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PAKISTAN'S SOIL RESOURCES

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A Pakistan National Conservation Strategy Sector Paper

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DIVISION,
GOVERNMENT
OF PAKISTAN

IUCN
The World Conservation Union

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PREFACE

This monograph is one of the 29 sectoral and programme papers produced to support the preparation of the Pakistan National Conservation Strategy. The NCS is a comprehensive review of the state of the country's environment, and of government and corporate policies, the voluntary sector, community and individual practices, which support or hinder sustainable development. The objective of the NCS is to identify strategic initiatives to conserve the country's natural resources which are the base for lasting improvements in the quality of life.

Environmental impacts do not respect sectoral or administrative boundaries. Yet, conventional development planning is frequently focused on narrow performance criteria and associated financial requirements, ignoring huge costs on downstream ecosystems and economic activities dependent on them. These costs cannot be avoided and must be paid by society, the only questions are when and by which group.

To facilitate an understanding of such 'externalities', one of the first steps of the National Conservation Strategy was to undertake assessments of cross-sectoral impacts from the point of view of each major activity sector. In order to facilitate comparison, the reports were prepared according to common terms of reference. Subsequently, major programme areas that must be given priority in the transition to a sustainable society were identified. The list of economic, environment and programme areas is given overleaf.

A paper on each sector was produced by a well recognized expert supported by peer reviewers in related specialities. The key insights have been incorporated into the Strategy. Since the papers are the reference base of the strategy and contain special interest material, a decision was taken to publish them serially in the form of monographs. It is hoped they will be found useful by researchers of sustainable development in various facets of national life as well as by the interested lay reader.

The sectors are:

1. Economic sectors:

- Agriculture, forestry, livestock, fisheries.

- Mining, energy, industries, transport.
- Human settlements and recreation.

2. Environmental impact sectors:

- Soil degradation, loss of biodiversity, and over harvesting of renewable resources.
- Municipal and industrial discharges, environmental health effects, and misuse of water resources.
- Destruction of cultural heritage.

3. Programme areas:

- Incorporation of environment in education, communication, and research; enforcement of laws and regulations; improved administration; use of economic instruments to align market forces with sustainability; promotion of conservation ethics.
- Programmes to promote population planning, women in development, and regional equity.
- Creation of grassroots institutions, with participative management.

PAKISTAN'S SOIL RESOURCES

1. INTRODUCTION

Soils represent the single-most important natural resource on which human existence and prosperity depend. A large variety of soils are found in Pakistan, which vary significantly in kind and distribution. This entails adopting different approaches to optimally and sustainably use this resource.

Although the country's soil resources are vast, good quality soils that form prime agricultural land are limited. The extent of such soils can be increased only a little by improving a part of relatively poorer quality soil, though this would be at formidable cost. Ultimately, Pakistan has to rely on the existing soil resources. The need of the day is to protect prime agricultural land from misuse that may result in its degradation or loss.

Optimal use of this resource would not only ensure continued availability of the basic human needs for food, fibre and shelter, but also improve the overall environment. This paper profiles the soil resources of Pakistan and points out the activities of various sectors which are degrading and affecting the sustainability of this resource. The objective is to guide the Government of Pakistan in preparing a viable National Conservation Strategy.

2. PRESENT SITUATION

SOIL INVENTORY

An inventory of soils in the country was initiated in 1962 through a Soil Survey Project undertaken by the Government of Pakistan with the assistance of the United Nations Development Programme, and the UN Food and Agriculture Organisation. The main purpose was to assist the government in projects such as new land settlements, irrigation extension and drainage schemes, soil reclamation and conservation, afforestation and rangeland improvement, and so on. In 1973, the Soil Survey Project became a permanent institution — the Soil Survey of Pakistan — under the Ministry of Food and Agriculture.

The Soil Survey of Pakistan (SSP) has surveyed about 715,000 square kilometres of land, covering 81% of the total area of the country (including the Federally Administered Tribal Areas, the Northern Areas and Azad Kashmir). The surveyed area is representative of all those parts of the country that are important for agriculture. An up-to-date province-wise inventory of soils is given in Table 1.

The inventory consists of 55 reconnaissance

TABLE 1

RECONNAISSANCE SOIL SURVEYS: PROVINCE-WISE COVERAGE

PROVINCE	TOTAL AREA	AREA SURVEYED	
	('000 square kilometres)	('000 square kilometres)	(% of total)
Punjab	206	206	100
Sindh	141	97	69
NWFP & FATA	102	88	86
Balochistan	347	286	83
Northern Areas	73	38	52
Azad Kashmir	13	—	—
Total	**882**	**715**	**81**

Source: Soil Survey of Pakistan. 1988. Annual Report. Lahore.

soil surveys and five integrated soil and vegetation reports, along with maps of 'Land Forms', 'Soils', 'Land Capability' and 'Present Land Use/ Natural Vegetation' at 1:125,000 or 1:250,000 scale, and of 'Generalized (Agricultural) Development Potential' at 1:750,000 scale. The reconnaissance reports provide basic data on soils for agricultural development planning and rational land use, to ensure that this resource is conserved while agricultural production is maximised.

The integrated survey reports provide data on soils as well as on natural vegetation to guide in the development and conservation of rangelands. All these reports have been distributed among prospective users in various national, provincial, semi-government as well as non-governmental organisations involved in the planning of development projects.

In addition, the Soil Survey of Pakistan has been engaged in semi-detailed soil surveys of areas under important forest plantations, livestock farms and soil conservation projects, covering over 700,000 hectares. These reports can be used in the planning and execution of development projects in these areas.

Detailed soil surveys of some important agricultural areas of the country have also been made, to guide in the planning of intensive agricultural development. About 320,000 hectares of land have been covered in different parts of Pakistan, and mainly in the Peshawar, Multan, Hyderabad and Nawabshah Districts. This information, in the form of over 300 reports along with relevant maps at the village/watercourse-command level, has been distributed among various agricultural organisations and enlightened farmers to help in the adoption of appropriate measures to improve and conserve agricultural land, and increase agricultural production.

Almost all important agricultural research farms/stations of the country have also been surveyed in detail to facilitate the application of agricultural research to the type of soil cultivated by the farmer. An area of about 5,000 hectares has been covered through these surveys.

SOIL POTENTIAL

SSP evaluated the soils of the surveyed area of Pakistan for sustained production of common and special agricultural crops, as well as their potential for forestry or range development. For this evaluation, the data on soils was integrated with climatic, hydrological, plant and other relevant information. About 750 different kinds of identified soils were then grouped into eight Land Capability classes (Class I to Class VIII) according to their agricultural potential or relative suitability for sustained agricultural use. The first four classes (I to IV) are meant for arable use and the last four (V to VIII) for non-arable use i.e., for forestry and range.

The Land Capability classification is primarily based on the relative degree, or severity, of limitations of a particular piece of land for agricultural use. Soils having no limitations for general arable use are placed under Class I (very good agricultural land), those with minor limitations under Class II (good agricultural land), those with a moderate degree of limitations under Class III (moderate agricultural land), and those having severe limitations are put under Class IV (poor or marginal agricultural land). Soils under Land Capability classes V to VIII are rated for forestry or range. Soils with minor or no limitations for forestry or range development are placed under Class V (good forest or rangeland); those having a moderate degree of limitations are put under Class VI (moderate forest or rangeland); those having severe limitations are grouped as Class VII (poor forest or rangeland); and soils which have no potential for any type of agriculture, including forestry and range, are represented by Class VIII (agriculturally unproductive or non-agricultural land).

Depending upon whether land capability is assessed under irrigated or dry-farmed conditions, the Land Capability classes relevant to arable farming (I-IV) are distinguished by a prefix 'ir' (for irrigated) or 'd' (for dry-farming).

Further differentiation within each class (except for Class I) is made in the form of Land Capability subclasses on the basis of the major kind of limitation faced. For this purpose, specific symbols (See Box 1) are used with the relevant class symbol.

An area of about 61.7 million hectares of land has been classified according to this system. Province-wise, this is presented in Table 2.

The Land Capability classification described above also ranks soils according to their capacity to respond to improved management. Soils placed in Class I are generally very responsive to high inputs of water, improved seed, fertilizers, labour, etc., and also to improved management techniques, while the lower classes have correspondingly decreasing response to inputs and management. Consequently, each Land Capability class/subclass has a specific set of requirements for land use along with management practices, which would ensure optimal utilization as well as conservation of this resource. These requirements as well as the appropriate measures to offset or minimise the relative limitations are discussed in the soil survey reports.

PRESENT TRENDS IN LAND USE

The present use of land is not quite in accordance with its potential. In fact, at present there is no organisation in the country responsible for co-ordinating and monitoring the use of land according to its potential. This makes the quantitative assessment of the impact of land misuse in Pakistan extremely difficult. Only some generalised examples of misuse can, therefore, be quoted.

Present land use in the country is based either on the opportunity and economic status or the socio-economic needs of the user. While much land on the steep slopes of mountains — suitable only for forestry or rangeland — has been brought under plough to meet the food requirements of the population, a significant portion of good and very good arable land in the Indus plains remains under irrigated forests or is used for non-agricultural purposes. Extensive areas in the Thal and Thar have been over-utilised for grazing and are now gravely threatened by desertification. Poor use of soil resources is emphasised when efforts are made to bring marginal or non-agricultural land into arable use, at the expense of large tracts of potential arable land in the Indus plains that remain under-utilised primarily because of water and economic constraints created by the diversion of resources to relatively unimportant land. Not only are there imbalances between current and potential use of land, but there are problems in crop planning for areas with high agricultural value also. Consequently, land optimally

BOX 1

LAND CAPABILITY CLASSIFICATION SYMBOLS

SYMBOL	TYPE OF LIMITATION
e	Erosion hazard (erosion by water or wind) or adverse effects of past erosion.
r	Relief relatively unfavourable, causing difficulty in irrigation or management.
w	Excessive wetness due to high water-table or surface ponding/ flooding.
s (sandy)	Soils either relatively sandy/gravelly/stony or less deep/relatively shallow and underlain by permeable bedrock or sandy/gravelly material.
s (clayey)	Soils either relatively clayey or having slowly permeable/dense/undeveloped layers or less deep (shallow) and underlain by clayey material or impermeable bedrock.
a (non-gyp)	Salinity and/or alkalinity/sodicity hazards, no gypsum in the profile to effect their self-reclamation.
a (gyp)	Salinity and/or alkalinity/sodicity hazard; gypsum present in the profile to effect self-reclamation.
x	Surface instability due to risk of river cutting or burial by fresh sediment.
c	Climatic limitation; too high/low temperatures or too low/erratic rainfall.
z	Soil freezes or snow/ice cover on soils for most part of the year.

TABLE 2

EXTENT OF LAND CAPABILITY CLASSES AND SUBCLASSES IN THE SURVEYED AREA OF PAKISTAN, BY PROVINCE

Class/	Province						Major	Agricultural
Sub-class	Punjab	Sindh	NWFP+ FATA	Baloch.	N.A.	Pakistan	Limitation(s)	Potential
			(thousand hectares)					
GEOGRAPHICAL AREA								
	20,625	14,091	10,174	34,719	7,300	86,909	—	—
AREA SURVEYED								
	20,625	9,222	9,139	19,141	3,685	61,812	—	—
CLASS I — VERY GOOD AGRICULTURAL LAND								
irI	3,486.4	1,097.8	187.3	463.2	2.4	5,237.1	No significant limitation for general agriculture; too high a permeability for rice	Very high for general agriculture; moderate for rice
Class I Total	**3,486.4**	**1,097.8**	**187.3**	**463.2**	**2.4**	**5,237.1**		

TABLE 2

Class/ Sub-class	Province: Punjab	Sindh	NWFP+ FATA	Baloch.	N.A.	Pakistan	Major Limitation(s)	Agricultural Potential
	(thousand hectares)							
CLASS II — GOOD AGRICULTURAL LAND								
irIIe	61.2	—	68.7	—	9.4	139.3	Slight erosion hazard or past erosion effects	High for general agriculture; moderate for rice
irllr	59.4	—	4.1	—	0.2	63.7	Difficulty in irrigation due to high surface level or uneven surface	High in its present state; behaves as irl if levelled
irIIw	239.2	39.4	36.9	—	—	315.5	Restricted aeration due to high water-table; in parts, occasional ponding by rainwater	High in its present state; behaves as irl if drainage provided
irlls (sandy)	596.9	105.1	56.7	39.0	—	797.7	The somewhat sandy/ gravelly nature causing undue loss of water and nutrients	High for general agriculture; low for rice
irlls (clayey)	2,236.1	1,996.6	325.1	356.7	—	4,914.5	Clayey nature, making it difficult for preparation; slow permeability leading to surface ponding	High for general agri. (very high, if mechanically tilled); very high for rice
irlla (non-gyp)	472.4	118.1	5.2	3.0	—	598.7	Surface/patchy salinity and/or sodicity	High for general agri. and rice; very high if reclaimed
irlla (gyp)	14.0	67.7	—	45.2	—	126.9	Salinity with sufficient gypsum in the profile	High for general agri. and rice; very high if reclaimed
dlle	—	—	17.5	—	—	17.5	Minor erosion hazard or past erosion effects	High for general rainfed agriculture
dllc	—	—	10.2	—	—	10.2	Somewhat erratic moisture availability from rains	High for general rainfed agriculture
Class II Total	**3,679.2**	**2,326.9**	**524.4**	**443.9**	**9.6**	**6,984.0**		

TABLE								2
Class/	Province						Major	Agricultural
Sub-class	Punjab	Sindh	NWFP+ FATA	Baloch.	N.A.	Pakistan	Limitation(s)	Potential
			(thousand hectares)					
CLASS III — MODERATE AGRICULTURAL LAND								
irIIIe	—	—	31.7	—	8.5	40.2	Moderate erosion hazard; uneven surface	Moderate for common crops; high for crops providing a good surface cover
irIIIw	53.3	189.2	20.7	4.3	—	267.5	Restricted aeration due to high water-table, part with slight salinity	Moderate for most crops; high for rice; low for cotton and orchards
irIIIw (flooded)	—	—	3.1	—	2.7	5.8	Seasonal flooding by river/torrent water	Moderate to high for a few crops
irIIIs (sandy)	225.7	55.7	47.8	45.5	0.4	375.1	Too sandy/gravelly causing undue loss of water and nutrients	Moderate for general agriculture; no potential for rice
irIIIa (non-gyp)	790.8	257.0	25.7	29.4	—	1,102.9	Salinity and sodicity with no gypsum in profile	Moderate for general agriculture & rice; low for pulses, sugar cane & orchards
irIIIa (gyp)	138.1	675.7	—	31.4	—	845.2	Severe salinity with gypsum in the profile	Moderate for general agri. including rice; high when reclaimed
irIIIc	—	—	—	—	0.7	0.7	Unfavourable temperature regime for common crops	Moderate to high for a few crops
dIIIe	175.4	—	246.9	—	—	422.3	Moderate erosion hazard, low moisture availability	Moderate for rain-fed agriculture
dIIIw	509.8	319.3	20.8	7.9	2.0	859.8	Seasonal flooding by river or torrents	Moderate for flood-watered winter cropping
dIIIs (sandy)	8.6	—	54.6	—	0.6	63.8	Too shallow, or sandy/ gravelly soils with low moisture availability	Moderate for rain-fed agriculture
dIIIc	493.4	—	214.5	78.0	6.9	792.8	Low moisture availability from rains or unfavourable temperature regime	Moderate for rain-fed agriculture
Class III Total	**2,395.1**	**1,496.9**	**665.8**	**196.5**	**21.8**	**4,776.1**		

TABLE 2

Class/ Sub-class	Province						Major Limitation(s)	Agricultural Potential
	Punjab	Sindh	NWFP+ FATA	Baloch.	N.A.	Pakistan		
	(thousand hectares)							
CLASS IV — POOR/MARGINAL AGRICULTURAL LAND								
irIVw	12.7	—	—	—	—	12.7	Restricted aeration due to very high water-table, part with slight salinity	Low for general cropping, moderate for rice
irIVs (sandy)	469.3	14.8	10.4	11.8	44.3	550.6	Very sandy/gravelly or shallow soils	Low for a few drought-resistant crops only
irIVa (non-gyp)	96.7	32.5	0.9	—	—	130.1	Salinity & sodicity with very slow permeability	Low for a few salt/sodium-resistant crops only
dIVe	63.7	—	22.4	—	—	86.1	Moderate to severe erosion hazard; low moisture availability	Low for a few rain-fed crops only
dIVw	12.6	—	0.9	—	—	13.5	Restricted aeration due to high water table or deep flooding/ponding	Low for a few dry-farmed crops resistant to waterlogging/ flooding only
dIVs (sandy)	279.1	70.2	126.8	—	2.2	478.3	Too shallow, or sandy/ gravelly soils; part season-ally flooded; minor erosion hazard for dune soils	Low for a few drought-resistant rainfed/flood-watered crops or some forest species only
dIVx	40.8	25.3	—	—	—	66.1	Instability of soil surface due to risk of river cutting or sedimentation	Low for a few short durations, flood-watered crops or some forest species only
dIVc	465.0	76.6	420.2	688.0	—	1,649.8	Very low and erratic availability of moisture from rains or torrents	Low for a few drought-resistant rain-fed/ torrent-watered crops only
Class IV Total	**1,439.9**	**219.4**	**581.6**	**699.8**	**46.5**	**2,987.2**		

TABLE 2

Class/ Sub-class	Punjab	Sindh	NWFP+ FATA	Baloch.	N.A.	Pakistan	Major Limitation(s)	Agricultural Potential
	Province							
	(thousand hectares)							
CLASS V — GOOD FOREST OR RANGELAND								
V	—	—	70.1	—	101.1	171.1	No major limitation	High for forestry or range development
Class V Total	**—**	**—**	**70.1**	**—**	**101.1**	**171.1**		
CLASS VI — MODERATE FOREST OR RANGELAND								
VIe	21.4	—	575.2	—	17.3	613.9	Slight erosion hazard; unfavourable relief/soil character for arable use	Moderate for forestry or range development only
VIw	3.1	8.3	15.8	3.3	—	30.5	Too much saturation with water throughout the year for arable use	Moderate for development of grassland and wildlife
VIs (sandy)	237.3	—	183.5	—	32.5	453.3	Too sandy/gravelly/ stony soils; also unfavourable relief for arable use	Moderate for forestry or range development only
VIc	—	—	52.5	81.3	38.8	172.6	Somewhat low availability of moisture; unfavourable relief for arable use	Moderate for development of forestry or range only
Class VI Total	**261.8**	**8.3**	**827.0**	**84.6**	**88.6**	**1,270.3**		

TABLE								2
Class/	Province						Major	Agricultural
Sub-class	Punjab	Sindh	NWFP+ FATA	Baloch.	N.A.	Pakistan	Limitation(s)	Potential
			(thousand hectares)					
CLASS VII — POOR FOREST OR RANGELAND								
VIIe	466.2	—	1,742.7	1,805.0	504.2	4,518.1	Moderate erosion hazard & somewhat shallow soils; too stony/gravelly or unfavourable relief for arable use	Low for forestry or range development only
VIIw	28.0	19.0	12.0	0.8	—	59.8	Restricted aeration in the root zone throughout the year	Low for development of rangeland and wildlife only
VIIs (sandy)	2,251.4	295.0	819.4	1,537.4	137.4	5,040.6	Too shallow or sandy/gravelly soils; slight to moderate erosion hazard	Low for forestry or range development only
VIIa (non-gyp)	501.0	150.1	7.8	73.5	—	732.4	Salinity and sodicity, partly with high water-table	Low for controlled grazing only
VIIa (gyp)	2.5	314.8	—	69.3	—	386.6	Severe salinity, part high water-table	Low for controlled grazing only
VIIx	17.4	33.6	—	—	—	51.0	Instability of soil surface due to hazard of erosion or sedimentation	Low for controlled grazing or forestry only
VIIc	1,344.1	180.9	21.9	3,065.2	9.9	4,622.0	Low and erratic moisture availability	Low for development of forestry or range only
Class VII Total	**4,610.6**	**993.4**	**2,603.8**	**6,551.2**	**651.5**	**15,410.5**		

TABLE								2
Class/	Province						Major	Agricultural
Sub-class	Punjab	Sindh	NWFP+ FATA	Baloch.	N.A.	Pakistan	Limitation(s)	Potential
			(thousand hectares)					
CLASS VIII — AGRICULTURALLY UNPRODUCTIVE OR NON-AGRICULTURAL LAND								
VIIIe	1631.9	273.8	1,527.9	930.5	1,570.6	5,934.7	Severe erosion (gulling/wind blowing) hazard	No potential for any type of economic agriculture
VIIIw	336.9	252.7	10.0	133.7	8.9	742.2	Permanent marshy conditions or open water lakes	No potential for agriculture; moderate to high for preser-vation of wildlife
VIIIs (sandy)	1,457.9	1,112.4	1,201.7	8,730.7	252.4	12,755.1	Very sandy/gravelly/ stony or very shallow/ patchy soils; slight to moderate erosion hazard	No potential for any type of economic agriculture
VIIIa (non-gyp)	530.0	379.7	8.9	159.5	—	1,078.1	Severe salinity/sodicity; very slow permeability	No potential for any type of economic agriculture
VIIIa (gyp)	122.0	114.0	—	90.8	—	326.8	Very severe salinity	No potential for any type of economic agriculture
VIIIx	19.1	—	—	—	1.0	20.1	Instability of soil surface due to severe risk of erosion or burial by fresh sediments	No potential for any type of economic agriculture
VIIIc	61.9	582.1	0.2	553.9	0.9	1,199.0	Extremely low and erratic availability of moisture	No potential for any type of economic agriculture
VIIIz	—	—	225.3	—	916.0	1,141.3	Snow/ice/glacial cover or permafrost conditions	No potential for any type of economic agriculture
Class VIII Total	**4,159.7**	**2,714.7**	**2974.0**	**10,599.1**	**2,749.8**	**23,197.3**		
UNCLASSIFIED	**592.3**	**364.9**	**704.9**	**102.3**	**14.0**	**1,778.4**	—	—
GRAND TOTAL	**20,625.0**	**9,222.3**	**9,138.9**	**19,140.6**	**3,685.2**	**61,812.0**	—	—

Source: Soil Survey of Pakistan. N.d. Data files on Extent of Land Capability Classes and Subclasses in Punjab, Sindh, NWFP, Balochistan and Northern Areas. Lahore.

suitable for one crop is used for growing a less suitable one e.g., the general cultivation of fine basmati rice on well-drained loamy soils of northern Punjab, when these soils are ideal for the cultivation of maize, sunflower, groundnut and pulses. Rice continues to be cultivated, partly because of climatic suitability, partly because it brings a higher return.

Besides the economic need of the local people, this mismatch is also because of the general recommendations made by agricultural research and extension organisations regarding cropping and management practices. Such recommendations are usually worked out on a particular kind of soil under a specific set of ecological conditions at an experimental farm, but are offered for general use on all kinds of soils in varying environments. The lack of an agency responsible for co-ordination between agricultural research and extension services is one of the reasons behind the improper or irrational use of land.

In addition, specific infrastructure developments in certain areas have had an adverse impact on cropping patterns. An example is the setting up of sugar mills in the Thal and the consequent large-scale cultivation of sugar cane on sandy soils — this has aggravated the waterlogging problem in the area.

To assist in rational land use through a more judicious application of agricultural research, the Soil Survey of Pakistan carried out a detailed soil survey of all important agricultural research farms. It is currently collaborating with various agricultural organisations in the selection and characterization of soils for agronomic experiments. In addition, through the Transfer of Soil Technology to Agriculture Departments scheme, training was imparted to provincial agriculture extension staff. This will help them identify various types of soils in the field; appraise the soil for its potential and for its inherent limitations for different kinds of agricultural use; adopt appropriate soil management techniques to overcome relative limitations; and assist the farmer in obtaining the maximum output from the land while ensuring soil conservation for posterity. The training programme was carried out in 14 districts: Sheikhupura, Gujranwala, Okara, Sahiwal, Sargodha and Rahimyar Khan in the Punjab; Hyderabad, Nawabshah, Sanghar and Tharparker in Sindh; Peshawar, Mardan and Swat in the North West Frontier Province (NWFP), and Lasbela in Balochistan. About 2,700 members of the technical staff of the provincial Agriculture Departments, including over 800 officers holding supervisory or executive positions, have benefited from the training programme.

3. MAJOR PROBLEMS RELATED TO SOIL CONSERVATION

WATER EROSION

General Occurrence and Forms

Soil erosion by water is one of the most severe problems in Pakistan. It is most evident in areas with steep slopes which, though relatively unimportant for agriculture, serve as the chief source of wood, fruit and forage and are the primary source of subsistence for the local inhabitants. Water erosion is most noticeable in the Potowar Plateau and the surrounding area, which are used extensively for cultivation; but virtually all sloping cultivated land is adversely affected by this problem to some degree.

Water erosion occurs in various forms, depending on the type and gradient of sloping-land, the soil material, and the amount and intensity of rainfall. The most commonly observed forms are sheet, rill, gully and riverbank erosion. In the Potowar area, slight to moderate sheet and rill erosion of cultivated land is most common. A considerable part of the area has been gulled and steeply dissected, while pinnacle erosion, piping and slumping are also quite pronounced. The resulting landform presents a bizarre scene of sharp, silty pinnacles alternating with deep valleys and remnants of old terraces.

In addition, there are vast areas of eroded land at the foot of mountain slopes and in the Indus plains, the latter being found mostly along the edges of the old alluvial terraces and along the banks of rivers and streams. Landslides and mud flows are the other important forms of water erosion, occurring in the northern and western mountainous lands. Moreover, glacial erosion is a prominent feature of the Northern Areas, commonly associated with landslides.

Main Causes and Examples

Soil erosion by water in the Indus plains, the Potowar Plateau, the foot-slopes and mountain areas is understood to be largely the result of geological processes initiated some 20,000 years ago or even earlier. But the erosion process has undoubtedly been accelerated by people who, through ignorance, have disturbed the ecological equilibrium of these areas. The activities include:

1. Destruction of natural vegetation cover by uprooting or cutting plants for cultivation, fuel, timber or forage needs and discouraging regeneration through uncontrolled browsing by livestock — a common situation in the northern and western highlands and the Potowar Plateau.
2. Loosening of old stabilised loess surfaces by bulldozing, in an effort to bring land under the plough, hastening the slumping of loosened loess material and its ultimate erosion by run-off — a common observation in the Potowar.
3. Persistent shallow tillage of sloping loess soils, resulting in the formation of a somewhat impermeable plough pan near the soil surface, reducing the water infiltration capacity of the soil and increasing run-off — a normal practice followed in the cultivated parts of the Potowar.
4. Cultivation on steep slopes having shallow soils without adequate measures to control run-off, leading to mountain slopes being stripped of soil — a situation most commonly faced in the highlands with relatively high annual rainfall.
5. Inadequate or ineffective terracing, low and weak field embankments and poor water control, allowing frequent overtopping of rainwater and a torrential flow on to the lower slopes — a situation frequently seen in the Potowar and in the relatively humid parts of mountainous areas.
6. Allowing or leaving sloping cultivated land without crop cover during the rainy season — mainly because of the unavailability of efficient tillage implements or labour, and also because of poor farmer awareness about appropriate crops for these climatic conditions.
7. Burrowing by wild animals such as mice, porcupines and boar, which allows rainwater to rush into the soil, leading to piping and slumping — a common phenomenon in the cultivated lands of the Potowar region, especially along the edge of terraces.
8. Decrease in the organic content of cultivated soils as a result of continuous cropping without fertilizer or organic manure use. This results in decreased soil permeability and increased run-off — a normal situation in the rain-fed or *barani* areas.

Although most human activities have accelerated soil erosion, a number of positive steps have been taken also. Bench terraces with water-drop structures, gully-plugging of sloping land, reseeding rangeland and replanting forest land have all helped slow down soil erosion.

Magnitude of the Problem

The province-wise extent of area affected by different degrees of water erosion is given in Table 3.

General Effects

Various short- and long-term effects of water erosion include:

1. A continuing decrease in the depth, fertility and extent of productive soils, which serve as the base of the agricultural economy and on which the livelihood of the people of this country depends.
2. Decreased agricultural production and

TABLE 3

AREA AFFECTED BY WATER EROSION

DEGREE OF EROSION	PUNJAB	SINDH	NWFP+ FATA	BALOCH.	N. A.	PAKISTAN
	PROVINCE					
	(thousand hectares)					
Slight (sheet & rill erosion)	61.2	—	156.3	—	180.5	398.0
Moderate (sheet & rill erosion)	896.8	—	853.8	1805.0	25.8	3581.4
Severe (rill, gully &/or streambank erosion)	588.1	58.9	1765.1	829.6	504.2	3745.9
Very severe (gully, pipe & pinnacle erosion)	357.9	—	1517.0	—	1571.6	3446.5
Total	**1,904.0**	**58.9**	**4,292.2**	**2,634.6**	**2,282.1**	**11,171.8**

Source: Soil Survey of Pakistan. N.d. Reconnaissance Soil Survey Reports from 1965-88. Lahore.

increased dependence on agricultural imports.

3. Continued deterioration of rangelands and forest reserves resulting in decreased availability of livestock products (milk, meat, wool, hides, butter, etc.), fuelwood, timber and recreational opportunities.
4. Increased rates of sedimentation in water reservoirs and channels affecting their maintenance costs and life span.
5. More flooding of agricultural lands and town/village areas by increased run-off.
6. Adverse effects on communication systems (roads, railway lines, bridges, etc.) and the overall living environment, tremendously increasing maintenance and living costs.

The water erosion process is not, however, all destructive. Some positive developments do take place as a result of long-term geological erosion. For example, the recently formed valleys of the Potowar have developed through the redeposition of loess by local streams and flash floods. Raw loess is not suitable for agriculture because of its relative infertility, poor structure, extremely low porosity and steeply dissected relief. But deposited in the valleys, it helps in the formation of deep, fertile soils: the admixture of loess with alluvial material, and increased biological activity due to higher moisture availability in the valleys, improves the physical properties and organic content of the soil.

WIND EROSION

General Occurrence and Forms

Soil erosion by wind is a prominent feature of the sandy arid areas represented mainly by the Thal and Cholistan Desert in the Punjab, Thar Desert in Sindh, and the Kharan Desert in Balochistan. Wind erosion depends mainly on the nature of the soil, wind velocities at different times of the year, soil moisture conditions and land relief. Drifts formed by creeping soil, and shifts through suspension and saltation of soil particles are common forms of wind erosion occurring in sandy areas characterised by sloping to hilly land. Formation of *saif* (crescent-shaped dunes) or *barchans* by shifting sands is a prominent feature of flat land located between sand ridges. In addition, dry fallow fields, saline soil surfaces and loose dust in village and town streets supply enormous amounts of material to be transported to distant places by winds.

Main Causes and Examples

Very dry conditions and fast winds, generally attributed to climatic conditions flowing from the west of the subcontinent, are the most important causes of wind erosion. In addition, various human activities have been responsible for accelerating wind erosion to alarming degrees. These activities include:

1. Denudation of sandy ridges through overgrazing, burning or uprooting and felling of plants by nomads and local inhabitants — a situation commonly experienced in all accessible parts of the sand plains. This situation is especially critical around the populated areas of Thal and in a 10-kilometre wide strip adjoining irrigated land in Cholistan and Thar.
2. Extension of cultivation on stabilised and semi-stabilised sand ridges resulting in the loosening of surface soil and favouring the 'pick up' of sand particles by the wind — a common situation in the northern parts of Thal and the south-eastern parts of Thar.
3. Levelling of the lower parts of sand ridges in an effort to facilitate tillage/irrigation or to overcome waterlogging in the adjoining flat irrigated areas — a fact commonly observed in the northern part of the canal area of Thal.
4. Fallowing of land during dry windy periods, allowing abrasion of topsoil by winds — a common practice enforced by the general shortage of irrigation water in the Indus plains.
5. Untimely tillage and undue loosening of topsoil of dry fallow fields by some farmers, facilitating the blowing-off of finer soil particles — a practice usually followed in intensively cultivated areas, by farmers with adequate family labour and by those employing labour on a monthly or annual basis.

Magnitude of the Problem

The extent of area affected by various degrees of wind erosion in Pakistan is presented in Table 4.

The effects of wind erosion are mostly manifested in the form of:

1. Sedimentation/burial by sand of good agricultural land in the vicinity of active sandy ridges. This decreases the potential and finally reduces the extent of total productive agri-

TABLE 4

AREA AFFECTED BY WIND EROSION

DEGREE OF EROSION	PROVINCE					PAKISTAN
	PUNJAB	SINDH	NWFP+ FATA	BALOCH.	N. A	
	(thousand hectares)					
Slight	2,251.4	295.0	13.1	36.0	—	2,595.5
Moderate	279.1	70.2	3.8	143.6	—	496.7
Severe to very severe	1,274.0	273.8	19.6	100.9	—	1,668.3
Total	**3,804.5**	**639.0**	**36.5**	**280.5**	**—**	**4,760.5**

Source: Reconnaissance Soil Survey Reports from 1965-88.

cultural land.

2. Choking or burial of irrigation channels by sand, increasing their maintenance costs.
3. Decreased range potential of sandy ridges, resulting in increased strain on existing agricultural land for fodder production.
4. Depletion of very good and good agricultural land, due to the finer particles and fertile portions of their soil being blown off.
5. Blockade or disturbance of communication systems (farm roads, highways, railway tracks, etc.).

A few measures have recently been taken by relevant organisations to control soil erosion. These include reseeding of sandy ridges in relatively moist regions and semi-controlled stocking in some areas. But these are insufficient and, for most part, ineffective due largely to the nomadic nature of graziers and accessibility of the affected areas.

SALINITY AND SODICITY

General Concepts and Facts

The problem of soil salinity and sodicity has often been ranked highest among the factors responsible for restricting the pace of agricultural development in the country. The problem, though not as severe as commonly visualised or reflected by some organisations with vested interests, is certainly one that needs special attention. It is generally considered to be related to the present system of canal irrigation. But the country-wide reconnaissance soil surveys have established that saline or saline-sodic soils occupy specific physiographic positions in the Indus plains, and are the result of long-term natural processes. Hence most of the existing saline/saline-sodic soils are not related to the present irrigation system; and their formation is mainly the consequence of gradual redistribution of salts already present in the soil. Salinity must, therefore, be regarded as one of the products of soil-forming processes which have remained operative over several centuries.

Main Causes and Examples

The salinity/sodicity problems vary, depending mainly on the soil parent material, landform, relief, climate and land use. Major roles in soil salinization and sodication have been played by the calcareous parent material of most soils, the physiographic and hydrological interaction occurring in a landform (e.g., levees affected by long-term ponding in adjoining areas; lateral seepage from streams/basins affected by a rising water-table; and collected water run-off) and the micro-relief of a site. Climate, however, has been the chief determinant of the kind and extent of salinity in different parts of the country. In general, salinity is least extensive in the northern, sub-humid parts, and most extensive in the southern, arid parts of the country. Salt composition, similarly, varies with climate, being dominated by carbonates in the sub-humid regions, by carbonates and sulphates in the semi-arid parts and by sulphates and chlorides in the arid areas.

A considerable area of cultivated land has undoubtedly been affected by this problem after the development of the canal irrigation system. This kind of salinity, identified as secondary salinity, is relatively temporary and can be easily eliminated by adopting appropriate rehabilitation measures. The important phenomena/activities which have contributed to the development of secondary salinity are:

1. Lateral seepage of water from the canal system and its evaporation from the surface of adjoining soils, after dissolving salts in the lower parts of the soil profile — a situation commonly occurring in old river terraces (which generally have slowly permeable layers and salt accumulations at around 1-metre depth) and in piedmont plains/basins which are underlain by impermeable bedrock within a 2-metre depth of the surface.
2. A rising water-table due to excessive percolation of water from the canal system, and capillary rise and evaporation of saline groundwater — a situation commonly found in basins and abandoned channels of relatively recent river plains.

3. Inadequate availability of water from rains or irrigation. If the leaching requirements of soils are not met, it results in the net upward movement or concentration within the soil profile, of salts liberated by the soil material or left as residue by irrigation water — a normal situation in cultivated (mainly clayey) arid and semi-arid parts of the Indus plains, where canal supplies are not commensurate with the irrigation requirements of annually cropped areas. Loamy soils are less affected by this situation as leaching requirements are better satisfied, especially when intensively irrigated crops like sugar cane and berseem are grown in rotation with other crops.
4. Excessive irrigation of old saline soils located within cultivated fields (especially when surrounding fields are left fallow/unirrigated). This results in the lateral migration of salts, through irrigation water, towards relatively dry fields and their accumulation at the surface of these fields through evaporation — a common phenomenon in old river terraces, where efforts to reclaim severely saline/saline-sodic soils through additional water supplies is being made without prior provision of a drainage system.
5. Irrigation through tubewell pumping of groundwater of poor/marginal quality with high salt concentration values, sodium adsorption ratios (SAR) or residual sodium carbonates (RSC), causing gradual salinization/sodication of soils — a situation commonly seen in the Salinity Control and Reclamation Project (SCARP) areas as well as in some areas irrigated by private tubewells.
6. Salt contamination by run-off passing over saline soils and ponding in, or being absorbed by, relatively low-lying soils — a situation generally seen when the embankments of fields located near saline soils are low and improperly maintained, especially common at the foot of escarpments of old river terraces.
7. Salts from saline soils transported by winds and spread over the soil surface — generally occurring during the dry early part of summer, when salt efflorescence at the surface is maximum and windstorms are frequent in almost all of the Indus plains.

Although the canal irrigation system and the misuse or inefficient use of normal soils by people are the two major causes of secondary salinity in the Indus plains, human efforts to reverse salinization/sodication through various reclamation measures cannot be ignored. Among these measures, the use of amendments (mainly gypsum which has been subsidised for this purpose), excessive irrigation for leaching of salts (through a highly subsidised supply of additional water) and drainage through open drains/tile drains/tubewells under SCARP, are the most important ones. As a result of these measures, a considerable portion of soils affected by salinity, especially those affected by secondary salinity, have been rehabilitated.

Types of Saline and Sodic Soils

The many types of saline and saline-sodic soils that occur can be classified on the basis of age, the nature of salinity/sodicity, the severity of the problem and the ease/economics of reclamation. The following general groupings have been adopted for easy understanding:

Soils with Surface/Patchy Salinity and Sodicity

These commonly occur in the form of scattered patches within cultivated fields. They are products of an incomplete natural process of salinization and sodication, which normally begins in small patches, occupying slightly higher, indistinctly convex shapes — these serve as shedding sites for scanty rainwater. The rainwater is absorbed by the adjoining lower areas, dissolving salts from the soil in its downward and lateral movement; the water rises through capillary action and evaporates from the convex sites, leaving behind a salt residue on the surface. This salinity is of relatively recent origin. While in some parts, this process has been reversed through reclamation efforts and intensive agricultural use, in other parts it has been accelerated through inadequate watering and a rising water-table after the introduction of the canal irrigation system.

The salinity/sodicity effect on most of these soils is restricted to the top 10-30 centimetres, while the subsoil is still non-saline. Although a significant portion of such saline soils do not have sodicity problems, for practical purposes all saline patches may be regarded as affected by both salinity and sodicity. The reclamation of these soils is relatively easy and does not, in most cases, require a drainage system. In some areas generally recognised as slick spots, salinity has affected soils to a greater (more than 1 metre) depth. These soils require about 3-4 tonnes of gypsum per hectare for their effective reclamation.

Soils with surface/patchy salinity and sodicity include those which have been misused by people. Such soils are commonly encountered in the SCARP areas and in some areas irrigated by low-quality tubewell water. Many SCARP and private tubewells pump water with high electrical conductivity (EC), SAR or RSC values. Water with high EC value is used limitedly, as the emergence of salts on the soil surface alerts the farmer to the possible salinization of land.

What is more damaging and less apparent is the use of water with high SAR/RSC but low EC values, which is quite extensive. Salinity is not generally visible on the surface of soils irrigated by such water. But their use greatly favours the sodication process and results in the gradual deterioration of the soil structure, decreased soil permeability, and increased soil pH and exchangeable sodium percentage (ESP), which may reach alarming degrees and severely affect the growth of crops. Since farmers generally remain unaware of this development, the sodication process continues for a long period, until the soil stops giving any return to the farmer. Such deteriorated soils generally have a 2-3 millimetre-thick, highly alkaline (sodic) crust on their surface, which severely hampers seed germination. The rehabilitation of these soils essentially requires the use of amendments i.e., 2-3 tonnes of gypsum per hectare.

Gypsiferous Saline/Saline-Sodic Soils

Soils included under this type are severely saline throughout their profile, generally have a 1-2 centimetre-thick salt layer on the surface, mixed with some gypsum in powder or crystal form. These soils occur mainly in the central and southern parts of the Indus plains as uncultivated patches with moist surfaces. They are old soils, formed under an arid climate on levees affected by water seepage from adjoining old streams and in basins collecting saline run-off. They contain adequate amounts of hygroscopic salts and, therefore, remain moist for most of the year, except for those occurring in very dry areas (e.g., the Cholistan Desert). The efflorescence of salts in these soils is understood to have been greatly accelerated in some areas by the rise of water-tables in adjoining land after the introduction of the canal irrigation system.

A small part of the area under these soils has recently been brought under irrigated cultivation, resulting in their partial reclamation. A major requirement for reclamation is leaching through heavy irrigation, and the provision of drainage where required. An important consideration for their amelioration is that surface salts should not be removed by scraping, as is commonly done, but must be passed through the soil with irrigation water.

Porous Saline-Sodic Soils

These soils occur mostly as large uncultivated patches with a sparse cover of natural grasses, shrubs and stunted trees. They are typical of a semi-arid climate, being formed mainly on levees affected by seepage from adjoining old streams or fluctuating past water-tables in adjoining, relatively low areas. The salinization process is quite advanced so that the whole soil profile (to more than 150 centimetres depth) is affected by salinity and sodicity. The salinity is relatively old, probably a few thousand years older than the present irrigation system.

Some of these soils have been brought under irrigated agriculture and support a few crops, mainly rice and wheat, that give moderate to low yields. These soils are sufficiently porous to be moderately to slowly permeable. They cannot be effectively reclaimed unless about 10-12 tonnes of gypsum per hectare (or an equivalent amount of some other amendment) are added. A drainage system is not necessary, except in cases where drainage is impeded. Reclamation is feasible only where good quality groundwater is available for irrigation.

Dense Saline-Sodic Soils

These soils have undergone severe sodication after salinization, which has caused structural instability and reduced water permeability. They are mostly formed in basins which have remained relatively moist due to run-off collection or intermittent flooding — a condition favouring the sodication process. Like porous saline-sodic soils, their salinity and sodicity is fairly old, probably a few thousand years older than the canal system. Sodication in these soils has, however, reached a stage where its reversal cannot be effected by normal means.

These soils mostly occur in the form of large, uncultivated patches with almost no vegetation cover. Efforts have been made to bring a few of these areas under irrigated cultivation but they can support only rice and wheat, which give very low yields. Reclamation of these soils is extremely difficult even if gypsum (or any other amendment) is used and cannot be accomplished unless an effective (short-spaced) drainage system is installed and the subsoil opened by deep ploughing or chiselling. Normally, 20-30 tonnes of gypsum per hectare is required for their amelioration. Presently, reclamation is not considered feasible because of the exceptionally high costs associated with it and the scarcity of irrigation water.

Magnitude of the Problem

The province-wise extent of area affected by various types of salinity and sodicity is given in Table 5.

WATERLOGGING

General Concepts and Facts

The problem of waterlogging in Pakistan has been reported differently by different agencies, depending on the purpose of their investigation. Their reports have, in general, presented a gloomy picture of waterlogging in the country — drawing the attention of development planners and putting an unnecessary drain on the economy. The problem is not as grave as has generally been reported, especially by agencies concerned with drainage system solutions. Waterlogging is limited mainly to a few specific areas because of their inherent hydrological characteristics. Though these areas may cover only a small fraction, say 5-10%, of a landscape most people generally visualise the whole of the landscape as being waterlogged. Such an understanding, when applied to the entire country, leads to alarming figures.

Also, the concept of waterlogging is not well understood. Many people regard land as waterlogged if the water-table occurs within a 3-metre (10-foot) depth of the surface. The soil surveys found that almost no crop suffers from excessive moisture as long as the water saturation zone remains below a 1.5-metre depth in all, except sandy types of soil. In fact, crops on sandy soils benefit, rather than suffer, from a rise in the water-table to within 1 metre of the surface. The inherent dry condition of these soils is then offset by below-ground irrigation from groundwater, especially fresh groundwater from canal seepage, as is usually the case in the canal-commanded areas.

Main Causes and Examples

Like salinity and sodicity, waterlogging is mainly a consequence of old hydrological processes — still operative in much of the area with specific geomorphological and physiographic characteristics such as playas and closed basins in hilly areas, infilled glacial lakes in the mountains, lagoons and tidal areas along the coast, and oxbow lakes, backswamps and open basins

TABLE 5

SOILS AFFECTED BY VARIOUS TYPES OF SALINITY AND SODICITY

TYPE OF SOIL	PROVINCE					PAKISTAN
	PUNJAB	SINDH	NWFP+ FATA	BALOCH.	N. A.	
	(thousand hectares)					
Soils with surface/patchy salinity and sodicity						
Irrigated	472.4	118.1	5.2	3.0	—	598.7
Unirrigated	—	—	—	—	—	—
Gypsiferous saline/saline-sodic soils						
Irrigated*	152.1	743.4	—	76.6	—	972.1
Unirrigated	124.5	428.8	—	160.1	—	713.4
Porous saline-sodic soils						
Irrigated*	790.8	257.0	25.7	29.4	—	1102.9
Unirrigated	501.0	150.1	7.8	73.5	—	732.4
Dense saline-sodic soils						
Irrigated	96.7	32.5	0.9	—	—	130.1
Unirrigated	530.0	379.7	8.9	159.5	—	1078.1
Total	**2,667.5**	**2,109.6**	**48.5**	**502.1**	**—**	**5,327.7**

Source: Reconnaissance Soil Survey Reports from 1965-88.

* Some of this land is not yet irrigated; but as it is located within the canal commands, it is likely to be irrigated in the near future.

(channels) connected with active streams in the river plains. People have, nevertheless, aggravated the problem through various activities including the introduction of the canal irrigation system. The latter is of importance, since the bulk of waterlogged land currently falls within the boundaries of canal-command areas.

The major cause of recent waterlogging in the cultivated areas is excessive percolation from the canal system, which builds up the groundwater level. Other human activities which have significantly contributed towards a rise in the groundwater-table include:

1. Cultivation of high-delta crops on moderately to highly permeable soils, resulting in excessive percolation of irrigation water — e.g., irrigated rice grown on loamy soils in northern Punjab and sugar cane grown on sandy soils in Thal.
2. Obstruction of natural drainage channels (old river courses) through the construction of buildings, roads, embankments, etc. This restricts the flow of underground water through these channels, which in turn are effected by increased flow during the rainy season.
3. Improper alignment and poor maintenance of artificial open-ditch drainage systems, which cannot efficiently remove excess water from the fields. Also, illegal embankments block the passage of stormwater into the system —

TABLE 6a

AREA WITH WATER-TABLE WITHIN A 1.5-METRE DEPTH: SOIL SURVEY OF PAKISTAN

WATER-TABLE DEPTH	PROVINCE: PUNJAB	SINDH	NWFP+ FATA	BALOCH.	PAKISTAN
(metres)	(thousand hectares)				
Non-saline soils (part with patchy/surface salinity)					
1.0-1.5	239.2	39.4	39.7	—	318.3
0.5-1.0	78.6	189.2	20.7	4.3	292.8
Under 0.5*	368.0	280.0	30.3	137.8	816.1
Total (under 1.5)	685.8	508.6	90.7	142.1	1,427.2
Saline soils (porous, dense and gypsiferous)					
Total (under 1.5)	10.0	116.0	1.1	—	127.1
Total area waterlogged	**695.8**	**624.6**	**91.8**	**142.1**	**1,554.3**

* Much of the soils in this category (except the sandy soils) have patchy surface salinity; includes open water ponds/lakes.

a situation found almost throughout the area where drainage ditches were constructed many years ago.

4. Inefficient disposal of excess rainwater, collecting in low-lying areas, resulting in ponding and deep water percolation.

Magnitude of the Problem

Estimates of waterlogged areas made by the Soil Survey of Pakistan from survey reports, are given province-wise in Table 6a.

Drainage conditions are, however, understood to have changed significantly since the completion of the surveys. In some parts of the Punjab, Sindh and the NWFP the extent of waterlogged area is said to have increased due to continual canal water seepage; it has decreased considerably in regions where groundwater is withdrawn, through tubewells, for irrigation and urban use or for drainage. Furthermore, there are yearly and seasonal fluctuations in water-tables, depending on the amount of precipitation received, river discharges, groundwater withdrawals, etc.

The latest record of waterlogged area is available from the Water and Power Development Authority (Report of the National Commission on Agriculture, 1988). This indicates that, on average, about 2.12 million hectares out of a gross surveyed area of 16.4 million hectares have a water-table within a 1.5-metre depth of the surface. The figures given in the table relate to the pre-monsoon (April/June) season while the extent is reported to be about twice this during the post-monsoon (October) season. See Table 6b.

FLOODING AND PONDING

General Occurrence

Flooding by torrents/rivers and ponding through collection of rainwater are two important prob-

TABLE 6b

AREA WITH WATER-TABLE WITHIN A 1.5-METRE DEPTH: WATER AND POWER DEVELOPMENT AUTHORITY

YEAR	PROVINCE				PAKISTAN
	PUNJAB	SINDH	NWFP+ FATA	BALOCH.	
(million hectares)					
1979	1.22 (12%)	1.19 (21%)	0.03 (5%)	0.05 (34%)	2.49 (15%)
1984	0.79 (8%)	1.17 (20%)	0.05 (10%)	0.04 (29%)	2.05 (13%)
1985	0.49 (5%)	1.22 (21%)	0.04 (7%)	0.05 (31%)	1.80 (11%)
1986	0.77 (8%)	1.27 (22%)	0.04 (7%)	0.06 (36%)	2.14 (13%)
Average	0.82 (8%)	1.21 (21%)	0.04 (7%)	0.05 (32%)	2.12 (13%)

lems related to the conservation of soil resources. While torrent/river flooding is restricted to narrow strips of land along river streams, ponding is widespread on agricultural land.

Flooding is generally recognised as a problem and flood protection embankments have been constructed along almost all main streams. But ponding, which leads to huge reductions in the annual yield of many important crops, has largely been ignored.

Flooding and its General Effects

Different types of flooded land differ in their agricultural potential. In mountainous areas, the flooded parts of river valleys generally have sandy and gravelly soils, which are of little value to agriculture. In the plains, the upper parts (as in the Punjab) have silty soils which are suitable for winter cropping using residual flood moisture and sandy soils which are suitable for riverine forests; the lower parts (as in Sindh) have a mixture of clayey and silty soils almost all of which are suitable for winter cropping using residual moisture from the floods. In the active flood plains, the physiographic position of the land determines the frequency, depth and duration of flooding — a fact which should be seriously considered while planning agricultural settlements and building permanent and temporary structures.

The main adverse effects of flooding include:

1. Preventing the cultivation of land during the summer season, decreasing annual agricultural production.
2. Destruction of farm houses and villages located in relatively low areas. This includes farm machinery (plus installed tubewells), resulting in annual financial losses, and at times, human lives.
3. Frequent burial of fertile soil by fresh, relatively infertile sediment laid down by flood water, leading to reduced crop yields.
4. Washing away of agricultural inputs, like fertilizers and pesticides, made by the farmer during the previous cropping season.
5. Erosion and cutting away of agricultural land located along stream banks.

These losses are partly compensated by some benefits accruing to the farmer from flooding, as in:

1. Availability of free and good quality river water for raising winter crops in case of river-flooded land, and of torrent water for raising summer crops (and in some parts, winter crops) in the case of torrent-flooded land. (The latter conditions are generally recognised as torrent watering instead of torrent flooding since the torrent water is diverted through unweired channels for the irrigation of cultivated/forested land).

2. Annual leaching of salts from the soils, eliminating the problem of salinity and sodicity.
3. Relatively low cost of pumping groundwater for irrigated cropping as the water-table is at shallower depths.

Magnitude of the Flooding Problem

The areas affected by river or torrent flooding vary from year to year, depending largely on amount of precipitation received and summer temperatures, which affect the melting of snow and glaciers. The province-wise extent of area annually flooded by rivers and watered by torrents is given in Table 7.

Ponding Problem and its Magnitude

Ponding restricts the aeration of plant roots, affecting adversely crop growth and yield. Rainwater ponding is a problem specially in the northern parts of the Indus plains. It occurs in relatively low-lying or basin areas, which collect run-off from the surrounding higher land. It may also occur in flat areas with soils of slow permeability, if these are embanked (as is the case of cultivated land) and the amount of rainfall received is high. In Pakistan, the summer monsoon rains are usually torrential and often result in ponding of large tracts of land for significantly long periods, especially in the rice-growing areas. This creates a serious drainage problem which is not related to the water-table and cannot be tackled by normal drainage measures i.e., sub-surface drains and tubewells. It, therefore, needs special attention.

The province-wise extent of area affected by varying degrees of ponding during the rainy season is presented in Table 8.

SOIL PANS

Most of the cultivated land of Pakistan has remained under the traditional country plough for many decades. The plough penetrates the soil upto a fixed depth of 7-8 centimetres. Continuous tillage to the same depth has resulted in the formation of a relatively dense layer, recognised as a plough pan, in a large portion of the cultivated area. The plough pan, which lies at a depth of 8-20 centimetres, is specially pronounced in soils which are high in silt. It acts as a weak barrier to the penetration of water and plant roots: irrigation water accumulates just above this pan and enters the subsoil only after creating temporary ponding conditions; plant roots tend to spread horizontally above the pan. These conditions inhibit or adversely affect crop growth, especially during the initial stages.

A plough pan is of much greater importance in the sloping areas of the Potowar, where most of the soils are silty and farming with the coun-

TABLE 7

AREA* ANNUALLY FLOODED/WATERED BY RIVERS AND TORRENTS

NATURE OF FLOODING	PROVINCE					PAKISTAN
	PUNJAB	SINDH	NWFP+ FATA	BALOCH.	N. A.	
	(thousand hectares)					
River flooding	759	545	49	6	5	1,364
Torrent flooding/watering	156	218	227	592	—	1,193
Total	**915**	**763**	**276**	**598**	**5**	**2,557**

Source: Reconnaissance Soil Survey Reports from 1965-88.

* Not including the riverbeds.

TABLE 8

AREA AFFECTED BY PONDING DURING THE RAINY SEASONS

PROVINCE DEGREE OF PONDING	PUNJAB	SINDH	NWFP+ FATA	BALOCH.	PAKISTAN
			(thousand hectares)		
Frequent, deep ponding	163	—	—	—	163
Frequent, shallow ponding	202	—	12	—	214
Occasional, shallow ponding	326	—	233	—	559
Total	**691**	**—**	**245**	**—**	**936**

try plough is the general rule. The resulting reduced permeability of the soil may be regarded as one of the major factors responsible for high run-off after the rains with increased soil erosion. The area where plough pans are significantly affecting crop yields is estimated to be quite large, although it cannot be presented in quantitative terms as this would require more detailed soil data.

The recent introduction of deep ploughing and chiselling have offered a solution to this problem. But these techniques are being introduced indiscriminately as normal tillage operations, as a way of improving crop yields. This may have a detrimental effect on soils with a good subsoil structure, since it may lead to structural deterioration and reduced productivity after an initial two to three years of high yield.

In addition to plough pans, a naturally-formed weakly-cemented layer of lime-rich silty material is almost invariably encountered within a 1.5-metre depth in the Potowar and in the old river terraces in the Indus plains. This layer, recognised as the *kankar* zone, is slowly permeable, restricts the infiltration of water and plant roots, and checks leaching of salts from the soil surface to lower depths. Water accumulating just above this layer for significant periods, after irrigation or rain, affects crops adversely, especially when they are near maturity, and is responsible for decreased crop yields. Soil underlying the *kankar* zone is generally high in silt and only slowly permeable — a condition which favours the accumulation of lime and soluble salts just above it.

SOIL NUTRIENT DEGRADATION

General Nature and Occurrence

A significant portion of cultivated soils are low in certain important plant nutrients. This nutrient deficiency, mainly of nitrogen, phosphorus, potassium, sulphur, zinc, copper, iron and manganese, has been indicated by various fertilizer experiments conducted on soils in different parts of the country. The problem is particularly severe in the case of irrigated sandy soils, moderate in the case of irrigated loamy soils of old river terraces, and of a minor degree in other soils.

Main Causes

The main causes of soil nutrient depletion are:

1. Leaching of nutrients by irrigation water (sandy soils and the more permeable loamy soils are commonly over-irrigated), and by rain in high rainfall areas.

2. Continuous cultivation of soils over long periods, with almost unchanged cropping patterns dominated by exhaustive crops like wheat, sorghum, maize, cotton, sugar cane and mustard.
3. A hot and arid climatic regime in many parts of the country, leading to high decomposition rates of organic matter and a net loss in the organic content of soils.
4. Inadequate addition of organic fertilizers or green manuring, resulting in a constant decrease in the organic content of soils.
5. Continued use of single-nutrient fertilizers (like urea) which has lead to increased extraction and hence deficiency of other plant nutrients from the soil.

Since regular surveys to assess the nutrient status of soils have not been conducted, it is not possible to quantify the problem of soil nutrient degradation. However, the extent of sandy soils presently under cultivation, which are most threatened by the problem, is presented in Table 9.

SURFACE SLAKING OR CRUSTING

A large proportion of soils in the country are mainly made up of silt or very fine sand. While medium to coarse sand and clay particles (by virtue of their general occurrence as aggregates) are relatively heavy and difficult for the water to transport, silt and very fine sand particles, occurring as isolates and being lighter in weight, are easily water-borne. When the topsoil is dominated by the latter, its surface material tends to flow with rain or irrigation water, and is deposited as a thin crust on the soil surface, subsequently sealing it — a phenomenon called surface slaking. Since this crust has almost no clay, it seldom cracks on drying and generally keeps the surface completely sealed unless broken manually by proper tillage implements. Its major impact is that it restricts the infiltration of irrigation or rainwater into the soil, and blocks air and temperature exchange between the soil and the atmosphere, severely hampering plant growth.

Surface slaking in silty soils is further favoured

TABLE 9

ESTIMATES OF THE EXTENT OF CULTIVATED SANDY SOILS AFFECTED BY NUTRIENT DEGRADATION

SOIL TYPE	PROVINCE				PAKISTAN
	PUNJAB	SINDH	NWFP+ FATA	BALOCH.	
	(thousand hectares)				
Loamy sands					
Irrigated	695.0	70.5	58.2	57.3	881.0
Rainfed	279.1	70.2	126.8	—	476.1
Sandy Loams*					
Irrigated	596.9	105.1	56.7	39.0	797.7
Rainfed	8.6	—	54.6	—	63.2
TOTAL	**1,579.6**	**245.8**	**296.3**	**96.3**	**2,218.0**

Source: Reconnaissance Soil Survey Reports from 1965-88.

* Includes shallow soils underlain by sandy material.

by the low organic content and the high percentage of exchangeable sodium in the topsoil; in the latter condition, even soils having low silt and high clay contents are affected by surface slaking, since sodium facilitates the dispersion of clay aggregates. A similar situation develops when soils are irrigated with poor quality groundwater with high SAR values. Crusts formed by sodic water restrict air, water and temperature exchange with the soil, which is detrimental to germinating seeds and sprouting plants.

The problem of surface slaking or crusting is widespread because of the extensive occurrence of silty soils, and is understood to affect crop production considerably when preventive measures are not adopted. It is, however, difficult to quantify the problem until detailed soil surveys are carried out.

NON-AGRICULTURAL USE OF PRIME AGRICULTURAL LAND

The use of prime agricultural land for non-agricultural purposes is one of the major problems vis-a-vis the conservation of natural resources. These uses include:

1. The unplanned expansion of towns and industrial estates e.g., the growing city of Lahore is encroaching on good and very good agricultural lands on its southern and eastern sides.
2. Mining of fertile topsoil for brick casting, construction of flood protection embankments and earthfill, reducing the agricultural potential of affected land — generally found in the areas around towns located in the plains.
3. The dumping of town and village refuse, sewage water and factory effluent on productive land, polluting the soil and rendering it unsuitable for agricultural use — a common situation around most large towns located in the plains.

It is hard to estimate the annual loss of agricultural land as the severity of this problem varies from place to place. In general, however, losses are relatively high around large cities located in the river plains like Lahore, Multan, Faisalabad, Gujranwala, Sialkot, Sargodha, Peshawar and Nawabshah, and low around towns which are small and are located outside the plains (along the foothills) like Karachi, Islamabad, Quetta, Hyderabad and Sukkur.

4. SUGGESTED STRATEGIES FOR SOIL CONSERVATION

The nature and severity of the problems leading to soil degradation vary for different parts of the country. The strategies for resource conservation have, therefore, to be site- as well as problem-specific. In light of the major problems outlined earlier, different strategies are being suggested for different areas.

STRATEGIES FOR THE CONTROL OF WATER EROSION

Mountain Areas

1. Protection of existing natural vegetation from excessive browsing, illegal cutting, uprooting and burning, etc., through active supervision by concerned organisations like the Forest Department.
2. Regreening bare slopes, where feasible, through reseeding and replanting with suitable plant species; proper care of growing plants until they are fully established and effective control, thereafter, on grazing particularly by nomadic livestock.
3. Restricting cultivation on steep slopes. If land has already been cleared for cultivation, such slopes should either be replanted or reseeded with suitable species; or proper bench terraces should be constructed and maintained.
4. Provision of alternate sources of fuel, food, fodder and other requirements for the local people.
5. Generally improving accessibility and the infrastructure necessary for administrative control and social welfare development.

Potowar Plateau

1. Protection of existing natural vegetation from excessive browsing, illegal cutting and uprooting/burning by the local inhabitants and nomads, through active supervision by concerned organisations like the Forest Department.
2. Protecting loess terrace remnants from being levelled for cultivation; the remnants along with their side slopes should, where feasible, be replanted to stabilise them.
3. Making mechanical power available to the common farmer for deep ploughing, chiselling and subsoiling where required, and to improve existing cultivated terraces to enhance water absorption and minimise run-off from sloping land.
4. Construction and improvement of bench terraces and water-drop structures, strengthening of field and terrace embankments and adoption of contour-ploughing and strip-cropping techniques on gently sloping, unterraced, cultivated land.
5. Growing strong-rooted plant species along the banks of gullies and active streams.
6. Plugging animal burrows with stone or earth.
7. Providing proper vegetation cover or leaving stubble on the fields during the rainy season.
8. Formulating soil-specific cropping patterns that include crops, such as groundnut, that provide effective soil cover during the rainy season.
9. Growing and ploughing-in of leguminous or green manure crops at regular intervals, to improve the organic content of soils and to reduce its erodibility.

River Plains

1. Afforestation of stream banks, especially those subjected to deep flooding, sedimentation or erosion by the rivers.
2. Local levelling/terracing of non-gullied escarpments and planting with suitable salt tolerant and drought-resistant species.
3. Proper levelling of fields, to minimise run-off.

STRATEGIES FOR THE CONTROL OF WIND EROSION

Thal, Thar, Cholistan and Kharan Desert Areas

1. Effective control of grazing, and a check on the uprooting, cutting and burning of natural vegetation growing on sandy ridges.
2. Restriction on the cultivation of sandy ridges, a check on their levelling and the use of their sandy material as cover for adjoining valley soils under arable use; scraping back sand from already affected soils onto adjoining ridges, and restabilization of ridges through vegetative cover.
3. Stabilization of sand dunes and activated parts of sandy ridges in areas adjoining irrigated land through reseeding with adapted plant species, followed up with proper plant care and control of grazing.
4. Growing shelter hedges around cultivated fields located near active sandy ridges and exposed to the wind.

The River Plains

1. Persuading farmers to avoid dry tillage of their fields, especially during dry and windy periods such as early summer.
2. Discouraging the removal of vegetative cover from sandy ridges, especially those located in arid and semi-arid areas, by providing alternative sources of fuel and other basic requirements.

STRATEGIES FOR THE CONTROL OF SALINITY AND SODICITY

Canal-Irrigated Areas

1. Adequately meeting the water requirements of crops and soils, by limiting the cropped area to match available water supplies, fully satisfying their leaching requirements.
2. Reclaiming saline and saline-sodic soils

through the use of gypsum. Heavy irrigation should be used only when a drainage system exists or when natural drainage, a permeable substrata, is available. If these conditions cannot be met, biological measures i.e., growing salt tolerant plants, should be used.

3. Temporarily embanking and slightly lowering the level of small saline patches within cultivated fields would effectively leach their excess salts; for the reclamation of slick spots, gypsum would have to be used (1-1.5 kilograms per square metre of the affected area) alongside the above practice.

Tubewell (or Canal Plus Tubewell) Irrigated Areas

1. Active guidance and supervision of farmers using tubewell water, by providing timely information e.g., on the quality of their tubewell water, as well as by explaining or demonstrating the consequences of using low-quality water for irrigation. The maximum permissible EC/salt concentration, SAR and RSC values of irrigation water for different kinds of soils may be standardised as given in Table 10.
2. Disposal of poor quality groundwater pumped by SCARP or private tubewells through drainage ditches or canals and distributaries, instead of use for irrigation; locally, such water may be used for the irrigation of sandy soils and for growing a few salt tolerant crops.
3. Amelioration of soils affected by poor quality water through the application of gypsum (2-3 tonnes per hectare) since most of these soils are afflicted only by sodicity.
4. Popularising the continuous use of gypsum on soils already affected by poor quality water or where irrigation with poor quality water is unavoidable.

Uncultivated Areas

1. Proper embankment of uncultivated saline soils to check salt contamination, through run-off, of adjoining low-lying cultivated areas.
2. Planting vegetation which could provide surface cover against salts blown by winds or which could improve soil fertility. Local plants, adapted to saline and drought conditions with some economic/social value in terms of forage, wood and shade, would be preferable.

TABLE 10

PERMISSIBLE UPPER LIMITS FOR IRRIGATION WATER

SOIL TYPE	PERMISSIBLE UPPER LIMITS[1]				
	Electrical Conductivity	Salt Concentration		Sodium Adsorption Ratio	Residual Sodium Carbonate
	mmho/cm	meq/l	ppm	$mmol^{1/2}/l^{1/2}$	meq/l
Loamy[2]	0.75	7.5	500	13	2.5
Sandy[3]	2.25	22.5	1,500	30	5.0
Clayey[3]	0.50	5.0	350	8	1.5

1. These limits correspond to the threshold between medium and high levels of salinization/sodication.
2. From Bolt, G. H. and M. G. M. Bruggenwert. 1978. *Soil Chemistry Basic Elements*. Amsterdam: Elsevier Scientific Publishing B.V.
3. Figures have been estimated to allow for relatively high or low permeabilities, cation exchange capacities and saturation percentages.

STRATEGIES FOR THE CONTROL OF WATERLOGGING

1. Control of excessive water seepage by lining canals and distributaries in sandy soil areas.
2. Encouraging the installation of small, shallow tubewells to pump groundwater, accumulated from canal seepage, for irrigation.
3. Effective control of irrigation in the more permeable soil areas, by not allowing the cultivation of rice on loamy soils and of sugar cane on sandy or somewhat sandy soils, through acceptance of advice given by agriculture or irrigation extension staff; farmers need to know the value of light, but more frequent applications of water on relatively sandy soils.
4. Provisions must be made for an effective drainage system (preferably with open ditches) in the waterlogged areas; the drains could be designed to keep the water-table below a 1.5-metre depth in areas growing cotton or fruit trees, and below 1 metre in other areas; improvement, realignment (where necessary) and proper maintenance of existing systems.
5. Opening old natural drainage channels in urban areas by constructing bridges for roads, railways and other structures blocking these channels; planned diversion of sub-surface water through artificial drainage systems where the opening of natural channels are not feasible.
6. Guiding farmers to adjust field size and irrigation timings according to the physical properties of the soil: a smaller field size for relatively sandy or more permeable soils and larger fields for clayey or less permeable soils; short watering periods to check flooding in the more permeable soils.

STRATEGIES FOR THE CONTROL OF FLOODING AND PONDING

River Flooded Areas

1. Construction, where feasible, and strengthening of flood protection embankments along streams that flood.
2. Afforestation of catchment areas, as well as of banks of major streams; in the latter case, especially those parts which are flooded deeply and frequently during a year.

Torrent Flooded Areas

1. Construction and strengthening of existing field *bandhs* and embankments of channels diverting torrent water to the fields.
2. Afforestation/reseeding of torrent catchment areas with adapted plant species.

Ponded Areas of River Plains and Terraces

1. Raising and strengthening field embankments located within basins, to check the inflow of run-off from surrounding fields.
2. Provision of a drainage system capable of carrying away excess rainwater from the basins; in the case of small isolated basins, deep wells may be constructed for the local disposal of ponded water.
3. Educating the farmer to the benefits of efficient and timely removal of excess rainwater from fields, by demonstrating the increased crop yields and improved soil health that results through this measure.

STRATEGIES FOR THE CONTROL OF PLOUGH PAN FORMATION

1. Breaking the plough pan and the *kankar* zone by deep ploughing and chiselling/subsoiling respectively; ploughing should not exceed a 15 to 20-centimetre depth or it may prove harmful to the subsoil structure.
2. Encouraging the use of mechanical implements and power for the improvement/levelling of terraces, deeper tillage and timely opening of the soil surface for maximum absorption of rainwater in the *barani* areas.
3. Popularising crop rotations to include both deep-root, shallow-root as well as leguminous or other green manure crops, which

would keep soils porous to about a 1.5-metre depth.

STRATEGIES FOR THE CONTROL OF SOIL NUTRIENT DEGRADATION

1. Changing the cropping patterns to include crops which add organic matter and nutrients to the soil i.e., leguminous crops like alfalfa, berseem, sesbania and groundnut; the stubble of these crops should be ploughed-in for green manuring.
2. Training the farmer in the technique of light irrigation (through small-sized fields) at short intervals instead of heavy irrigation at long intervals for sandy soils, to minimise nutrient loss through leaching.
3. Popularising the use of balanced fertilizers by demonstrating their benefits as against the use of urea only, which is abundantly available in the market.

STRATEGIES FOR THE CONTROL OF SURFACE CRUSTING

1. Effective control of the use of low-quality tubewell water for irrigation.
2. Regular addition of organic manure (farmyard/green manure) especially to very silty soils.
3. Amelioration of sodic soil surfaces by the addition of gypsum (2-3 tonnes per hectare) or some other (acid-forming) soil amendment.
4. Evolving, through research, irrigation techniques which would discourage the formation of a surface crust.
5. Frequent breaking of the surface crust by proper manual or mechanical implements (light spades, rakes or harrows) during the crop growing period, especially during seed germination.

STRATEGIES FOR THE CONTROL OF NON-AGRICULTURAL USE OF AGRICULTURAL LANDS

1. Imposing restrictions on the spread of urban settlements and the establishment of industries on good and very good agricultural lands located in the suburbs of large towns, and legally enforcing these restrictions; potentially good and very good agricultural land would be identified through detailed soil surveys and mapped.
2. Legal restrictions on the mining of soil material, for urban purposes, from good or very good agricultural land, as identified on potential agricultural maps.
3. Protection of potentially productive agricultural land from city refuse and household or industrial effluent.

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