to carry out organized research on (i) erosion, (ii) the monitoring of soil and water losses under different soil, topographic and ecological conditions, and (iii) water harvesting; and to develop a package of technology for both arable and non-arable lands. It is expected that the institute will make an important contribution to erosion studies and to developing soil and water conservation technology appropriate to conditions in Pakistan.