rocess. Where these soils have been under old irrigated cultivation, they are ot saline.

0.3 Soil resources of Pakistan

akistan covers an area of 80.0 million ha of mainly arid or semiarid land, f which about 39% or 31.0 million ha is suitable for agricultural and forest- y activities. Approximately 20.0 million ha are cultivated (16.2 million ha eing irrigated), 3.0 million ha are exploitable forest, and 8.0 million ha are angelands. In about 95% of the country, the mean annual rainfall is less han 600 mm, and is concentrated in two seasons—the summer monsoon hich falls in July–August, and winter rains which fall in January–February. hese two rainy seasons help define Pakistan's two crop seasons, kharif summer) and rabi (winter).

Nearly 61% of the cropped area is under food grains (primarily rice, heat, and maize), 16% is under cash crops, and the remaining 23% is hared by minor crops such as oilseeds, fruits, fodder, etc.

There are a large number of different kinds of soils which, because of ifferences in their chemical and physical characteristics, have different otentials for agricultural use. The different soils have been classified for heir relative suitability for sustained production of common agricultural rops, for grazing, or for forestry. They have been grouped into eight land apability classes. Class I land is the best for all purposes, and Classes II hrough VIII have a progressively increasing number of limitations for gricultural use. Soils in the highest class (I) have no limitations for agricul- ural use, and relatively little effort is required to produce high yields of a vide range of crops. Soils in Class I give a very high response to good nanagement, including inputs of water, improved crop varieties, and fertiliz- rs. The suitability of soils for farm crop production gradually diminishes, ntil by Class IV, the soils are marginally suitable for this purpose. The ower classes give successively lower responses to various inputs. Class V hrough VII lands are not fit for regular farming; these are, however, de- reasingly suitable for forestry and range management. Class VIII land is of o agricultural use whatsoever.

The extent of different kinds of land in the cultivable commanded area s given in Table 10.1.

Table 10.1 Area under different land classification categories in culturable commanded area (CCA) (thousands of hectares)

	NWFP	Punjab	Sindh*	Pakistan	Percent of CCA
a. Cultivated land					
NON-SALINE					
Class I					
Flawless	79.2	2999.0	1077.3	4155.6	30.6
Class II					
Clayey	102.7	1607.7	2356.6	4067.1	
Sandy	22.0	574.9	39.1	636.0	
Waterlogged	34.0	215.4	7.6	257.2	
Uneven	31.4	27.0	–	58.4	
Subtotal	190.1	2425.2	2403.3	5018.7	37.0
Class III					
Sandy	4.1	169.6	131.2	305.1	
Waterlogged	10.6	34.0	174.3	219.1	
Subtotal	14.7	203.7	305.6	524.2	3.9
Class IV					
Sandy	–	295.7	29.3	325.1	
Waterlogged	–	7.4	1.8	9.1	
Subtotal	–	303.1	31.1	334.2	2.5
Total non-saline	284.1	5931.0	3817.4	10,032.6	74.0
SALINE					
Class II					
Slightly saline	2.4	464.6	334.2	801.2	5.9
Class III					
Saline–sodic and saline, gypsiferous	1.6	126.0	124.2	251.8	1.8
Class IV					
Saline–sodic	–	42.4	102.1	151.8	1.1
Total saline cultivated	4.0	633.0	560.6	1197.6	8.8
Total cultivated	288.1	6564.1	4378.0	11,230.2	82.8
b. Uncultivated land					
NON-SALINE					
Class VII					
Severely eroded	9.4	–	–	9.4	
Sandy	12.8	298.8	0.12	311.8	
Marsh	–	1.1	1.1	–	
Subtotal	22.2	299.9	1.2	321.2	2.4

	NWFP	Punjab	Sindh*	Pakistan	Percent of CCA
Class VIII					
Shifting sand dunes	–	43.1	–	43.1	0.3
Total non-saline	22.2	343.0	1.2	364.4	2.7
		SALINE			
Class VII					
With sparse vegetation	9.6	911.7	858.5	1779.8	13.1
Class VIII					
Almost bare	–	69.0	112.2	181.2	1.4
Total saline, uncultivated	9.6	980.7	970.7	1961.1	14.5
Total uncultivated	31.8	1323.8	971.8	2326.5	17.2
Grand total or CCA	320.1	7887.8	5349.8	13,556.8	100

* Including commanded area of Pat Feeder canal in Balochistan.
Source: Bhatti et al. (1988).

The cultivated land is by and large suitable for growing crops, as detailed below.

Class I. Very good agricultural land. This land occupies an area of 4.2 million ha. It is well suited for a wide range of crops. Soils in this class have no limitations for crop production. They are medium-textured and easy to work. They are nearly level, deep, and well drained. They show the highest response to good management including the application of fertilizers. They are used for general cropping, vegetables, and orchards.

Class II. Good agricultural land. Class II land occupies 5.0 million ha in the cultivated part of the cultivable commanded area. Soils in this class have minor limitations for crop production: either the range of suitable crops is somewhat narrow, or the management cost is somewhat high. Generally, the net return from this soil is about 25% less than that from Class I land.

Class III. Moderate agricultural land. This land covers an area of 0.76 million ha of the cultivated part of the culturable commanded area. Soils in this class have moderate limitations for crop production. They have a limited range of suitable crops. The net return from this land is generally about 50% of that of Class I land.

Class IV. Poor agricultural land. This land occupies an area of about 0.48 million ha in the cultivated part of the cultivable commanded area. Soils in this class have severe limitations on account of shallow soil depth or

strong salinity and sodicity combined with slow permeability, etc. The net return from this land is generally negligible.

Soils in Classes I to IV are cultivated for farm crops, while some of the lands in Classes V to VII are suitable for perennial woody vegetation and grasses, etc.

10.3.1 Uncultivated areas of CCA (Culturable Comand Area)

About 17% of the CCA is presently not under cultivation. Class V, VI, and VII land has severe limitations or hazards for cultivation, most being level but strongly affected by salts. A large proportion of the saline land can be considered culturable because its reclamation is economically feasible provided sufficient water is available after the water needs of good land have been met. The rest of the saline land is so bad that its reclamation, though technically useful, would not be economical. Some parts of the uncultivated land are either too sandy or too rough and broken to be cultivable.

About 60% of the uncultivated land has moderate potential for irrigated agriculture (Class III land); about 30% is not culturable, but supports a cover of vegetation providing some grazing (Class VII land), and the remaining 10% is fit neither for cultivation nor for grazing (Class VIII land).

10.3.2 Irrigated area

Canal-irrigated area constitutes the major part of agricultural land in our country. The canal-commanded lands spread over approximately 13.8 million ha of a variety of land in the Indus plains. Of this, nearly 2.4 million ha, although within the command of canals, is virgin, but the bulk of the land, measuring about 11.3 million ha, is actually under cultivation.

10.3.3 Barani areas

About 3.68 million ha are under barani farming, which includes rainfed (1) cultivation, riverine *sailaba* areas (2) (*kacha* area), and torrent-watered (3) *sailaba* cultivation in Balochistan and the outwash plains (4) of the Suleiman and Kirthar ranges.

The main barani areas of the Punjab, Sindh, NWFP, and part of Balochistan have been covered by soil survey, and the soils have been evaluated in terms of their agricultural potential. Class I and II lands do not exist under barani cultivation because of the limitations imposed by climate, especially inadequate rainfall. The best barani land falls in Class III—moderately productive agricultural land. About half of the barani area consists of Class III lands. They occur in areas with annual rainfall of more than 50 cm. A major part of Class III barani lands have no soil limitation, whereas slope, limited soil depth, and erosion are the important soil problems in the re-

maining part of this class. Class IV lands are either located in low-rainfall areas where moisture availability is inadequate and uncertain, or have severe problems of slope, limited soil depth, and erosion. Possibilities for increasing agricultural production on this land are limited. Low-rainfall areas and the torrent-watered *sailaba* areas fall into this class.

10.3.4 Uncultivated areas not in CCA

The uncultivated areas (Class V through VII) are used for grazing or forestry. The natural forest areas are confined to the northeastern parts of the country, where adequate precipitation and the effect of high altitude permit growing of natural forests. The soils under these forests are generally deep and quite stable in spite of their position on steep slopes. But due to strong biotic pressures, not only are the areas under natural forests dwindling, but the denuded soils are also being subjected to erosion.

Large areas of the uncultivated land in the country are used for grazing. The grazing potential varies with the availability of moisture, and is influenced by rainfall, temperature, and the depth of the soil. Soils in these areas show a great range of physical and chemical characteristics.

10.4 Sustainability of land resources

It is commonly believed that most of our prime agricultural land, though inherently problem-free and fertile, is in impending danger of deterioration due to salinization and waterlogging.

Hazard of salinization. Studies of soils all over the Indus plains have revealed that most of the soil salinity there is very old, produced in the process of soil formation much before the introduction of the modern canal system. The extent of (secondary) salinity produced as a result of irrigation is limited and includes no more than a small proportion of the affected land.

There is, however, another process of soil deterioration that should be of great concern to the nation. It is the sodication of first-rate agricultural land caused by irrigation with low-quality tubewell water. This type of salinity was introduced with the accelerated use of ground water. The symptoms of the sodicity of soils are widespread, as observed from hardening of the soil surface, decrease in rate of infiltration, and inadequate seed germination—especially of alkali-sensitive crops. This mode of soil degradation is treacherous, beginning insidiously at a slow rate.

Hazard of submergence. The apprehension of submergence of large parts of the irrigated plains is not based on fact. The irrigated Indus plains, although apparently level, are far from being flat. There are small but important local variations in relief inherited from depositional patterns of

the river alluvia. The rise in water table due to seepage from the canal system does not affect all the land uniformly. In depressional areas representing filled-in channels and basins the water table comes close to the surface, and in some cases small local areas are submerged and turn into marshes. In most areas, the water table remains deep enough not to affect crop production and cropping patterns.

The general layout of land and the net input of water in the Indus plains are such that not more than about one percent of canal-commanded area can ever be submerged, and the prediction that unless a massive drainage system is provided certain regions will turn into lakes has no basis.

Hazards of soil erosion. Soil erosion is another important factor adversely affecting the productivity of our cultivated soils. Water and winds are gradually taking away the fertile upper parts of the cultivated soils. The process of erosion is more active on sloping and naked lands. About 1.4 million ha are affected by erosion in the Punjab alone, which accounts for 11.7% of the total affected area. Erosion is a threat to our valuable resources, and protection of our soils needs immediate attention.

Protective measures on a large and costly scale are necessary, but much can be done in simple ways at the level of the individual farm. Proper crop management, contour farming, and strip cropping are economical and effective ways to reduce soil erosion. One of the secrets of good crop management is to keep the ground covered for the major part of the year.

10.5 Managing soil resources

Land differs considerably from place to place in its response to agricultural use. The new lands which can now be developed for agriculture are mainly those which have no or only a low potential for that purpose, so that very low or negative returns are expected from most of them. The proportion of potentially productive land is rather small. The following points should be considered for the management of soil resources in the country.

1. Soil fertility. The nutritional status of soil varies with the difference in the parent material and is likely to affect the availability of some micro nutrients. Slight differences in clay mineralogy can also be expected, depending upon the differences in the parent materials (Indus river alluvium Suleiman piedmont alluvium, loess or eolian silt, and eolian sand). Indus alluvium is low in zinc and copper, but relatively high in iron and manganese because of biotite mica. Therefore zinc and copper nutrient deficiencies are the first to appear in plants in the Indus plain.

2. Soil tillage. Tillage operations are affected mainly by soil texture and type of clay. Seedbed preparation is affected mainly by soil texture, as the clay type is almost uniform in the Indus plain, except in some clayey soils

the rice tracts of the Punjab. At present, seedbed preparation is done by tilling the soil to a depth of about 8 cm, whether by bullock-drawn local cultivator (*munnah*) or by tractor-operated tine cultivator. This practice is suitable for loamy and sandy loam soils. For clayey soils, however, we need special tillage implements like the disc harrow, clod breaker, etc. The present cultivator is completely inadequate for clayey soils, no matter how many times it is worked. It is through field experiments that suitable tillage operations can be evolved for proper seedbed preparation in clayey soils.

Our tillage operations work the surface soil layer to a depth of about 8 cm, below which is formed a dense layer about 5–7 cm thick. This layer is called **plough pan**; it hinders the movement of water and air as well as the growth of plant roots. The problem is severe in clayey soils and loamy soils of irrigated areas, and in loamy soils of rainfed land. The plough pan can be shattered by working a chisel plough to about 15 cm depth when the soil is nearly dry. Performing the operation at *wattar* condition (soil moisture level suitable for cultivation) is totally ineffective. If ploughing is done to greater depth, it will be harmful because the soil pores in the layer below the plough pan will be destroyed. In clayey soils, tillage operations should be performed when the soil layer at a depth of 7–15 cm is in a moist condition suitable for tillage operations. Field experiments are needed to evolve suitable tillage operations to control the plough pan problem.

3. Cultural practices. In clayey soils, the effect of inadequate seedbed preparation can be overcome by adopting a better method of sowing crops. Sowing on ridges may prove to be useful on clayey soils. For loamy soils, however, this method of sowing may not be any better than sowing on the flat.

Improper seedbed preparation in clayey soils adversely affects the germination of crop seeds, but the problem can be overcome by using a higher seed rate. Through field experiments, suitable seed rates for various crops can be found on different soils—sandy, loamy, and clayey.

4. Irrigation water management. This involves the adoption of suitable methods of irrigation, and managing water application depending on the water infiltration rate of the soil and the thickness of the root zone. For example, sprinkler and drip irrigation methods are suitable in all sandy soils. For loamy and clayey soils, basin or border irrigation is appropriate. The size of the basin will depend upon the water infiltration rate and the discharge of the irrigation ditch. The amount of water to be applied depends upon the thickness of the effective root zone. Through field experiments, irrigation schedules can be evolved for various crops on different soils. At present, half an acre (2000 m^2) is the common size of the basin. It results in the loss of water through percolation in sandy loam soils, but causes underwatering of crops in clayey soils.

5. Special management practices. Some special management practices are required for fields having saline-sodic patches. The water intake is much slower in saline patches than in the non-saline parts of the fields. So when irrigation water is applied the saline patches are unable to absorb their due share of water because it goes to the non-saline part of the field, which has a higher rate of water infiltration. It is postulated that if a *bund* dike is built around each saline patch and water is let into it through an opening in the dike and then the opening is closed immediately after water application, it will help to reclaim the saline patch. If the normal crop, for example cotton, does not grow in the saline patches, a salt-tolerant crop like *Sesbania* (*dhaincha*) should be sown. This way it may be possible to reclaim saline patches using the present irrigation water supplies, without waiting for additional water.

QUESTIONS

1. In what respect does the northern mountainous region differ from the western mountainous region?
2. What are the general features of the Indus delta?
3. Explain how the soils of Pakistan have been grouped according to their land capabilities.
4. Summarize the characteristic features of the land placed in land capability Class III.
5. Name the different soil hazards and the extent to which they affect Pakistan's soils.
6. How can alkali and saline soils be reclaimed?
7. What is soil erosion and how can it be checked?
8. (a) What is soil management? (b) Explain the agro-techniques involved in it.
9. What special management practices are needed to manage problem soils?

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