

Board of Economic Inquiry Punjab (Pakistan)

PUBLICATION No. 111

General Editor :
Prof. M. HASSAN

SOIL EROSION IN THE PUNJAB

Surveyed by
ABDUL AZIZ ANWAR, M.A., LL.B.

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(The Board of Economic Inquiry, Punjab (Pakistan), does not hold itself responsible for any opinion expressed or conclusions reached by the writer).

P R E F A C E

Soil erosion is called the 'creeping death' of the soil. It is a world-wide problem, but it is much more assertive in under-developed countries where the modern discoveries in scientific knowledge have not been applied commensurate with their needs in agriculture. It works out its serious effects through this process : loss of surface soil, plant-food and sub-soil water, silting up of water channels, disruption of communications, reduction in productivity of land and ultimately lowering the already low standard of living of the peasantry.

Soil erosion has affected vast areas of our fertile land, rendering them completely unfit for cultivation. In Rawalpindi Division alone about 5 lakh acres of productive land have become uncultivable while another 10 lakh acres are seriously affected. The menace of soil erosion is fast spreading. It needs effective measures for combating it.

It need hardly be emphasised that soil is a basic national resource and its conservation is the prime necessity. For, without its due care, we may not be left with enough land to raise food and commercial crops for our growing economy. Some measures have been taken in the past to combat soil erosion, with emphasis on afforestation and terracing. A more effective approach, however, is needed in view of the gravity of the situation existing in the country by taking adequate steps, which involve planned land use, control of running water, contour cultivation, stabilisation of gullies, proper stocking and management of grazing lands, growth of permanent vegetation on steep slopes, digging the diversion ditches, etc. It requires pooling of efforts of various experts working in agriculture like foresters, soil scientists, agronomists, irrigation engineers to plan various control measures so as to check further erosion of the soil and to reclaim land already affected by it.

It was, therefore, decided to survey the problem of soil erosion and the remedial measures that have been taken in this connection. The Survey was under taken by Mr. Abdul Aziz Anwar, M.A., LL.B., of the Research Staff of the Board. Dr. Abdul Moquit, Ph. D. (Wisconsin) assisted me in editing the Report.

The Board is grateful to Mian Mushtaq Ahmad, P. Ft. S. Mr. K.A. Ghafoor, I.S.E., Mr. H.J. Asar, P.S.E., Mian Shamim Ahmad P.S.E., and Dr. Mohammad Abdullah Khan Ph. D., who have gone

through the Report. Their valuable suggestions have been incorporated in it. The help given by the Departments of Forest, P. W. D. Irrigation, Co-operative, Land Records and the Directorate of Erosion Control & Soil Conservation is also acknowledged.

M. HASSAN.

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CHAPTER 1

Introduction

The fact that agriculture provides employment, directly or indirectly, to about 80 per cent. of the total population, brings out the role of agriculture as a premier industry in Pakistan. It is, at present, the basis of our export trade consisting, mainly, of agricultural and semi-agricultural raw materials like jute, cotton, tea, hides and skins and wool. Another important aspect of our agriculture is the part it is playing normally in feeding the vast growing population of Pakistan. West Pakistan was known for its surplus foodgrains which were exported to other countries. During recent years, however, deficits of foodgrains have been experienced and Pakistan had to import large quantities to meet this shortage. Although the immediate causes were connected with the failure of the monsoons, reduction in the water supply in the canals, diversion of acreage from food to non-food crops, etc., the more permanent causes of the food deficit were those underlying soil deterioration caused by erosion and waterlogging, low standard of cultivation, fast growing population etc., which have been at work for a long time. These have been eating into our agriculture gradually and imperceptibly. The growth of population and the increase in cultivated acreage in the Punjab, during the first half of the 20th century, are given in the table below.

TABLE 1

Growth of Population and Cultivated Acreage in the Punjab

Year	Population		Cultivated Acreage	
	Total*	Percentage of 1901	Total*	Percentage of 1901
1901	94 72,372	100 0	1,31,05,000	100 0
1911	1,01,12,625	106.7	1,47,70,166	112.7
1921	1,08,94,013	115.0	1,59,47,343	121.6
1931	1,28,08,458	135 2	1,83,28,733	139 8
1941	1,57,17,389	165.9	1,78,78,010	136.4
1951	1,88,28,015	198.7	1,94,72,129	148.5

* Agricultural Statistics of the Punjab, P. 13

The table makes it clear that both population and cultivated acreage have been on the increase. While population has almost doubled during the first half of the present century, the cultivated acreage has increased only by about one-half. This, combined with other factors, explains the cause of shortage of foodgrains and points to the imperative need of giving top priority to the measures calculated to augment agricultural production in the country. Among the various factors, working to the detriment of agriculture, soil erosion has caused serious consequences. In its effects, erosion implies lingering death of the soil, resulting in its impoverishment. The upper layer of the soil which, under the natural phenomena, contains a heavy proportion of plant food and humus, gets washed away by rushing rain-waters due to absence of vegetation and forests, leaving the soil unfit for cultivation. Floods in the rivers and their tributaries cause devastation on their way and make large areas unfit for agricultural purposes. Due to deforestation and absence of vegetation in the sub-montane areas there remains nothing to check the rain-water from rushing down and, as such, its percolation into the soil gets considerably decreased. Gullies begin to develop, water table gets lower and pasture begins to disappear. The upper fertile layer finds its way into the rivers, resulting in low crop yields and gradual lowering of the standard of living of the people of those areas.

To minimise the devastating effects of soil erosion, forests and vegetative cover of the soil play a prominent role. Such measures tend to break down, to a considerable extent, the velocity of sweeping rain-water and allow a large quantity of it to be absorbed into the ground. These devices do not allow the soil to be washed away and help combat the menace by promoting retention of more moisture in the soil. It is estimated that, for a balanced economy, a country requires 20 to 25% of its total area under forests. The percentage of land under forests in some of the countries of the world is given below.¹

<i>Country</i>		<i>Percentage of Land under Forest</i>
Austria	...	33
Belgium	...	18
Burma	...	63
Canada	...	35
Czechoslovakia	...	34
Finland	...	74
France	...	19
Germany	...	19

1, The Pakistan Journal of Forestry, July 1954.

<i>Country</i>			<i>Percentage of Land under Forest</i>
India	...	...	24
Italy	...	...	20
Japan	...	...	57
Norway	...	...	31
Poland	...	...	33
European U. S. S. R.	...	...	44
Sweden	...	...	55
Switzerland	...	...	23
U. S. A.	...	...	33

These statistics show that most of the countries have paid due attention to achieve the required percentage. Even our neighbouring country, India, has 24% of her total area under forests. But unfortunately Pakistan has inherited a very low percentage of forests as is clear from the following figures : 1

<i>Province</i>			<i>Percentage of Land under Forest</i>
East Pakistan	...	...	9.7
Baluchistan	...	...	4.1
N.-W. F. P.	...	...	4.0
Punjab	...	...	3.2
Sind	...	...	2.3
Total Pakistan	...	...	<u>4.5</u>

Pakistan has got only 4.5% of the total area under forests. At the same time, the demand for timber and firewood increased sharply with the increase in population, especially with the unprecedented influx of refugees from India in August, 1947.

Pakistan has large areas of cultivable waste which can help in increasing agricultural output a great deal. Along with extensive cultivation, equally important, or perhaps of greater magnitude of importance, is the urgent need for reclaiming the area already eroded and preventing further erosion of the threatened soil. This menace has already seriously affected the upland districts of Rawalpindi, Jhelum, Attock, Mianwali and Shahpur as these areas lie within the catchments of various tributaries that drain into the Rivers Jhelum and Indus. A great part of these areas is rugged, broken and full of gullies and deep ravines.

1, Ibid. .

Adequate attention has not so far been paid to this problem as is evident from the lack or absolute absence of soil conservation measures to combat the erosion menace. Due to this neglect larger and larger areas of once good agricultural lands are going out of cultivation as a result of sheet and gully erosion. This has been so because a greater emphasis has always been laid on reclamation operations rather than conservation measures in this country. Reclamation of totally broken and waste lands as against conservation of good and productive agricultural lands as an anti-erosion measure will never be able to achieve anything and must result in negative progress as more and more good land goes out of cultivation quicker than can be brought back through this agency of reclamation. In view of the dangers of the soil erosion and increasing deterioration of our land, it was decided by the Board of Economic Inquiry to survey the problem in the Punjab so as to provide facts and figures of the area affected as well as the measures taken and the possibilities of its control.

Various Government Departments, like Forest, Co-operative, P.W.D. Irrigation (Bunds Circle), Agriculture, Revenue, Land Reclamation, Land Records, etc., were requested to provide statistical data and material regarding the work done by them with regard to this problem. Detailed reports were obtained from the Assistant Registrars of Co-operative Societies on the working of the Land Reclamation and Anti-Erosion Co-operative Societies, especially from the Rawalpindi Division. Information regarding afforestation, *watbandi*, etc., was obtained from the Annual Reports of the Forest Department. Various survey plans and detailed reports prepared by the P.W.D. (Bunds Circle) regarding soil erosion, its control and schemes for raising the water table in the upland districts were also consulted. It may be mentioned here that no official survey on the extent of the eroded area has been made in the province so far. The figures given in the report are, therefore, estimates of various eminent writers on this subject.

CHAPTER 2

Nature and Extent of Erosion

Soil erosion is generally found in the deforested hill sides in the arid plateaux and the flooded parts of river valleys. In Pakistan, the area eroded is considerably large. In the Punjab, Rawalpindi Division has been very seriously affected by this menace. The entire area of Baluchistan is threatened by erosion as the bed rock has been exposed by over-grazing and loss of top-soil. Similar are the conditions in the Kohistan Tehsil of Sind while in Tharparkar, Khairpur State and Chohistan area of Bahawalpur, it has been caused by wind. Sind has suffered a great loss due to two big land erosions of 1948 and 1952 by the River Indus. In the North-West Frontier Province, with the exception of Mardan District, the entire area suffers from soil erosion. In East Pakistan, about half a lakh acres in Sylhet District alone have been affected by this menace due to the over-flowing of Jalalpur Dhalla River. Uptil now there has been no official survey of the eroded area in Pakistan. Whatever figures are available, therefore, are mostly estimates.

Some estimates had been made before the Partition. According to Sir Harold Glover, in 1944, soil erosion, at a very low estimate, was seriously lowering the productivity of 150 million acres out of a total of 330 million cultivated acreage of the undivided India.¹

The figures of acreage requiring terracing and of the area under ravines in the Punjab, given on the next page, were estimated by Dr. R. Maclagan Gorrie in 1946.² These figures show that 18,50,000 acres required terracing and 16,50,000 acres were full of ravines, bringing the total affected acreage to 35,00,000. According to this estimate, 17.7% of the total acreage of 11 districts was under erosion. It also shows that Attock, Rawalpindi and Jhelum Districts were the worst affected ones. D. G. Khan and Sialkot had large eroded areas and the figures given by Dr. Gorrie appear to be underestimated.

According to a detailed investigation into the seven upland districts of the Punjab, i.e., Rawalpindi, Attock, Gujrat, Sialkot, Mianwali, Shahpur and Jhelum, with a total area of 14.7 million acres (half under

1. Soil Erosion by Sir Harold Glover. August 1944.

2. Soil and Water Conservation in the Punjab, pp. 146-147.

TABLE 2

Gross Area, Acreage Requiring Terracing and that Under Ravines

District	Gross Acreage	Requires terracing	Ravines	Total eroded area	% of 5 to 2
1	2	3	4	5	6
<i>Rawalpindi Division</i>					
Attock ...	26,80,437	7,00,000	5,00,000	12,00,000	44.8
Jhelum ...	17,70,859	2,00,000	4,00,000	6,00,000	33.9
Rawalpindi...	13,11,768	2,00,000	3,00,000	5,00,000	38.1
Gujrat ...	14,58,151	2,00,000	2,00,000	4,00,000	27.4
Shahpur ...	30,71,407	...	1,00,000	1,00,000	3.2
Mianwali ...	34,36, '40	...	1,00,000	1,00,000	2.9
Total ...	1,37,28,762	13,00,000	16,00,000	29,00,000	21.1
<i>Lahore Division</i>					
Gujranwala...	14,73,542	2,00,000	...	2,00,000	13.6
Lahore ...	16,67,568	1,00,000	...	1,00,000	6.0
Sheikhupura	14,79,539	2,00,000	...	2,00,000	13.5
Sialkot ...	10,04,670	50,000	...	50,000	5.0
Total ...	56,25,319	5,50,000	...	5,50,000	9.8
<i>Multan Division</i>					
D.G. Khan...	34,75,769	...	50,000	50,000	1.4
Montgomery	27,21,510	...	...	...	...
Lyallpur ...	22,49,049	...	...	...	...
Jhang ...	21,69,231	...	...	...	...
Multan ...	36,03,531	...	...	...	...
Muzaffargarh	35,59,677	...	...	...	...
Total ...	1,77,78,767	...	50,000	50,000	0.3
Grand Total...	3,71,32,848	18,50,000	16,50,000	35,00,000	9.4

cultivation), as many as 1.75 million acres had been badly gullied by soil erosion. Most of this area was classed as cultivable waste¹ in the records.

About 5 lakh acres were said to have been permanently destroyed by erosion in the Punjab. The figures of the less seriously affected areas alone exceeded 20 lakh acres. In the Rawalpindi District, due to the deepness of drainage channels, on account of severely undulating nature of the region, soil erosion has become the greatest single menace to its prosperity.

The UNESCO Mission, that visited Pakistan in January 1952, disclosed that the extent of soil erosion in the Rawalpindi Division was over 50% of its cultivated acreage. They stated that the authorities were fighting a losing battle as they lost more land yearly than the land they reclaimed.

A more recent estimate put the seriously eroded area in the Punjab at 10 lakh acres involving the districts of Rawalpindi, Jhelum, Attock, Gujrat, Sargodha, Sialkot and Mianwali.²

After giving due consideration to all the available figures, the following estimate has been made with regard to the eroded area in the Punjab :

<i>Category</i>	<i>Lakh acres</i>		
Area destroyed by erosion	5
Seriously affected area	10
Less affected area	15
Under the threat of erosion	10
Total	40

The problem of development of the upland districts is, however, under the consideration of the Punjab Government. In topography, this tract is rugged, broken and full of gullies and deep ravines. Good fertile land has been destroyed by sheet erosion and gully formation thus exposing the rocks underneath. This has also affected the food production required for the increasing population of the country.

1. Economy of Pakistan, by Dr. S.M. Akhtar.

2. Dr. Khan A. Rahman—Address at the All Pakistan Science Conference, Karachi, January 1954.

Area and Population

The divisionwise area, population and density per square mile of the Punjab according to the 1951 Census are given in the table below:

TABLE 3

Area, Population and Density Per Square Mile in the Punjab

Division	Area (sq. miles)	Population	Persons per sq. mile
Rawalpindi ...	21,393	51,52,851	241
Lahore ...	9,119	53,39,873	586
Multan ...	31,733	83,35,291	263
Total Punjab ...	62,245	1,88,28,015	302

Rawalpindi Division, where the problem of soil erosion is very serious, has the minimum density per square mile, i. e., 241 as compared with 302 of the Punjab. Tehsilwise area, population and density per square mile is given in the Statistical Appendix.

The total population, actual acreage and per capita acreage under food and non-food crops in the Punjab during the last 50 years is given on the opposite page.

The table shows that the percentage of total acreage and per capita acreage under food crops have been declining. In 1911, the per capita acreage under food-crops was 1.2 which decreased to 0.7 in 1951.

Classification of Area

The districtwise cultivated and uncultivated acreage of the Punjab for the year 1953-54 is given on page 10.

It is clear from the table that dry areas, like Muzaffargarh and D. G. Khan, have less than 30% of their total area under cultivation. The canal colony areas of Lyallpur and Montgomery have more than 75% of their acreage under cultivation. But in spite of the fact that Rawalpindi, Jhelum and Attock get maximum rainfall, which help cultivation, the percentage of area under cultivation is less than 45. The percentage shares of areas under various heads in the Punjab are given on page 11.

TABLE 4

Population and Acreage under Food and Non-food Crops in the Punjab During the Last 50 Years

Year	Population	Food Crops			Non-food Crops			Total		
		Actual acreage	Percentage	Per capita acreage	Actual acreage*	Percentage	Per capita acreage	Total acreage*	Percentage	Per capita acreage
1911	1,04,12,625	1,17,30,715	85	1.2	20,00,567	15	2.0	1,37,31,282	100	1.4
1921	1,08,94,013	1,12,56,976	80	1.0	28,87,038	20	2.6	1,41,44,014	100	1.3
1931	1,28,08,458	1,24,90,731	77	1.0	37,15,724	23	2.9	1,62,06,455	100	1.3
1941	1,57,17,389	1,23,84,309	73	0.8	46,05,985	27	2.9	1,69,90,294	100	1.1
1951	1,88,38,015	1,36,77,527	75	0.7	46,41,544	25	2.5	1,83,19,071	100	1.0

* Decennial Average

TABLE 5

Districtwise Classification of Area in the Punjab for the Year 1953-54

District	Total Area		Cultivated Area		Uncultivated Area	
	Acreage	% of Punjab	Acreage	% of Distt.	Acreage	% of Distt.
<i>Rawalpindi Division</i>						
Rawalpindi ...	13,12,805	3.5	5,78,301	44.1	7,34,504	55.9
Jhelum ...	17,87,350	4.8	7,13,244	39.9	10,74,106	60.1
Attock ...	74,309	7.2	11,32,311	42.3	15,42,058	57.7
Gujrat ...	14,57,741	3.9	10,47,163	71.8	4,10,578	28.2
Shahpur ...	30,44,821	8.2	18,89,306	62.1	11,55,425	37.9
Mianwali ...	34,34,680	9.3	1,52,661	42.3	19,82,019	57.7
Total ...	1,37,11,766	36.9	68,13,071	49.7	68,98,690	50.3
<i>Lahore Division</i>						
Sialkot ...	13,16,508	3.6	10,62,100	80.7	2,54,408	19.3
Lahore ...	14,07,272	3.8	9,86,052	70.1	4,21,220	29.9
Gujranwala ...	14,73,599	3.9	9,49,378	64.4	5,24,221	35.6
Sheikhupura ...	14,79,537	4.0	9,28,776	62.8	5,50,761	37.2
Total ...	56,76,916	15.3	39,26,306	69.2	17,50,610	30.8
<i>Multan Division</i>						
D. G. Khan ...	4,75,991	9.3	9,80,211	28.2	24,95,780	71.8
Jhang ...	21,74,086	5.9	11,01,534	50.7	10,72,552	49.3
Lyallpur ...	22,49,073	6.0	17,45,127	77.6	5,03,946	22.4
Montgomery ...	27,21,509	7.3	20,51,951	75.4	6,69,558	24.6
Multan ..	36,03,522	9.7	23,67,557	65.7	12,35,965	34.3
Muzaffargarh ...	35,60,893	9.6	10,40,697	29.2	25,20,196	70.8
Total ...	1,77,85,074	47.8	92,87,077	52.2	84,97,997	47.8
Total Punjab ...	3,71,73,756	100.0	2,00,26,459	53.9	1,71,47,297	46.1

TABLE 6

Percentage Shares of Acreage Under Various Heads in the Punjab

Classification of Area	1948-49	1949-50	1950-51	1951-52	1952-53	1953-54
<i>Uncultivated Area</i>						
(i) Forest ...	3.1	3.0	3.1	3.2	2.7	2.7
(ii) Not available for cultivation.	18.0	18.4	18.4	18.2	18.6	18.5
(iii) Cultivable waste ...	25.8	26.8	26.1	26.1	25.8	24.9
Total ...	46.9	48.2	47.6	47.5	47.1	46.1
<i>Cultivated Area</i>						
(i) Current Fallow.	7.5	7.0	6.8	7.5	9.1	6.6
(ii) Actually Sown ...	45.6	44.8	45.6	45.0	43.8	47.8
Total ...	53.1	51.8	52.4	52.5	52.9	53.9
Grand Total ...	100.0	100.0	100.0	100.0	100.0	100.0

Provincewise acreage under different heads in Pakistan is given in the Statistical Section.

Definitions—

1. *Forest.* Includes areas under natural or planted forests.
2. *Area not available for cultivation.* Includes areas used by the people for residential purposes, footpaths, cart tracks, sites of wells and grave yards as well as the area covered by ponds and the rivulets.
3. *Cultivable waste.* Includes lands where agriculture is possible if attempts are made at improvement of the soil. If a field is left uncultivated continuously for four years it is treated as 'abandoned' and included in 'cultivable waste'.
4. *Cultivable area.* Includes the lands which have been cultivated or which have been left fallow.
5. *Wasteland.* The term implies to land available for cultivation but which is not actually brought under plough. It includes all grazing lands and groves, quite distinct from forests. *Sem* and *thur* lands which are classed under 'not available for cultivation' as soon as they are reclaimed, though not actually brought under cultivation and not yielding any crop, are also treated as 'wasteland'.

The table shows that the percentage of area under forests has declined from 3.1 in 1947-48 to 2.7 in 1953-54. Of the total area of the province, 47.3% was actually sown in 1953-54.

Size of Holdings

The average size of holdings in the various districts of the Punjab is very small and uneconomic. In Jhelum District, the average holding was 2.2 acres. It was 1.7 acres in Jhelum Tehsil, 2.2 acres in Pind Dadan Khan Tehsil and 2.9 in Chakwal Tehsil. In Gujrat and Kharian Tehsils average holdings were 7 and 8 acres in 1916-17 which decreased to 4.5 and 5.0 acres respectively in 1940-41. ¹

Rainfall

The districtwise figures of 20-years' average rainfall (1931-32 to 1950-51) in the Punjab are given below :

TABLE 7

Districtwise 20-Year Average Rainfall in the Punjab

<i>District</i>	<i>Rainfall</i>	<i>District</i>	<i>Rainfall</i>
Rawalpindi ...	35.48	Shahpur ...	14.54
Sialkot ...	33.68	Lyallpur ...	12.11
Jhelum ...	27.95	Mianwali ...	11.43
Gujrat ...	26.70	Montgomery ...	10.07
Attock ...	23.66	Jhang ...	9.38
Gujranwala ...	23.03	Multan ...	6.57
Lahore ...	18.08	D. G. Khan ...	5.82
Sheikhpura ...	17.54	Muzaffargarh ...	5.50
Total Punjab...17.64			

It will be seen that out of the eight districts, seriously affected by erosion, five receive the heaviest rainfall in this province. This heavy rainfall is one of the factors for the serious nature of this problem in these areas. It may be noted that by saving or reclaiming one acre of land from erosion in Rawalpindi District, which receives the highest rainfall, the addition in the prosperity of the province will be equivalent to 3 or 4 acres of land under cultivation in other districts where the rainfall is low. This is due to the fact that higher the rainfall, the more valuable becomes the land for cultivation, especially for growing fruits. Districtwise annual rainfall figures since 1931-32 have been given in the Statistical Section.

1. 'Erosion in the Punjab.—Its Causes and Cures' by Sir Harold Glover, pp. 67 and 75

Forests

It has already been stated that forests play an important part in eradicating this evil. But in the early days, forests were gradually destroyed with every increase in population, for bringing more land under cultivation and for making more pasturelands. With their destruction in the hill sides, rain and flood water could flow without any hinderance causing vast quantities of soil to be carried away into the sea. The quinquennial averages of the area under forests in the Punjab are given below :

TABLE 8

Quinquennial Total Acreage and that under Forests with their Respective Percentages

Quinquennium ending with	Total acreage	Acreage under forests	Percentage
1906-07	3,70,13,700	18,62,704	5.03
1911-12	3,70,86,293	17,72,014	4.78
1916-17	3,71,39,162	16,15,133	4.35
1921-22	3,72,29,355	14,32,422	4.96
1926-27	3,72,27,520	13,70,900	3.68
1931-32	3,71,31,526	12,56,310	3.38
1936-37	3,71,15,044	12,00,163	3.23
1941-42	3,71,18,234	12,00,220	3.23
1946-47	3,70,40,412	11,56,872	3.12
1951-52	3,71,43,588	11,46,707	3.09

Director Land Records, Punjab.

Our share in total forest area of the undivided Punjab was only 28%. The result is that Punjab (Pak) has only about 3% of the total area under forests which is only about 1/8th of the required area. The position has rather worsened since the area under forests has registered a decrease of about 8,65,389 acres during the first half century. The percentage of area under forests has come down from 5.0 in 1906-7 to 2.7 in 1953-54. In order to arrest the ruthless destruction of forests, the pre-Partition Government of India made rules and regulations in 1855 to preserve forests and a special Forests Act was passed in 1878. The details about these measures have been given in Chapter 5. The table on the next page shows the post-Partition acreage under forests:

TABLE 9
Total Acreage and Area under Forests in the Punjab

Year	Total Acreage	Under Forests	Percentage
1947-48	3,71,91,516	11,49,200	3.09
1948-49	3,71,55,217	11,41,806	3.07
1949-50	3,71,45,136	11,21,427	3.02
1950-51	3,71,42,453	11,47,626	3.09
1951-52	3,71,83,619	11,73,478	3.16
1952-53	3,71,83,68	10,02,704	2.70
1953-54	3,71,73,756	9,97,315	2.68

In spite of the efforts of the Forest Department to keep on expanding the areas under forests, this steady decrease only shows increase of erosion and consequent decline in forest area. Districtwise acreage under forests in the Punjab since 1931-32 has been given in the Statistical Section.

Cattle Population and Grazing

The total cattle population has also been increasing which is clear from the following table :

TABLE 10
*Livestock Population (in Thousands) of the Punjab**

Year	Livestock Population		Sheep & Goats	
	Total	Percentage of 1904	Total	% of total livestock
1904	1,30,28	100.0	57,96	44.4
1909	1,36,97	105.1	54,92	40.1
1914	1,49,71	114.9	58,94	39.4
1920	1,32,48	101.6	46,00	34.7
1923	1,47,56	113.2	57,13	38.7
1928	1,49,47	114.7	56,62	37.9
1930	1,41,52	108.6	53,58	37.9
1935	1,56,77	120.3	59,10	37.7
1940	1,54,55	118.6	56,55	36.6
1945	1,52,50	117.1	53,17	34.8

* Agricultural Statistics of the Punjab

It will be noticed that the total cattle population increased from 1,30 28,255 in 1904 to 1,56 76,811 in 1935 after which it decreased to 1,52,49,860 in 1945. The sheep and goats population has, however, decreased, which may be due to decrease in pasture areas on account of erosion. Livestock population in the Punjab in detail has been given in the Statistical Section.

Local livestock and seasonal grazing of nomadic herds have done considerable damage to the vegetation and the forests. When uncontrolled grazing takes place by cattle it almost strips the soil naked, exposing it to erosion. Cases of unauthorised grazing are registered by the Forest Department. During drought conditions, following a bad monsoon, an increase in the number of unauthorised grazing is generally noticed. When the fodder becomes scarce, the cattle have to intensify their efforts for searching vegetation and, as a result, further deterioration of the soil takes place. Unauthorised grazing is thus responsible to a great extent in destroying vegetation and forests. The number of cases of unauthorised grazing for the post-Partition period is given below :

TABLE 11
Circlewise Number of Cases of Unauthorized Grazing

Year	Lahore	Multan	Rawalpindi	Total
1947-48	2,171	3,299	13,857	19,327
1948-49	4,831	5,382	15,684	25,897
1949-50	1,573	4,360	14,667	20,600
1950-51	4,712	3,127	16,793	24,632
1951-52	5,936	3,869	20,943	30,748
1952-53	4,260	4,442	16,193	24,895

The above table shows that the major part of the unauthorised grazing took place in Rawalpindi Division which is also the most seriously eroded area. The magnitude of this problem can be imagined from the fact that for every case detected 100 remain undetected, as the local saying goes. Both uncontrolled grazing and heavy rainfall are jointly responsible for the destruction of the soil in this area. Further details regarding the cases of unauthorised grazing are given in the Statistical Appendix.

Some details about the eight eroded districts of the Punjab are given below.

1. *Rawalpindi District.*—This is one of the worst eroded districts of the Punjab. The plateau of cultivated fields is traversed by ravines

which are cutting into it, destroying valuable agricultural land. With an area of 2,023 square miles, the total population, is 8,75,504, of which 29% is urban and 71% rural. The density, per square mile, was 433 compared with 302 of the province. The total population, cultivated acreage and the per capita acreage of the district during the last 50 years is given below.

TABLE 12

Population, Total and Per Capita Acreage in Rawalpindi District

Year	Total population	% of 1901	Cultivated acreage	% of 1901	Per capita acreage
1901	5,58,699	100	6,01,056*	100	1.08
1911	5,47,827	98	6,02,000	100	1.10
1921	5,69,224	102	5,80,963	97	1.02
1931	6,34,357	114	5,70,720	95	0.90
1941	7,85,231	141	5,80,657	97	0.74
1951	8,75,504	157	5,77,608	96	0.66

*1901-4 figures.

This shows that whereas population has risen from 100 to 157 during the last 50 years, the cultivated acreage has decreased from 100 to 96. The per capita acreage has also dropped from 1.08 in 1901 to 0.66 in 1951. The following table shows the actual and normal rainfall and rainy days recorded at the Rawalpindi Station :

TABLE 13

Actual and Normal Rainfall and Rainy Days at Rawalpindi

Year	Rainfall			Rainy Days	
	Actual	Normal	Deviation	Actual	Normal
1947	21.28	33.89	- 12.61	...	...
1948	58.88	33.89	+ 24.99	58	47.4
1949	31.79	33.89	- 2.10	44	47.4
1950	43.90	33.89	+ 10.01	56	47.4
1951	24.59	33.89	- 9.30	42	45.7
1952	33.34	33.89	- 0.55	53	47.4
1953	29.45	33.90	- 4.45	...	...
1954	32.51	32.99	- 0.48	52	...

This district receives the heaviest rainfall, *i. e.*, 35.48 inches (average of 20 years) as compared with 17.64 inches, for the whole of the Punjab. The average rainfall in this district is almost double that of the province. The rainfall, however, varies to a great extent from year to year. In 1947, for instance, it was 21.28 inches while during the next year it was 58.88 inches. Obviously, when there occurs such a heavy rainfall, the destructive capacity of the running rain-water in removing the valuable upper layer of the barren lands must be high.

Owing to vast areas people have never paid attention to the menace of erosion as there were always more lands to be taken up. Of course, people with small holdings and consequently less land to waste have no doubt been alive to the danger and have constructed terraces and stone walls to check erosion. Successful demonstration, however, in Gujjar Khan Tehsil has caught the imagination of the zamindars who now feel sure that through Reclamation Cooperative Societies they can organise themselves for the reclamation of their eroded lands. They now realise that it is only through the combined efforts of the village community, that they can cope with the task. As a result, some societies have already been registered and many more are being formed.

The situation in the Murree Hills has been accentuated by the settlement policy and the misuse of land. Under the recorded rights, a right holder of the Murree Hills, apart from enjoying other rights, is entitled to, more or less, five trees free of charge after every five years during his life time, and when he dies, he earns for his dependents the right to fell a tree in the near forest. Most of the land in these hills, technically speaking, is not fit for cultivation except the lower slopes on foot hills or valleys. But cultivation of steep slopes, of even 20 % or more, is a common sight to see in these hills, which helps the devastating agency of erosion to act quicker. When a steep slope—instead of being covered with a thick vegetative growth as the nature had originally provided—is stripped naked and exposed to the beating action of rain and the fast eroding velocity of the run-off, it is washed away quickly leaving only the bed rock in place. The increased pressure of population in Murree Hills is resulting in more and more clearing of forests and bringing it under plough for which it is not meant. A complete change in the agricultural economy of this area along with strict enforcement of a sound soil conservation policy is the only method of saving this area. Soil conservation work is, however, in its inception. A start was made in certain compartments of Murree Hills Division where intensive work of stone check damming was taken in hand. In addition, a comprehensive programme of afforestation of the denuded

and exposed slopes will have to be undertaken before any success can be expected.

2. *Jhelum District.*- The surface conditions of the soil suggest that erosion has been playing its havoc here. The ravines, gullies and streams are innumerable. Vast tracts of cultivation are affected or threatened by the erosion. This district has an area of 2,786 square miles with a total population of 6,82,061. 89% of the total population live in rural areas. Its density is 245 per square mile. The population, total cultivated and the per capita acreage from 1901 is given below.

TABLE 14
Population, Total and Per Capita Acreage of Jhelum District.

Year	Total population	% of 1901	Cultivated acreage	% of 1901	Per capita acreage
1901	5,01,424	100	7,51,388 *	100.0	1.50
1911	5,11,575	102	7,49,812	99.8	1.47
1921	4,77,068	95	7,16,243	95.3	1.50
1931	5,41,076	108	7,15,355	95.2	1.32
1941	6,29,658	126	7,16,077	95.3	1.14
1951	6,82,061	136	7,11,715	94.7	1.04

* 1903-4 figures

The population has increased from 100 to 136 during the first half century but the cultivated acreage has dropped from 100 to 94.7. Large tracts of this district, affected by erosion, have been abandoned by the villagers. "In Jhelum District alone 50,000 acres of good land have passed out of cultivation in a period of 35 years as a result of gullying, sheet erosion and torrent action".¹ Jhelum occupies the third position with regard to rainfall in the Punjab, receiving 27.95 inches, on an average, compared to 17.64 inches of the province. It varied from 47.18 to 27.30 inches in the district and 22.05 to 55.66 inches at the Jhelum Recording Station. The table on the next page shows the actual and normal rainfall and rainy days at Saddar Station Jhelum.

¹ 'Soil and Water Conservation in the Punjab' by R. MacLagan Gorrie, 1946

TABLE 15

Actual and Normal Rainfall and Rainy Days at Jhelum

Year	Rainfall			Rainy Days
	Actual	Normal	Deviation	Actual
1947	22.05	26.13	- 4.08	38
1948	55.66	26.13	+ 29.53	52
1949	22.17	26.13	- 3.96	35
1950	32.13	26.13	+ 6.00	43
1951	23.42	26.13	- 2.71	40
1952	23.18	26.13	- 2.95	37
1953	26.15	26.43	- 0.28	37
1954	32.29	26.43	+ 5.96	39

It is to be pointed out that no amount of reclamation can achieve anything substantial. It is the proper land use, along with other soil conservation practices, hitherto unknown to the cultivators, that can result in any progress. It is advisable to stop further deterioration of areas and conserve whatever is left rather than create a small piece of land through reclamation at a great cost.

About 60 Anti-Erosion Co-operative Societies were reported to have been doing useful work, but they were not adequate even to reclaim the area which actually goes out of cultivation during a particular year. For decades, the forests of the Salt Range have suffered from inefficient protection. The causes were investigated by the Punjab Government Forest Committee of 1937-38. The Government is making every effort in educating the people of this area in the value of closure as a means of increasing fodder supplies and improving cattle stock and to create a new outlook about the forest as an asset which should not be wasted but should be developed in their own interest.

3. *Attock District.*—This district covers an area of 4,149 square miles. Its total population is 7,23,124, 88% of which live in rural areas. Its density is 174 persons per square mile as compared with 302 of the Punjab. Its population, total cultivated and the per capita acreage are given on the next page.

TABLE 16
Population, Total and Per Capita Acreage in Attock District

Year	Total population	% of 1901	Cultivated acreage	% of 1901	Per capita acreage
1901	4,64,430	100	10,34,170*	100	2.23
1911	5,19,273	112	10,74,461	104	2.07
1921	5,12,249	110	10,77,369	104	2.10
1931	5,81,960	126	10,68,320	103	1.83
1941	6,75,875	146	11,13,624	108	1.65
1951	7,23,124	156	11,24,795	109	1.56

* 1903-4 figures

This table shows that while the population has increased from 100 in 1901 to 156 in 1951, the cultivated acreage has risen from 100 to 109 only. The per capita cultivated acreage has dropped from 2.23 to 1.56 during this period. The following table shows the actual and normal rainfall and rainy days at the Campbellpur Recording Station :

TABLE 17
Actual and Normal Rainfall and Rainy Days at Campbellpur

Year	Rainfall			Rainy Days
	Actual	Normal	Deviation	Actual
1947	16.51	23.79	- 7.28	22
1948	26.95	23.79	+ 3.16	36
1949	22.55	23.79	- 1.24	34
1950	26.98	23.79	+ 3.19	34
1951	19.81	23.79	- 3.98	38
1952	16.11	23.79	- 7.68	31
1953	16.82	22.61	- 5.79	30
1954	21.64	22.63	- 0.95	38

The average of 20 years' rainfall in this district was 23.66 inches compared with 17.64 inches of the Punjab. The soil of this district is very poor and the standard of cultivation is generally low. Most of the area is broken by small hill tracts and ravines and is badly eroded. The progressive destruction of the *guzaras* by the villagers themselves has seriously reduced local fuel supplies and the number of grazing lands.

Hence pressure on the forest is increasing. The poverty of the villagers is reflected by the increased number of forest offences.

Large number of hill torrents running throughout the district are responsible for eroding about one-third of the district. Rain-water which flows through the district to the River Indus is enough to irrigate large tracts of areas requiring water if it can be made available by conserving it, by constructing storage reservoirs and check dams.

4. *Gujrat District*.—This district has an area of 2,258 square miles. It has a population of 11,58,675 souls, of which 89% live in rural areas. Its density is 513 compared with 302 of the Punjab. The population, total cultivated and the per capita acreage are given below :

TABLE 18
Population, Total and Per Capita Acreage in Gujrat District

Year	Total population	% of 1901	Cultivated acreage	% of 1901	Per capita acreage
1901	7,92,159	100	8,51,557*	100	1.08
1911	7,87,999	99	8,88,779	104	1.13
1921	8,24,046	104	9,82,680	115	1.19
1931	9,22,427	116	10,18,495	120	1.10
1941	11,04,952	139	10,28,262	121	0.93
1951	11,58,675	146	10,43,091	123	0.90

* 1902-3 figures

It is clear that while the population of this district has increased from 100 in 1901 to 146 in 1951, the cultivated acreage has increased from 100 to 123. The per capita acreage has come down from 1.08 to 0.90 during the same period. The average rainfall here comes to 26.70 inches compared with 17.64 inches of the Punjab thus occupying the fourth place in the province. The actual and normal rainfall and rainy days at Sadder Gujrat are shown on the next page.

TABLE 19
Actual and Normal Rainfall and Rainy Days at Gujrat

Year	Actual	Normal	Deviation	Rainy Days
1947	19.57	26.20	- 6.63	28
1948	43.50	26.20	+ 17.30	49
1949	29.95	26.20	+ 3.75	41
1950	42.57	26.20	+ 16.37	44
1951	29.47	26.20	+ 3.27	45
1952	25.31	26.20	- 0.89	30
1953	23.30	26.20	- 2.90	31
1954	21.73	25.36	- 3.63	30

It has been estimated that about 1/5th of the area in the district is subject to erosion. Reclamation and terracing of the large areas lying above the destructive torrents which rise in Kashmir State and traverse the northern part of the district is urgently required. A demonstration area in terracing and *watbandi* was set up at Kotla. In conjunction with the *watbandi* and terracing schemes many check-dams were constructed in the ravines towards the cost of which the Government also contributed. Progress with *watbandi* and terracing is, however, slow; but the land where it is most required is of low quality and it is not easy to get the zamindars to take interest in it.

5: *Mianwali District*.—This district has an area of 5,389 square miles and a population of 5,50,499, 89% of which live in rural areas. Its density is 102 per square mile. The population, total cultivated and the per capita acreage for the first half century are given below :

TABLE 20
Population, Total and Per Capita Acreage in Mianwali District

Year	Total population	% of 1901	Cultivated acreage	% of 1901	Per capita acreage
1901	3,01,910	100	7,42,265*	100	2.46
1911	3,41,377	113	6,55,931	88	1.92
1921	3,58,205	119	7,06,230	95	1.97
1931	4,11,539	136	10,50,791	142	2.55
1941	5,06,321	168	10,24,640	138	2.02
1951	5,50,499	182	12,65,454	170	2.30

1902-3 figures

The total population has increased from 100 in 1901 to 182 in 1951, but the cultivated acreage has increased from 100 to 170 only. The per capita acreage, after going down from 2.46 in 1901 to 1.97 in 1921, has again risen to 2.30 in 1951. The following table shows the rainfall and rainy days at the Mianwali Recording Station :

TABLE 21

Actual and Normal Rainfall and Rainy Days at Mianwali

Year	Rainfall			Rainy Days	
	Actual	Normal	Deviation	Actual	Normal
1947	8.39	11.40	— 3.01	...	...
1948	12.96	11.40	+ 1.56	28	20.7
1949	6.26	11.94	— 5.68	18	20.7
1950	13.48	11.94	+ 1.54	22	20.7
1951	11.75	11.94	— 0.19	19	20.0
1952	10.62	11.94	— 1.32	21	20.7
1953	9.96	11.68	— 1.72	...	...

The average rainfall in this district was 11.43 inches compared to 17.64 inches for the whole of the Punjab.

6. *Shahpur District.*—This district has an area of 4,788 square miles. Its population comprises of 11,62,986 souls, of which 82% live in rural areas. Its density is 243 per square mile. The following table shows the population, total cultivated and the per capita acreage during the first half century.

TABLE 22

Population, Total and Per Capita Acreage in Shahpur District

Year	Total population	% of 1901	Cultivated acreage	% of 1901	Per capita acreage
1901	4,88,149	100	8,34,963	100	1.71
1911	6,45,001	132	12,35,313	148	1.92
1921	7,19,918	147	13,50,591	162	1.88
1931	8,21,490	168	15,56,670	186	1.89
1941	9,98,921	205	16,17,123	194	1.62
1951	11,62,988	238	18,51,259	222	1.59

* 1902-3 figures

This table shows that while the population of the district has increased from 100 in 1901 to 238 in 1951, the cultivated acreage has increased from 100 to 222. The per capita acreage has, however, come down from 1.71 to 1.59 during the same period. The following table shows the actual and normal rainfall and rainy days at Shahpur Recording Station :

TABLE 23
Actual and Normal Rainfall and Rainy Days at Shahpur

Year	Rainfall			Rainy Days
	Actual	Normal	Deviation	Actual
1947	1.87	13.92	-12.05	7
1948	21.45	13.92	+ 7.53	23
1949	10.23	14.55	- 4.32	22
1950	9.56	13.92	- 4.36	22
1951	9.61	13.92	- 4.31	14
1952	11.36	13.92	- 2.56	21
1953	11.97	13.92	- 1.95	15
1954	14.39	13.92	+ 0.47	23

7. *Sialkot District*.—This district has an area of 2,071 square miles and a population of 14,74,253. 85% of the total population live in rural areas while only 15% live in urban areas. The following table shows the population, total cultivated and the per capita acreage during the last 50 years :

TABLE 24
Population, Total and Per Capita Acreage in Sialkot District

Year	Total population	% of 1901	Cultivated acreage	% of 1901	Per capita acreage
1901	9,33,205	100	9,50,333	100	1.02
1911	8,71,650	93	9,19,387	97	1.06
1921	8,77,867	94	8,64,991	91	0.99
1931	9,79,617	105	7,83,397	82	0.80
1941	11,90,497	128	8,04,800	85	0.68
1951	14,74,253	158	10,27,637	108	0.70

* 1902-3 figures

The table shows that while the total population has increased from 100 in 1901 to 158 in 1951, the cultivated acreage, after falling down, has increased from 100 to 108 during the same period. The per capita acreage has come down from 1.02 to 0.70. This district occupies the second position in the province with regard to rainfall, with an average of 33.68 inches compared with 17.64 inches of the Punjab. The following table shows the actual and normal rainfall and rainy days at the Shakargarh Recording Station :

TABLE 25
Actual and Normal Rainfall and Rainy Days at Shakargarh

Year	Actual	Normal	Deviation	Rainy Days
1947	33.30	34.30	- 1.00	42
1948	36.88	34.30	+ 2.58	47
1949	28.01	34.31	- 6.30	39
1950	54.68	34.31	+20.37	50
1951	17.75	34.31	-16.56	45
1952	27.79	34.31	- 6.52	38
1953	35.38	34.31	+ 1.07	45
1954	33.87	34.29	- 0.42	39

Actual rainfall has varied from year to year. In 1950, it was 54.68, inches but during the next year, it amounted to only 17.75 inches. In Shakargarh Tehsil of this district, numerous demonstration centres were established by the Government to guide zamindars. Attempts were also being made to get them agree to convert these eroded lands into forest plantations.

8. *Dera Ghazi Khan*.—D. G. Khan District is one of the worst victims of erosion and denudation. It has an area of 9,371 square miles, with a population of 6,30,694 persons. The density, per square mile, was 67 compared with 302 of the Punjab. The population, total cultivated and the per capita acreage of this district during the first half of the 20th century are given on the next page.

TABLE 26

Population, Total and Per Capita Acreage in D. G. Khan District

Year	Total population	% of 1901	Cultivated acreage	% of 1901	Per capita acreage
1901	4,71,786	100	9,84,180	100 *	2.09
1911	4,99,860	106	11,61,381	118	2.32
1921	4,69,052	99	11,46,902	117	2.44
1931	4,91,044	104	9,08,367	92	1.85
1941	5,81,350	123	8,68,254	88	1.49
1951	6,30,694	134	9,95,859	101	1.58

* 1902-3 figures

This table shows that the population rose from 100 in 1901 to 134 in 1951, whereas the cultivated acreage, after fluctuating, was almost the same in 1951. The per capita acreage has decreased from 2.09 to 1.58 during the same period. The following table shows the actual and normal rainfall and rainy days recorded at D. G. Khan Centre :

TABLE 27

Actual and Normal Rainfall and Rainy Days at D. G. Khan

Year	Actual	Normal	Deviation	Rainy Days
1947	0.97	5.94	-4.97	...
1948	2.94	5.94	-3.00	11
1949	5.55	5.94	+0.39	11
1950	6.75	5.94	+0.81	9
1951	6.89	5.94	+0.95	8
1952	5.03	5.94	-0.91	5
1953	5.01	5.94	-0.93	...
1954	4.83	5.74	-0.91	8

The actual rainfall has varied from 0.97 inches to 6.89 inches in D. G. Khan while the normal rainfall is 5.94 inches.

CHAPTER 3

Erosion—Its Causes, Effects and Control

Soil erosion is one of the most serious problems facing Pakistan. It is caused by the inter-action of various natural agents, like water, wind and snow. The soil which takes centuries to develop is lost in only a few decades. The humus organic matter and various chemicals and nutrients which are usually stored within a few inches of the upper layer of the soil, feed the plants and crops. The removal of top soil affects not only the fertility of the land but also results in a gradual fall in the sub-soil water level. This, in turn, has the effect of lowering the standard of living of those whose lands have been affected. The eroded lands can now grow only vegetation of the lowest types and cannot support human life.

Agents of Erosion

Three natural agents, *i.e.*, water, wind and snow cause the erosion of the soil and are discussed below.

Water Erosion. When the soil is covered with vegetation and forests, the force of rain shower is broken and does not damage the surface soil. Part of the rain-water is absorbed by the top cover, part of it is permeated into the soil and some of it is lost by evaporation. There is thus very little run-off from such a soil. Rain-fall on the bare or naked soil, damages its texture to some extent by disintegrating it into small particles. The upper layer of the soil, thus loosened, flows away with the rain-water. In case of crest of the earth being soft, the torrents of the running waters cut their way into the soil and create ravines which render that area unfit for cultivation.

The factors that determine the amount of run-off are rainfall intensity, duration, frequency and time of occurrence, steepness of slopes, the amount of vegetative cover of the soil, physical and chemical nature of the soil etc. With heavy precipitation received gently all the year round, little erosion is caused while a lower annual rainfall received in torrential showers may result in tremendous damage. Experiments in U. S. A. have revealed that the eroding power of a stream is proportionate to the square of its velocity. The capacity of a stream in transporting eroded material varies as the 6th power of its velocity. Thus, if the velocity of a stream increases 10 times, the erosion increases 100 times, and its carrying capacity becomes a million times.

Wind Erosion.—Strong winds do a lot of damage to the soil. They remove fertile soil from the fields and deposit it on other lands. In desert regions, sand particles are swept away and are deposited on neighbouring lands. This diminishes the fertility of the soil affected and in some cases renders it absolutely unfit for further cultivation. But wind erosion seldom causes any deep ravines. In Tharparkar, Khairpur State and Chohistan area of Bahawalpur the soil erosion has been caused by wind.

Snow Erosion.—Snow erosion also involves geological erosion. Erosion by snow, in the form of huge glaciers hurtling down the high mountain sides, is common in snow line regions and is beyond human control.

Forms of Erosion

Water erosion takes three forms—sheet, rill and gully. Two or more of them may occur simultaneously in the same field and one may develop into another. In a way, these represent three stages of the same process.

1. *Sheet Erosion.*—It means the washing away of the top-soil by rain-water, slowly or rapidly. It is not easily observed as the soil is removed in thin layers and the farmers do not notice it until it is far advanced.

2. *Rill Erosion.*—It is an intermediate stage leading towards gully erosion. After heavy showers of rain it is visible in the form of rills over the surface of the bare field.

3. *Gully Erosion.*—It is an advanced stage of rill erosion. During heavy rains, channels are often formed where the earth crest is comparatively soft. When this action of the rain-water spreads, it leads to the formation of ravines which become deeper and deeper with the passage of time. Its effects are much more apparent than those of sheet and rill erosions. Ravines created in this manner are known to have destroyed hundreds of thousands of acres of very fertile land in this province.

Factors Affecting Erosion

Rainfall, land cover, slope and topography, crop rotations and management practices, soil characteristics, etc., are the factors affecting erosion.

Roots of trees and vegetation bind the soil particles together. Vegetative cover of the soil acts as a natural sponge which breaks the onslaught of heavy downpour and causes it to reach the ground slowly and soak into it. This, in simpler words, clothes the catchment areas of the

rivers. Over-grazing on pasutre or grassy plots ultimately leads to erosion of the soil. The cattle eat away or root out good grasses and bushes and lay bare the surface of the ground which becomes open to attack by the eroding agencies.

The illiteracy and ignorance of our cultivators have also been responsible for an increase in the eroded area. They do not know how to avoid conditions leading to soil erosion. Ploughing parallel to the slope, which is often practised by the cultivators, is very faulty as it provides rills for the rain-water to flow down. The greater the degree of slope, other conditions remaining constant, the greater the erosion due to increased velocity of water flow. Faulty methods of cultivation and burning of dung rather than its application to the crops are other wasteful practices. Our tenancy system is also responsible for the menace. As a result of the leasing out of the land on year-to-year basis, the tenants have little incentive to improve the land during that short period.

Effects of Erosion

Various effects of erosion relate to loss of plant food and water, fall in the sub-soil water level, silting up of rivers and streams, intensified floods, threat to communications, changes in climate, reduction in production and deterioration of the economy of the whole country.

Loss of Soil and Water.—Erosion results in loss of plant food and removes the entire physical mass of land, the mineral particles, the microscopic organism and other constituents.

In the pre-Partition days, the Forest Department had been maintaining batteries of erosion trays at the Nurpur Experimental Area and at Banni in the Pabbi Hills. At Nurpur farms it was found that, in the course of 4 years, the bare surface lost 1,120 maunds of soil per acre or 280 maunds per year per acre. The total soil lost from the bare surface was over 12 times surface soil lost from the grass-covered area since the beginning of the experiment. The Banni experiment revealed a total loss of nearly 911 maunds per acre from the bare surface against 187 maunds for grass-covered and 100 maunds for grass-and-bush-covered soil per year. The results of these experiments show the quantity and intensity with which the upper layer of the soil is washed away from bare surface. The details of these experiments have been given in the Statistical Appendix.

Deforestation has been the contributory cause of the lowering of sub-soil water level. The precipitation mostly runs to waste and a

very little percentage gets absorbed with the result that the replanishment of the sub-soil water does not take place. The deep ravines, on the other hand, drain away the sub-soil water reservoir gradually and the level lowers down day by day. These effects have become very prominent in the upland districts of the Punjab. How far soil conservation helps in this direction is obvious from the work done by the Forest Department. The water level rose many feet in certain tracts of Rawalpindi District as a result of certain remedial measures which led to greater quantity of water percolating through the sub-soil, thus sending the water level up.

Silt.—Streams bring with them sand, silt, etc., from the hills and deposit these in the bed when the velocity of the water decreases. This results in silting up of the reservoirs, and rising of the beds of rivers and streams. The implications of the rising river beds are very serious, especially during floods. Excessive silt proves troublesome in the branch and distributary canals. It is also harmful to hydro-electric turbines where clearance costs quite a lot.

Intensified Floods.—No less violent is the action of floods in the rivers, especially in the Ravi and Chenab. Due to denudation of the hilly catchments of these rivers, the catchments do not offer any obstruction to the rapid flow of rain-water and, as a result, a large part of the precipitation quickly runs down. With progressive sedimentation in their beds, the rivers rise during floods, and the water spills over the banks into the adjoining low lands, thus causing heavy damage to crops as well as life and property. The increasing number of engineering works, such as weirs in the rivers, bridges across the rivers, canals, roads, and railway embankments provided with insufficient cross drainage, also obstruct the free flow with the result that in the event of any of these giving way under heavy heading-up, the onrush of flood water downstream does more damage than otherwise.

Threat to Communications.—Soil erosion undermines the compactness of the ground and often leads to landslides in hilly tracts which interrupt communications. In monsoon season, parts of the road and rail tracks get submerged and are covered with silt, sand and gravel.

Climate and Games Affected.—Destruction of forests and denudation tend to raise the atmospheric temperature. The bare soil left gets heated and the hot air, as it ascends, forces up the clouds, and consequently lessens rainfall on the tract. A forest, on account of its

humid climate, keeps the temperature lower than outside and this high humidity causes quick condensation of the clouds.

Animals usually live in thick forests which are rather difficult of access to human beings. With the thinning out of forests, they retreat to remote forest reserves, causing shortage of game animals. Besides, indiscriminate felling of trees and removal of vegetation mars the scenic beauty of that area and it thereby becomes less attractive for outdoor excursions and activities.

Deteriorated Economy.—The natural result of all this is the lowering of the living standards of those whose lands have been affected. The fields yield less or go out of cultivation entirely, while the pastures deteriorate leading to the under-feeding of the cattle. The grazing animals become too weak, to be employed profitably in various agricultural pursuits. This means reduced income derived from lower agricultural production. Malnutrition and diseases, sooner or later, lead to the disability of agricultural workers. There is further deterioration in the total agricultural production which may even adversely affect the food position of the country and upset her economy.

Control of Erosion

Early efforts to control erosion largely concentrated on afforestation and terracing. But the modern approach to erosion control consists of a planned system of land use in the entire catchment area, afforestation and regrassing of land, management practices and engineering projects, etc., devised by a team of experts in the fields of agronomy, soil science, agricultural engineering and forestry.

Afforestation and Regrassing of Land.—Forests have been described as "flesh upon the stony skeleton of earth". They form the best cover on land not fit for cultivation, and play a very important part in controlling erosion of the soil. The rain-water that filters through the covered areas augments the winter supplies in the tributaries and the rivers, which is of great help for irrigating *rabi* crops at a time when the river supplies available are indeed very scanty. This percolation causes underground flow in the sub-soil, replacing brackish water in those tracts where sweet water is not available. It causes gradual rise of the sub-soil water table where it is too low and irrigation from shallow wells and deep tube-wells becomes a practicable proposition. The rise of the sub-soil water table accelerates afforestation as well as vegetative cover. To deal effectively with this menace, it is, therefore, essential to control catchment areas by afforestation.

Besides, top priority should also be given to the conservation of the existing forests. The bare soil should also be reclaimed by growing vegetation over it. Controlled grazing must be introduced to improve the conditions. Stabilization of sand with a vegetative cover and growing of shelter belts are essential to control wind erosion.

For the reclamation of land, destroyed by torrents, the first necessity is the closure of the uncultivated parts of the catchment areas. Rainfall would soon clothe the land with vegetation sufficient in itself to prevent erosion. The data collected by the Forest Department in Pabbi Hills on the efficiency of the protection of ranges as an anti-erosion measure is given below ¹

<i>Soil under the action of erosion but</i>	<i>Speed of run-off water on the soil (cusec/sq. mile)</i>
Controlled by plantation and construction of bunds	100
Grazing is going on, and vegetation destroyed	1,600
Grazing stopped	600

The figures show that the speed of run-off water was minimum on the soil which was controlled by plantation and construction of bunds. It was maximum where uncontrolled grazing was going on and vegetation was destroyed.

Engineering Devices.—For efficient and quick results, engineering devices have to be necessarily combined with agronomical practices. Building of check dams and bunds is essential for preventing the run-off of all the rain-water and minimising its velocity. The design of bunds depends upon the information regarding the catchment area of *nallah* above the proposed site, rainfall record of any station in the catchment or of the nearest station, probable storage capacity, maximum flood on record, contour survey plan of the reservoir area, geological data at the bund site and proposed location of spillway and its capacity. While building check dams, spillways for the excessive rain-water should also be made to lead excessive water to the streams down.

Terracing and gully plugging are also helpful. All the lands should, therefore, be more or less terraced. The stray channels formed by running water should be plugged. Digging of contour trenches at small distances is also done on the slopes to obstruct the flow of water.

1. 'Soil Erosion and Its Control', by Ch. Hassan Mohammad, (The Punjab Farmer).

Most of the water, thus collected in the trenches, percolates through the ground.

Scientific Farming.—When ploughing is done in rows crosswise of a slope rather than running up and down along the slope, the rows act as moisture terraces and tend to hold water where it falls, thus increasing absorption and reducing run-off. The removal of entire growth at harvesting, keeping a long fallow and indiscriminate tillage are some of the faulty practices in vogue which must be modified.

Fragmentation of holdings is a very serious draw-back in erosion control. Our holdings are very small and scattered. For scientific farming consolidation of holdings becomes very essential and strip cropping and contour tillage cannot be carried out without it

Three years' observations* at a model farm show that yield of crops, gradually improved in portions of fields where erosion was controlled as compared with other portions, as detailed below :

TABLE 28

Treatment	Kind of crops	1945-46 yield before treatment	Yield per acre in maunds after the year of treatment		
			1946-47	1947-48	1948-49
Control measures adopted	Maize	6	8	9	8½
	Wheat	5	6	7	10
No control measures	Maize	...	6½	6	4
	Wheat	...	5	4½	6

The decrease in yield during kharif 1948 was due to heavy rain which adversely affected the maize crop.

Flood Control Measures.—In fact all anti-erosion measures are automatically flood-control measures. Considering the colossal damage done to life and property by the floods in the Ravi and Chenab in the past, it is essential to set up a Flood Control Organisation in West Pakistan to save this province from further damage. The Central Government appointed. The Punjab Flood Commission which was dissolved after submitting its Report in June 1951.

The Pakistan Agricultural Inquiry Committee, 1951-52, reports about anti-erosion and flood control work as follows :

“Anti-erosion work in West Pakistan provides the second main

* ‘Soil Erosion and its Control’.

and immediate field for mechanisation. In the districts of Attock, Rawalpindi, Jhelum, Gujrat, Sialkot, Shahpur and Mianwali there is an area of 14.7 million acres requiring reclamation. In a scheme proposed by the Forest Department it is stated that 7.26 million acres of the above area is cultivated but 41% of it requires attention. There are 1.17 million acres under forest, 60% of which requires flood control work. Total uncultivated area is 6.2 million acres, of which 60% is reclaimable. A capital expenditure of Rs. 85 crores would be required for reclaiming this land. Briefly, Rs. 15 crores are required for reconditioning 3 million acres, Rs. 60 crores for reclaiming 4 million acres and Rs. 10 crores for flood control and afforestation of 2.5 million acres. It is estimated that the reconditioned land will yield 6 maunds per acre extra wheat and this and the new land reclaimed would produce 3.2 million tons of wheat per annum which, valued at Rs. 6 per maund, will be worth 56 crores of rupees. These rough figures indicate the magnitude of the problem. Several smaller projects are possible in the adjoining tracts in Campbellpur and parts of Rawalpindi Districts. There are other areas also requiring attention in Dera Ismail Khan in N.-W. F. P., Muzaffargarh and Dera Ghazi Khan in the Punjab and various tracts in Baluchistan and Kalat State. These require further survey and study."

Soil erosion holds a very potent threat to the fertility of soil and, therefore, to the prosperity of Pakistan. Conservation of our soil resources becomes the prime necessity as, otherwise, we may not be left with enough land to raise food as well as commercial crops for feeding our growing population and for maintaining the pace of our industrialisation.

This calls for an elaborate survey by a team of soil scientists, agronomists, agricultural engineers and foresters to ascertain the extent of the problem and the measures to be adopted, not only for the reclamation of the affected area, but also for preventing further erosion of soil, on more or less permanent basis. An effective solution of the problem, however, would be greatly facilitated by the close co-operation of the various Government Departments concerned through planned coordination of their work. But this is *not* all. The public must also be made to extend a helping hand in this matter, particularly, those engaged in agricultural pursuits as their chief means of livelihood.

CHAPTER 4

Role of the Government

Much important work has been done by the Government in the Punjab to control soil erosion and to reclaim land, pastures and hills affected by denudation.

In the last quarter of the 19th century, the growing damage caused by the denudation and erosion in the Punjab attracted the attention of the Government. Early enquiries in this connection were conducted by Mr. Coldstream. Later, the Government appointed Mr. Baden Powell, the then Conservator of Forests, Punjab, to report on soil erosion, after a thorough survey of the conditions and to suggest ways and means for combating it. His report, submitted in 1879, recommended mainly the closing and reforestation of the catchment areas and the restriction on grazing. This was followed by Mr. Moir's enquiry in 1883 which was more or less on the same lines. Col. Bailey reviewed in 1883 stating that in tracts like Salt Range, etc., the destruction of forest had been accomplished within comparatively recent times and the private forests of Rawalpindi and some districts in N.W.F.P. were rapidly disappearing.

No substantial measures were taken by the Government until the passing of the Punjab Land Preservation (Chos) Act of 1900. The foundations of proper conservation were laid, in fact, by Sir Patrick Fagan who devised this Act. The Act, being only of local application, did not extend beyond the Hoshiarpur and Ambala Districts, now in the Punjab (India). The Act was, however, amended and amplified in 1944. Among other things it prohibited the following acts which were causing denudation and erosion of the soil :

- (i) The clearing or breaking up or cultivating of land not ordinarily under cultivation unless permitted by the Forest Officer.
- (ii) The admission, herding, pasturing or retention of sheep and goats, except where sickness necessitated the keeping of goats for milk. A limited number of stall-fed goats for a specified period were permitted to be retained.
- (iii) The collection or removal of grass for any purpose except from those parts of the notified areas where grass may have sufficiently established itself.

(iv) The pasturing of any cattle other than sheep and goats.

A Denudation Committee was appointed in 1910 by the Punjab Government which was mainly concerned with the denudation in the sub-montane districts. It recorded the net loss according to the various districts by *cho* action. The important recommendations of the Committee were the following :

- (a) The *Chos* Act required amendments.
- (b) The Government should take direct action in the reclamation of at least one *cho* bed and also give grants to various individuals, village societies and district boards to encourage reclamation work in the *chos* and ravines.
- (c) With regard to the denudation and erosion going on in the hill districts, the Committee realised the gravity of the problem and recommended that an enquiry by Revenue and Forest Officers working together be started in the affected districts.

Various decisions were taken since the report of the Denudation Committee. Cattle tax was imposed in Kangra District in 1916 in order to discourage and restrict heavy and indiscriminate grazing. Then, in 1926, the Punjab Government appointed another Committee to go into the effects of the cattle tax on the number of cattle, the attitude of the people towards its payment and to recommend changes in the light of experience gained. It was followed by Mr. Holland's Report in 1928 on the work of afforestation and its progress and the necessity of a Forest Reclamation Division for the whole province. This further stimulated interest in the subject and led to the appointment of Punjab Erosion Committee in 1931. According to the findings of the Committee, great damage was done to the forests in the Siwalik Hills due to the increase of cultivation in the plains below, the cultivation on the hill slopes, the increased firewood demand and the construction of the Sind-Punjab-Delhi Railway and the Sirhind Canal. The damage was far greater than that caused by the ever-swelling herds of goats, sheep and cattle.

The menace of erosion was concerned principally with the hills and forests. It was later on realised that even greater damage had been caused by the uncontrolled run-off of the rain-water to the lands lying below the hills. The Garbett Committee in 1937 found erosion prevalent throughout the low hills of the province, and recommended the formation of a Circle to combat the menace of erosion. Realising

its importance, the provincial Government opened an Anti-Erosion Circle in the Punjab Forest Administration in April 1939 for conserving soil and moisture in the cultivated fields and village common lands, which proved beneficial to the province.

In the undivided Punjab 'Post-War Development Plan' prepared in 1945 it was provided to reclaim 1,50,000 acres of useless *darray* and to increase the productivity of 3,50,000 acres of poor and unterraced land threatened with erosion. This was to be done with the help of heavy earth-moving machinery consisting of bull-dozers, terracers, sub-soilers and other specialised equipment for levelling down the land. In the post-Partition period, a special Bunds Circle was opened in the P.W.D. Irrigation Branch in January 1953 to conserve the supplies of water that go to waste and utilise these in a period of keen demand. The Government's latest efforts consist in creating the Directorate of Erosion Control and Soil Conservation in the upland districts.

The post-Partition activities of the Departments of Forest, Co-operative, Irrigation (Bunds Circle) and the Directorate of Erosion Control with regard to the measures taken to combat soil erosion are briefly discussed below.

Forest Department

In order to facilitate reclamation work and to achieve better coordination, the province had been divided into three Circles, namely, Lahore, Rawalpindi and Multan. Various remedial measures adopted by the Department from time to time, relate to afforestation, making contour trenches, *watbandi*, terracing, check dams, stone bunds, earth work and prevention of unauthorised grazing, etc., which are given below.

Every year the Department closes and opens, to grazing by cattle, certain areas according to the conditions of vegetation on that soil. The number of animals grazed and browsed varied considerably from year to year in accordance with the situation and the Government policy prevailing at the time. Unauthorised grazing, i.e., grazing in excess of the limit prescribed by the Department resulted in the destruction of vegetation, laying the soil bare. In spite of the restrictions imposed, many cases of unauthorised grazing were noticed and most of these were detected in Rawalpindi Circle which happens to be the worst eroded area. This also explains partly the cause of erosion in this

area. The details about cases of unauthorised grazing are given in the Statistical Section.

The acreage on which various remedial measures were taken by the Department with the co-operation of the villagers since 1948-49 is given below. These measures consisted of constructing check dams and stone bunds, *watbandi* and terracing of the areas and making contour trenches for afforestation, etc.

TABLE 29

(Figures in acres)

Year	Check dams & stone bunds	Watbandi & terracing	Contour trenches
1948-49 ...	1,562	11,138	1,842
1949-50 ...	294	19,907	3,219
1950-51 ...	921	1,209	3,514
1951-52 ...	3,514	304	...
1952-53 ..	4,939	3,446	...

The Forest Department is reclaiming annually an area of approximately 2500 acres by various methods. But the annual area going out of cultivation due to this menace is much greater than the area reclaimed. The Government sanctioned a scheme of advancing *taccavi* loans and the amount was placed at the disposal of the district officers. Generally speaking, loans are a good attraction to the owners of affected lands for improving them.

The Forest Department has been carrying on propaganda by arranging lectures, illustrated by magic lantern shows, and by the display of soil conservation posters and models. Cinema films were also reeled on silent projectors to show the reclamation of land by machines in other countries. *Sanads* from the Government and cash rewards were also distributed to win the sympathy, help and co-operation of well-to-do and influential section of the zamindars for pushing forward soil conservation programme.

With a view to controlling erosion and thereby increasing agricultural production, the Department is implementing a project under which demonstration areas will be set up in Rawalpindi, Attock, Jhelum and Gujrat Districts. The project will take three years for completion and it will, for the present, be confined to demonstration work in selected areas but in due course the work will be spread over all agricultural land. Extension work will also be done simultaneously. It is estimated that it would cost the Government about Rs. 7 lakh to carry on the demonstration work in selected areas.

Co-operative Department

The Co-operative Department has also been contributing towards the reclamation of eroded land. Anti-erosion, Cho and Land Reclamation Co-operative Societies were organised and encouraged by the Department. Its objects were to promote the economic interests of its members and more particularly to arrange to (i) conserve, reclaim and improve the land, (ii) construct check dams, spillways and bunds in fields and gullies and to adopt other measures in order to check the rapid run-off of water leading to erosion; (iii) plant grasses, shrubs and trees on lands under erosion and conserve and reclaim such land by enforcing closures to grazing, browsing and wood cutting thereon; (iv) supervise and manage the income derived from lands subject to erosion; and (v) adopt other measures designed to encourage in the members the spirit and practice of thrift, mutual help and self-help. The number of Anti-Erosion Co-operative Societies located in various parts of the Puajab during the year 1953 is given below :

<i>Districts</i>		<i>No. of Societies</i>
(i) Rawalpindi	...	226
(ii) Attock	...	66
(iii) Jhelum	...	60
(iv) Gujrat	...	52
(v) Sialkot	...	27
Total		431

This shows that Rawalpindi Division has 404 Societies whereas in Lahore Division, only 27 Societies were working in Sialkot District. The number of such Societies, membership, their working capital and total area under their control are as follows :

TABLE 30

Division	1948-49	1949-50	1950-51	1951-52
<i>Number of Societies</i>				
Lahore	27	27	27	27
Rawalpindi	328	342	356	367
Total	355	369	383	394
<i>Membership</i>				
Lahore	580	580	572	547
Rawalpindi	6,216	6,740	7,092	7,489
Total	6,796	7,320	7,664	8,036

Division	1948-49	1949-50	1950-51	1951-52
<i>Working Capital</i>				
Lahore	633	633	797	797
Rawalpindi	5,598	18,143	21,692	20,870
Total	6,231	18,776	22,489	21,667
<i>Area Under Control</i>				
Lahore	11,047	6,875	6,875	6,875
Rawalpindi	20,404	30,952	71,818	80,631
Total	31,451	37,827	78,693	87,506

The number of such Societies has been gradually increasing. Similar was the case with respect to their membership and total working capital. Total area under their control also showed a progress.

These Societies are useful but their number is insufficient to solve this problem. The work done by these Societies consisted of bunding, terracing, gully-plugging, tree and *kharkhana* plantation, spurs construction, etc. At various places they have been working in co-operation with the Forest Department. The reclamation work done by them is reviewed below :

TABLE 31

(Figures in Acres)

Year	Bunding & terracing	Gully plugging	Area brought under cultivation	
			During the year	Total up-to-date
1948-49	1,865	50	243	2,339
1949-50	883	10	407	2,746
1950-51	1,979	188	609	3,355
1951-52	2,927	...	827	4,152

The area reclaimed by bunding, terracing and gully-plugging has been on the increase except for the year 1949-50. Each year more and more area is also being brought under cultivation after reclamation. Tractors and bull-dozers brought very seldom into service for reclamation of land. The reclamation work done in the shape of plantation of trees, *kharkhana* and *nara* grass, construction of bunds, spurs, *thokar*, etc., by these Societies is given on the next page.

TABLE 32

Work done	1948-49	1949-50	1950-51	1951-52
Number of trees planted	1,55,228	1,97,748	2,20,634	1,21,702
Kharkhana plantation (acres)	2,537	72,190	1,29,712	488
Nara grass (acres)	5,255	1,12,280	18,812	3,469
Bunds	43	337	184	279
Spur constructions	4	29	42	16
Watbandi (acres)	240	...	...	...

Most of the work has been done in the Rawalpindi Division, which claims the largest number of such Societies. A part of the cost was generally borne by the Government while the rest was contributed by the members in the form of cash, labour and material. Various difficulties were encountered by the Societies. These were guided and supervised by the general duty staff who could not pay adequate attention to the guidance of the people. Due to the temporary allotments of land to the refugees, not much interest is shown in these Societies. The tenancy system offers another impediment in the way of its progress. The Societies lack funds for the purchase of heavy machinery to facilitate the operations of *watbandi* and construction of bunds. The people require some incentive in the shape of subsidies to undertake this useful work. The holdings, being small, are scattered and cannot be properly terraced unless zamindars collectively agree to a common plan.

P.W.D. Irrigation Bunds Circle

A Bunds Circle was organised in the P. W. D. Irrigation Branch, in January 1953, to explore the possibilities of impounding the available monsoon flow in the various *nallahs* and tributaries of the rivers by means of low earthen dams and of releasing the supplies thus conserved in the month of September to contribute their share in meeting the overall acute shortage of irrigation supplies in the Punjab.

Various possible storage sites were explored at all the tributaries of the Rivers Ravi, Chenab and Jhelum. In deciding whether the scheme at a particular site was feasible a detailed and thorough investigation was made which included, (i) Field study consisting of detailed contour survey of the dam site, reservoir and spillway channel, (ii) Geological examination of the scheme, (iii) Survey of material available, (iv) Collection of the complete hydrological data of the tributary to correlate the rainfall and the discharge passed down by the tributary, (v) Silt analysis to determinethe silt load brought down by the water.

Bunds Sites.—Surveys were carried out by the Bunds Circle and the following sites for the proposed bunds were selected :

1. *Tributaries of River Ravi.*

(i) *Basantar Nallah.* The requisite of a good storage site was not available, however, one site near village Nadala was examined for the purpose and the project estimates were made. (ii) *Bein Nallah.* A site near Tehra village was investigated and an another site near village Khosa was under investigation. (iii) *Deg Nallah.* A scheme was under investigation. (iv) *Saida Nallah.* It was proposed to arrange the supply of water in Bhag and Ghag *Nadies* from the Saida Nallah which maintains adequate flow throughout the year.

2. *Tributaries of River Chenab.*

(i) *Bhimber Nallah.* One bund site near village Murarian was investigated. (ii) *Bhunder Nallah.*—One storage site near village Kotla was under investigation. (iii) *Halsi Nallah.* Dilawarpur, Saka, Deyan and Kotla Dhinda sites were selected. (iv) *Doara Jalalpur.* A site near village Chohan was selected and the project estimates were under examination. (v) *Doara Tanda.* A site near village Tanda was found most suitable and investigations were in progress.

3. *Tributaries of River Jhelum.*

Various sites were selected after careful study which included (i) Kotla Kund and Nurpur on Bunha River. (ii) Pirkhana on a tributary of Jabba torrent. (iii) Jabba on Jabba torrent. (iv) Jatli on Suketar Nallah. (v) Katha on Katha torrent. (vi) Dokhari on Dokhari torrent. The survey of Kotla Kund, Pirkhana and Jabba sites was in advanced stage. The work on other sites was in progress. The possibilities of adopting the following measures to develop the upland areas were under examination. (a) Water conservation through small artificial bunds and utilising the supplies for irrigating the adjoining areas by gravity or lift. (b) Terracing of area to retain the precipitation. (c) Sinking of tubewells for plain areas, wherever possible.

The P. W. D. Irrigation Branch was also making arrangements for the investigation of ground water resources, possible surface and underground water storage, in the upland districts of Jhelum, Rawalpindi and Attock. The final report was expected to contain all soil investigations; test borings, pumping tests, geological

cross-sections and to elaborate all specifications and recommendations for setting up schemes of tubewells, underground barrages for raising the ground-water table and controlling the in and out-flow from a given ground-water basin. The circle was, however, closed after about a year for want of funds.

Directorate of Erosion Control and Soil Conservation

In view of the increasing menace of soil erosion it was decided by the Government of Pakistan to invite foreign experts on the subject. Consequently, in 1953, a soil conservation expert from U.S.A. was called who went round the upland districts of the Punjab and compiled a comprehensive report on the damage done as a result of erosion and made his recommendations for combating it. An organisation was suggested by him on the same lines as the United States Soil Conservation Service. Pakistan Government asked for foreign aid for setting up this organisation as a result of which an agreement was entered into with the Foreign Operations Administration of U.S.A. Free technical advice in the form of four experts and all other necessary equipment and machinery was to be given free by the American Government while Pakistan was to incur the rupee expenditure in running the organisation.

The organisation consists of a Director assisted by four specialist officers in Agronomy, Soil Science, Forestry and Agricultural Engineering. This team will conduct operations in five project areas to be located one in each the districts of Rawalpindi, Attock, Jhelum, Gujrat and Sialkot. Each of the project area consists of about 15-20 thousand acres in extent and is placed under the charge of a project officer with necessary field staff. More attention will be paid to the control of running water by introducing new methods which include contour cultivation, stabilisation of gullies, proper stocking and management of grazing lands, growth of permanent vegetation on steep slopes and digging of diversion ditches. The field staff will be provided with necessary machinery and equipment in the form of tractors along with all the accessories for carrying out actual operations on the cultivators' fields and demonstrating to them the benefits of various agricultural and tillage operations that help in conserving the soil and water. The scheme is to be run for an initial period of three years and involves the voluntary co-operation of the cultivators with the staff. If the project meets with success then it is contemplated by the Government to set up this organisation on a larger basis for executing the work over the entire upland districts. The plans of the organisation involve work in the

actual agricultural areas where the soil, though at present under cultivation, is subject to deterioration as a result of erosion. The idea is to conserve whatever resources are left and avoid wastage of energy by going to badly cut-off gullied areas which would require a lot of energy and money to reclaim small pieces of land behind huge bunds.

Out of the five project areas, four have finally been selected and the work on them has already been started. They are located in Attock, Rawalpindi, Jhelum and Gujrat Districts.

CHAPTER 5

The Future

Pakistan is an agricultural country and the produce of land not only supplies bread, clothes and shelter to the teeming millions, but also determines the magnitude and variety of our foreign exchange. Apart from fast growing population there is a ceaseless influx of refugees from India. Contrary to this, the total land resources of the country are not increasing proportionately. In order to meet the menace of soil erosion there appears to be three ways open to action, i.e., increase in cultivated acreage, developing irrigation resources, and increased agricultural yield. The first two are, however, not without limitations. The new areas that can be brought under the plough are limited. Water resources that can be exploited for irrigation projects are also not unlimited, particularly in view of the position created as a result of Partition whereby most of the catchment areas of our rivers are situated in India. Under such conditions it will not be a sound policy to go ahead with new schemes of land development and irrigation without proper regard to the measures for checking soil deterioration of the existing cultivated area. Our agricultural yield is low and needs to be increased. After all other resources have been fully exploited, the increased production per acre seems to be the only remedy left for us. But unfortunately not much attention has been paid to this aspect of our agricultural economy. Therefore, our future plans must be based on a proper land use and management policy.

It is well known that the state, as the supreme body of a country, can play a most vital role in the organisation of its economic resources. The Punjab Government is aware of the serious nature of the erosion problem. The reclamation and conservation of the soil is the main task of the Government and it has to provide for its planning, funds and expert advice. But the work of the soil conservation as an anti-erosion measure has never been seriously taken up in this province. Whatever was done was in the form of reclamation operations which by itself was too inadequate as compared to the magnitude of the problem.

The Royal Commission on Agriculture suggested that protective measures against soil erosion be left to private co-operative

efforts. But Sir John Russell advocated in 1937 that such measures should be the State responsibility. Private co-operative effort is, however, very necessary but it should largely be the State responsibility.

Programme

To combat erosion we must follow a comprehensive programme which essentially requires execution for a number of years based on proper land use and soil management, better agronomical practices and such supplementary engineering practices as terracing, proper control of run-off by means of permanent drop structures as spillways, shoots and grassed waterways, etc. Agricultural engineers, soil scientists, agronomists and forest experts should co-operate in evolving a joint action to fight the menace. It may also be stated here that the problem of soil erosion is of water-cum-soil conservation, each factor being dependent on the other and if monsoon rain-water is conserved, the soil is conserved and *vice versa*.

The various steps involved in developing such a programme are the collection of statistics for land and manure resources, the amount and distribution of rain-fall, kind of crops and the prevalent cropping practices, cattle wealth, farmers' requirements, etc. Land capability classification is also required which will aid in planning a proper land use. Engineering surveys should be started to work out details about laying out the terraces, waterways, structures and gully-plugging, etc.

In order to make such a programme successful recognition of soil erosion as a national problem and its wide understanding by the Government, public and cultivator alike is very essential. To acquaint the people with the problem, education should begin right from the school. In high schools and agriculture colleges soil erosion and soil conservation should form an essential part of our curriculum. Agriculture includes soil erosion at present, but needed emphasis is lacking. Guest speakers should be invited and persons qualified in this field should be approached to deliver lectures to the students. The farmers should be approached systematically through press, radio, movie films and platform to arouse their personal interest in the problem because it is the villagers alone who in the last resort have to put into effect the Government policy of soil conservation and, therefore, to them must the attention be directed. To win their cooperation, simple demonstrations should be arranged on their own fields. The importance of publicity campaign becomes all the

more greater when it is realised that a vast majority of our cultivators is illiterate and ignorant of the methods of dealing with the menace.

Then the actual programme be set in motion. Work on laying out new terraces, improving existing ones, aligning waterways, construction of structures like spurs, spillways and check dams, etc. should be taken in hand. This work should finish before the rainy season starts. The land use which results from land manure and cattle resources and farmers' requirements should now be delineated into *kharif* and *rabi* programmes along with other management practices. Engineering devices should be combined with the agronomical practices. Wherever green manuring is done, a part of the green stuff should be left on the surface to guard it against beating rains. During rains stabilization of gully beds, banks, bunds of cultivated fields, and gully-pulging should be undertaken. Suitable tree and grass species should be introduced to ensure success.

Land which is unsuitable for either crops or pastures may be usefully utilised for growing forests. Suitable sites should be selected for forest plantation to serve as wind breaks and thus minimise the intensity of wind storms. Controlled grazing should be introduced. Village Soil Conservation Cooperative and Credit Societies should be started and entrusted with the task of arranging demonstrations, establishing and protecting forests and vegetation, carrying out of agronomical-cum-engineering programme on the crop lands, maintenance and care of engineering structures in collaboration with Government agencies and advancing credit to deserving members. Such Cooperatives in every catchment might be pooled for coordinated and collective action.

Erosion Control Authority

There is a great need for the creation of an Erosion Control Authority to cope with this colossal problem effectively. This Authority, besides having senior officers of the Government as its members, must include experts in agriculture, forestry and engineering. They may be the heads of the various Government Departments who could help coordinating various activities through their respective offices. This Authority should be vested with necessary powers and charged with the operation of a programme for conservation of soil and water on the basis of modern concept of the problem as it is developed and tackled in advanced countries of the world. Under this Authority, a full fledged field organi-

sation could be made responsible for execution of an overall programme.

It is hoped that with mutual cooperation, assisted by official supervision, new life will be infused into our depleted soils. In this way only can we preserve our people's precious soil resources and look forward to raising their living standards.

CHAPTER 6

Summary and Conclusions

Soil erosion has destroyed hundreds of thousands of acres of fertile land in Pakistan and is capable of involving very serious consequences if allowed to grow unchecked. Recently Pakistan Government had to import large quantities of wheat to meet the shortage created by various factors. Apart from the immediate causes, the more permanent were soil deterioration caused by erosion and water-logging, exhaustion through continuous crop removal, fast growing population, etc., which have been at work for long. Erosion implies lingering death of the soil and results in its impoverishment and the undernourishment of crops leading to poor harvests. The upper layer of the soil is washed away by heavy rainfall due to the absence of forests and vegetative cover. There are three natural agents which cause erosion of the soil, namely, water, wind and snow. Water erosion takes three forms, *viz.*, sheet, rill and gully. Wind erosion is also a nuisance to plant and human life. Various factors affecting erosion consist of rainfall, slope and topography, land cover, rotation and management practices, soil characteristics, etc.

At Nurpur, it was found that the total soil lost from the bare surface was over 12 times the soil lost from the grass-covered area. The Banni experiment revealed a total loss of nearly 911 maunds per acre from the bare surface against 187 maunds for grass-covered and 100 maunds for grass-and-bush-covered soil per year. The speed of run-off of water was minimum on the soil which was controlled by plantation and construction of bunds and was maximum where vegetation was destroyed. Three years' observation at a model farm showed that the yield of crops gradually improved in portions of fields where erosion was controlled as compared with other portions.

The effects of soil erosion are very serious as the soil which takes centuries to develop is lost in only a few decades thus upsetting the economy of the country. The various effects of erosion are: loss of surface soil, plant food, humus and fine soil particles, rain water, falling sub-soil water level, drying up of springs, silting up of canals and streams, high floods, threat to communications, reduced

productivity, shortage of fodder and deterioration of cattle, etc. The modern approach to soil conservation programme consists in the proper land use, continuous soil cover, modern management practices, various engineering devices and growing shelter belts, etc.

Our population has been increasing faster than the increase in the cultivated acreage. It has increased from 100 in 1901 to 199 in 1951, but cultivated acreage has increased from 100 to 149 only during the same period in spite of the development of the most widely spread net work of canal system. The animal population has also increased. Uncontrolled grazing especially of goats result in the destruction of vegetation. The major part of unauthorised grazing took place in Rawalpindi Division which is the most seriously eroded area.

Pakistan did not inherit the required acreage under forests needed for a balanced economy and even this is on the gradual decline. Starting from 5.0% acreage under forests in 1906-07 it has come down to 2.7 in 1953-54. In 1947-48 the acreage was 11,49,200 acres while in 1953-54 it declined to 9,97,315 acres. A propaganda campaign should be launched for making the people conscious of the importance of the trees.

This menace has seriously affected the upland districts of Rawalpindi, Jhelum and Attock. Other affected districts are D. G. Khan, Gujrat, Shahpur Mianwali and Sialkot. Out of these, five receive heaviest rainfall in the province.

Uptill now there has been no official survey of the eroded areas in Pakistan or the Punjab and whatever figures are available are mostly estimates. From the various facts and figures available, it has been estimated that about 5 lakh acres have been permanently destroyed while 10 lakh acres are seriously eroded, 15 lakh acres are less affected and 10 lakh acres are under the threat of erosion. An elaborate survey at the official level is required by a team consisting of soil scientists, agronomists, agricultural engineers and foresters to ascertain the extent of the problem and the measures to be adopted. A greater emphasis has always been laid on reclamation operation rather than conservation measures in this province. Reclamation of totally broken and waste lands as against conservation of good and productive agricultural lands as an anti-erosion measure will never be able to achieve anything substantial and must result in negative progress as more and more good land goes out of cultivation faster than can be brought back through the agency of reclamation. This clearly points to the inadequate emphasis being placed in planning for the

problem. This is high time that adequate measures are taken by the Government which will prove equal to the magnitude of the problem.

Erosion in the Punjab has attracted the attention of the Government ever since early seventies of the last century. Various enquiries have been conducted bearing upon this problem by the Government since then and the Punjab Land Preservation (Chos) Act of 1900 was also passed. The Government opened an Anti-Erosion Circle in the Punjab Forest Administration in April, 1939. The Co-operative Department has also organised 431 Land Reclamation and Anti-Erosion Co-operative Societies of which 404 are in Rawalpindi Division alone. These Societies have also been contributing their share in conserving soil and reclaiming eroded lands by various methods. The question of finding money for investing in soil conservation is also important because except for a handful of big zamindars, the financial position of the tillers is far from being sound. In the case of refugees little interest in conserving the soil has been shown due to the temporary allotment of land. The tenancy system also offers another impediment in the way of its progress. Co-operation and understanding between the various Government Departments is essential as soil erosion is their common enemy. The importance of a publicity campaign becomes essential when we recall that majority of our cultivators is illiterate and ignorant of the methods of dealing with the problem.

A new approach to combat this menace has been made with the opening of the Punjab Erosion Control and Soil Conservation Project at Rawalpindi. The organisation consists of specialised officers in agronomy, soil science, forestry and agricultural engineering. The plan involves work in the actual agricultural areas where the soil, though at present under cultivation, is subject to deterioration as a result of erosion. The idea is to conserve whatever resources are left and avoid wastage of energy on badly cut-off and gullied areas.

The crying need of the hour is to establish an Erosion Control Authority for the whole of the West Pakistan vested with certain powers. This Authority should be charged with formulating and executing the programme and suggesting suitable enactment.

**STATISTICAL TABLES
&
APPENDICES**

TABLE I

Tehsilwise Population, Area & Density Per Square Mile in the Punjab.

Tehsils and Districts	Actual Population			Percentage			Area (Sq. miles)	Density per square mile.	
	Urban	Rural	Total	Urban	Rural	Total		Rural	Total
Gujranwala Dist. ...	2,51,057	7,95,975	10,47,032	24	76	100	2301	352	455
Gujranwala ...	1,54,414	4,23,809	5,78,223	27	73	100	930	461	622
Hafizabad ...	36,866	2,14,745	2,51,611	15	85	100	915	235	275
Wazirabad ...	59,777	1,57,421	2,17,198	27	73	100	456	369	476
Lahore Dist. ...	9,80,821	9,14,407	18,95,228	52	48	100	2429	400	780
Lahore ...	8,59,364	2,75,536	11,34,900	75	25	100	679	500	1671
Chunian ...	37,297	4,78,225	5,15,522	27	73	100	1106	436	466
Kasur ...	84,160	1,60,646	2,44,806	5	95	100	644	251	380
Sheikhupura Dist. ...	82,617	8,40,743	9,23,360	22	78	100	2318	370	398
Sheikhupura ...	56,962	3,97,321	4,54,283	13	87	100	877	470	518
Nankana ...	16,599	2,32,023	2,48,622	7	93	100	690	341	360
Shahdara ...	9,056	2,11,399	2,20,455	4	96	100	751	284	294
Sialkot Dist. ...	2,20,396	12,53,857	14,74,253	15	85	100	2071	613	712
Sialkot ...	1,67,543	2,50,850	4,18,393	40	60	100	387	753	1081
Daska ...	20,294	2,71,086	2,91,380	7	93	100	398	685	732
Narowal ...	15,298	2,36,434	2,51,732	6	94	100	416	574	605
Pasur ...	17,261	2,34,730	2,51,991	7	93	100	381	621	661
Shakargarh ...	...	2,60,757	2,60,757	...	100	100	489	533	533
LAHORE DIV. ...	15,34,891	38,04,982	53,39,873	29	71	100	9,119	429	586

TABLE 1—contd.

D.:G. Khan Dist. ...	74,999	5,55,695	6 30,694	12	88	100	9,271	59	67
D. G. Khan ...	38,932	1,99,215	2,38,147	12	88	100	1,945	103	122
Biloch T. F. Tracts... ..	...	45,016	45,016	...	100	100	3,990	11	11
Jampur ...	16,999	94,956	1,11,955	15	85	100	900	106	124
Rajanpur ...	8,955	1,22,616	1,31,571	7	93	100	1,944	63	68
Sanghar ...	10,113	93,892	1,04,005	10	90	100	592	159	176
Jhang Dist. ...	1,35,307	7,41,454	8,76,761	15	85	100	3,400	220	258
Jhang ...	73,402	2,75,877	3,49,279	21	79	100	1,328	209	263
Chiniot ...	50,111	2,79,983	3,30,094	15	85	100	1,012	277	326
Shorkot ...	11,794	1,85,594	1,97,388	6	94	100	1,060	1271	186
Lyallpur Dist. ...	2,83,039	18,69,824	21,52,863	13	87	100	3,534	532	609
Lyallpur ...	1,87,202	5,14,872	7,02,074	27	73	100	771	677	910
Jaranwala ...	28,068	4,09,919	4,37,987	6	94	100	709	581	618
Samanduri ...	6,637	4,02,267	4,08,904	2	98	100	771	522	530
T. T. Singh ...	61,132	5,42,766	6,03,898	1	99	100	1,283	442	471
Montgomery Dist....	1,54,833	16,61,287	18,16,120	7	93	100	4,208	397	432
Montgomery ...	62,268	5,41,586	6,03,854	10	90	100	1,228	444	492
Dipalpur ...	16,369	2,90,271	3,06,640	5	95	100	965	301	318
Okara ...	40,325	3,83,616	4,23,941	10	90	100	722	536	587
Pakpattan ...	35,871	4,45,814	4,81,685	7	93	100	1,293	347	373
Multan Dist. ...	3,41,307	17,66,296	21,07,603	16	84	100	5,619	317	375
Multan ...	1,90,122	3,16,693	5,06,815	38	62	100	777	415	652
Kabirwala ...	9,485	2,41,749	2,51,234	4	96	100	672	363	374
Khanewal ...	58,002	3,26,396	3,84,398	15	85	100	981	336	392
Lodharan ...	25,998	2,63,090	2,89,088	4	96	100	1,064	248	272
Mailsi ...	10,242	1,74,490	1,84,732	6	94	100	633	276	292
Shujahabad ...	23,089	1,95,303	2,18,392	11	89	100	688	284	317
Vehari ...	24,369	2,48,575	2,72,944	9	91	100	804	310	339

TABLE 1—Contd.

Tehsils and Districts	Actual Population			Percentage			Area (Sq. miles)	Density per square mile	
	Urban	Rural	Total	Urban	Rural	Total		Rural	Total
Muzaffargarh Dist.	54,361	6,96,889	7,51,250	7	93	100	5,601	125	134
Muzaffargarh ...	15,679	2,19,177	2,34,856	7	93	100	750	293	313
Alipur ...	10,677	2,00,505	2,11,182	5	95	100	932	216	227
Kot Adu ...	10,507	1,32,502	1,43,009	7	93	100	1,504	88	95
Leiah ...	17,498	1,44,705	1,62,203	11	89	100	2,415	60	67
MULTAN DIV. ...	10,43,846	72,91,445	83,35,291	13	87	100	31,733	231	263
Campbellpur Dist.	90,075	6,33,049	7,23,124	12	88	100	4,149	153	174
Compbellpur ...	66,036	2,00,181	2,66,217	25	75	100	652	159	408
Fatehjang ...	5,127	1,38,845	1,43,972	4	96	100	853	163	169
Pindi Gheb ...	10,157	1,54,176	1,64,333	6	94	100	1,438	107	114
Talaang ...	8,755	1,39,847	1,48,602	6	94	100	1,206	116	123
Gujrat Dist. ...	1,31,183	10,27,492	11,58,675	11	89	100	2,258	464	513
Gujrat ...	73,962	3,22,668	3,96,630	19	81	100	565	592	702
Kharian ...	30,126	3,16,316	3,46,442	9	91	100	664	481	522
Phalia ...	27,095	3,88,508	4,15,603	7	93	100	1,029	384	404
Jhelum Dist. ...	77,275	6,04,786	6,82,061	11	89	100	2,786	221	245
Jhelum ...	56,617	2,09,153	2,65,770	22	78	100	905	238	294
Chakwal ...	13,319	2,09,019	2,22,338	6	94	100	1,016	207	219
P. D. Khan ...	7,339	1,86,614	1,93,953	4	96	100	865	219	224

TABLE 1—Concl'd.

Tehsils and Districts	Actual Population			Percentage			Area (Sq. miles)	Density per square mile	
	Urban	Rural	Total	Urban	Rural	Total		Rural	Total
Mianwali Dist. ...	58,204	4,92,295	5,50,499	11	89	100	5,389	92	102
Mianwali ...	23,341	2,16,795	2,40,136	10	90	100	1,528	142	157
Bhakar ...	17,974	2,16,498	2,34,472	8	92	100	3,144	69	75
Isakhel ...	16,889	59,002	75,891	22	78	100	717	83	106
Rawalpindi Dist. ...	2,55,128	6,20,376	8,75,504	29	71	100	2,023	312	433
Rawalpindi ...	2,37,219	2,04,949	4,42,168	54	46	100	750	280	590
Gujjar Khan ...	8,503	2,01,344	2,09,847	4	96	100	564	358	372
Kahuta ...	...	1,23,810	1,23,810	...	100	100	454	273	273
Murree ...	9,406	90,273	99,679	9	91	100	255	383	391
Shahpur Dist. ...	2,13,616	9,49,372	11,62,988	18	82	100	4,788	202	243
Shahpur ...	29,019	1,46,378	1,75,397	17	83	100	605	255	290
Bhalwal ...	49,749	2,61,683	3,11,432	16	84	100	826	278	377
Khushab ...	49,168	2,22,197	2,71,365	18	82	100	2,526	88	107
Sargodha ...	85,680	3,19,114	4,04,794	21	79	100	831	387	487
RAWALPINDI DIV.	8,25,481	43,27,370	51,52,851	16	84	100	21,393	205	241

TABLE II

*Circlewise cases of Unauthorised Grazing in the Punjab
Since 1947-48*

Circle		Lahore	Multan	Rawalpindi	Grand Total
1947-48	A	625	362	2,190	3,177
	B	1,389	2,711	11,621	15,721
	C	157	226	46	429
Total ...		2,171	3,299	13,857	19,327
1948-49	A	946	1,099	2,375	4,420
	B	3,740	4,045	13,156	20,941
	C	145	238	153	536
Total ...		4,831	5,382	15,684	25,897
1949-50	A	908	538	3,318	4,764
	B	665	2,846	11,201	14,712
	C	...	976	148	1,124
Total ...		1,573	4,360	14,667	20,600
1950-51	A	1,691	819	2,608	5,118
	B	3,020	2,056	13,825	18,901
	C	1	252	360	613
Total ...		4,712	3,127	16,793	24,632
1951-52	A	2,081	1,111	5,505	8,697
	B	3,126	2,732	15,147	21,005
	C	729	26	291	1,046
Total ...		5,936	3,869	20,943	30,748
1952-53	A	1,759	2,226	2,521	6,506
	B	2,501	2,201	13,475	18,177
	C	...	15	197	212
Total ...		4,260	4,442	16,193	24,895

A—Means cases taken to court.

B—Means cases disposed of under Section 67 of I.F. Act 1878.

C—Means undetected cases.

TABLE III
Hydrological Data Concerning Indus Basin Rivers

Name of the river:	Catchment area at debouchment in plains in sq. miles	Maximum recorded flood discharge in cusecs	Minimum monthly discharge in cusecs
Ravi ...	3,562	200,000	2,086
Beas ...	5,384	500,000	4,641
Chenab ...	11,399	750,000	6,830
Jhelum ...	12,445	800,000	7,246
Sutlej ...	23,400	400,000	4,325
Indus ...	118,400	1,000,000	26,584

TABLE IV
Distribution of Forests in the Hill Catchments of Indus River System

Name of the river	Hill catchment area in India and Pakistan (sq. miles)	Area still under forest inside the hill catchments (sq. miles)	Forest area ruined by human misuse (sq. miles)
Ravi ...	3,560	2,580	380
Beas ...	5,400	3,740	130
Chenab ...	10,540	2,590	2,010
Jhelum ...	16,280	10,520	1,250
Sutlej ...	12,660	3,110	710
Indus ...	79,440	11,760	10,710
Total ...	127,880	34,300	15,240

Source: The Pakistan Journal of Forestry, October 1954.

TABLE V

The Indus River System

Name of the river	Length in miles	Himalayan area included in the catchment basin (sq. miles)	Total discharge of water in one year (estimated*)	Ratio of discharge to area taking that of Ravi to be unity
Ravi ..	420	3,100	1.0	1.0
Beas ...	220	5,600	2.5	1.3
Chenab ...	640	10,500	5.5	1.6
Jhelum ...	430	13,000	5.5	1.3
Sutlej ...	900	18,500	3.5	0.6
Indus ...	1,830	103,800	9.0	0.3
Total ...	4,440	154,500	...	...

(*Taking the Ravi discharge as unity ; the numbers do not represent any actual units of measure but show the ratio of river discharge to that of the Ravi. These are based on short observations and rough estimates.)

Source : The Pakistan Journal of Forestry, October 1954.

TABLE VI

Classifications of the Area in the Punjab.

Quinquennial Average.	Uncultivated Acreage				Cultivated Acreage			Grand Total	% of cultivated area to total area.
	Forest.	N. A. For Cultivation.	Cultivable Waste.	Total.	Current Fallow.	Net Area actually sown.	Total.		
1906-7	18,62,704	59,50,666	1,54,18,170	2,32,31,540	20,93,500	1,16,88,660	1,37,82,160	3,70,13,700	37.24
1911-12	17,72,014	61,81,986	1,44,64,536	2,24,18,536	26,91,254	1,19,76,503	1,46,67,757	3,70,83,293	39.55
1916-17	16,15,133	62,44,220	1,41,56,605	2,20,15,958	22,70,763	1,28,52,441	1,51,23,204	3,71,39,162	40.72
1921-22	14,32,422	63,35,535	1,32,85,322	2,10,53,279	32,92,635	1,28,83,441	1,61,76,076	3,72,29,355	43.45
1926-27	13,70,900	63,41,933	1,30,01,347	2,07,14,180	23,98,204	1,41,15,136	1,65,13,340	3,72,27,520	44.36
1931-32	12,56,310	64,48,089	1,23,31,757	2,00,36,156	24,81,273	1,46,14,097	1,70,95,370	3,71,31,526	46.04
1936-37	12,00,163	66,69,844	1,17,77,279	1,96,47,286	24,14,464	1,50,53,294	1,74,67,758	3,71,15,044	47.06
1941-42	12,00,220	67,66,653	1,13,63,531	1,93,30,404	22,84,816	1,55,03,014	1,77,87,830	3,71,18,234	47.92
*1946-47	11,56,872	66,99,441	1,03,98,146	1,82,54,459	21,76,411	1,66,09,542	1,87,85,953	3,70,40,412	50.72
1951-52	11,46,707	67,61,860	98,79,971	1,77,88,538	27,93,870	1,65,61,180	1,93,55,050	3,71,43,588	52.11

* Data for the years 1944-45 and 1945-46 is not available. Therefore the figures relate to the trienium average.

N.A.—Not Available.

Year.	Lahore.	Sialkot.	Gujranwala.	Shiekhupura.	Gujrat.	Shahpur.	Jhelum.	Rawalpindi.
1931-32	34.5	30.2	24.9	22.6	23.2	9.4	23.6	34.6
1932-33	13.6	25.4	16.5	13.1	25.3	14.9	26.5	29.9
1933-34	22.6	38.9	32.3	22.6	37.5	22.7	31.7	27.3
1934-35	24.5	37.2	33.3	20.1	28.6	18.3	26.4	43.2
1935-36	12.9	34.7	23.1	15.8	23.5	12.9	30.3	42.8
1936-37	22.5	48.4	20.1	20.7	27.7	18.2	24.4	40.3
1937-38	14.1	24.3	15.6	10.1	19.8	11.8	20.6	25.2
1938-39	12.9	37.4	22.5	10.1	24.1	9.8	28.8	47.9
1939-40	13.6	22.5	16.1	10.6	21.4	9.8	14.9	23.3
1940-41	10.2	33.8	14.5	12.4	19.2	14.4	22.4	29.0
1941-42	16.8	28.4	26.9	17.1	26.8	16.1	35.2	36.1
1942-43	15.8	36.5	21.4	15.7	29.9	10.3	31.5	35.3
1943-44	11.2	22.5	15.3	20.4	23.6	20.3	26.7	32.8
1944-45	16.8	33.0	32.7	18.3	25.6	23.2	32.2	33.3
1945-46	17.7	22.7	19.8	20.1	18.6	15.4	21.7	31.2
1946-47	13.9	39.5	11.1	7.5	16.8	8.6	23.6	34.9
1947-48	16.8	34.5	20.3	14.5	27.9	5.1	33.2	30.2
1948-49	27.3	42.6	39.2	32.8	38.6	14.5	47.2	56.5
1949-50	15.4	34.7	29.9	15.9	30.7	20.5	30.5	33.5
1950-51	28.2	46.3	35.2	30.4	45.1	15.6	27.3	41.8
Average	18.1	33.7	23.0	17.5	26.7	14.5	27.9	35.5

TABLE
Districtwise acreage under Forests

Year.	Lahore.	Sialkot.	Gujranwala.	Sheikhu-pura.	Gujrat.	Shahpur.	Jhelum.
1931-32	27,522	1,578	884	3,983	50,882	3,64,941	2,20,323
1932-33	27,621	1,578	884	3,952	52,471	3,63,634	2,20,351
1933-34	27,624	1,578	884	3,957	52,870	3,59,539	2,20,355
1934-35	26,998	1,572	884	3,796	54,050	3,57,490	2,20,355
1935-36	28,449	1,572	884	3,895	54,921	3,58,461	2,20,369
1936-37	25,881	1,572	885	3,895	55,190	3,58,466	2,20,369
1937-38	25,158	1,572	885	3,952	55,113	3,58,461	2,20,317
1938-39	25,996	1,572	885	3,952	55,112	3,59,292	2,20,022
1939-40	25,149	1,572	885	3,983	55,112	3,59,293	2,19,850
1940-41	26,303	1,572	885	3,983	55,110	3,57,880	2,20,495
1941-42	25,301	1,572	885	3,983	55,115	3,55,232	2,20,496
1942-43	23,835	1,572	885	3,983	55,115	3,51,860	2,20,496
1943-44	20,011	1,572	885	3,983	55,115	3,49,543	2,20,496
1944-45							
1945-46							
1946-47	18,673	1,734	885	3,983	54,796	3,45,160	2,20,412
1947-48	18,505	1,734	885	3,983	54,797	3,46,314	2,20,412
1948-49	18,408	1,734	885	3,983	54,799	3,46,313	2,20,422
1949-50	18,498	1,734	885	3,983	54,907	3,46,313	2,20,465
1950-51	18,498	14,334	2,003	4,775	54,907	3,46,256	2,20,575
1951-52	18,496	12,563	1,390	4,775	54,907	3,46,248	2,20,575

in the Punjab since 1931-32.

(Figures in acres)

Attock.	Mianwali.	Montgomery.	Lyallpur.	Jhang.	Multan.	Muzaffargarh.	D. G. Khan.	Average.
15.9	10.1	15.2	18.0	10.1	5.4	4.9	3.4	17.9
19.0	14.9	4.0	5.2	13.6	5.8	7.4	9.0	15.3
27.1	13.6	14.6	14.1	10.0	7.3	5.5	9.4	21.1
29.7	9.5	6.2	16.9	9.5	8.6	7.6	8.8	20.5
27.1	18.3	9.9	8.0	8.4	3.5	2.1	2.9	17.3
23.3	16.2	16.6	13.7	9.9	12.9	11.0	13.6	21.2
18.7	8.1	4.5	8.2	4.7	2.9	2.9	4.6	12.2
31.3	13.9	7.8	8.6	6.1	5.7	4.3	4.0	17.2
20.1	9.0	5.8	8.8	6.8	4.7	4.5	3.1	12.2
19.6	11.2	9.3	4.9	5.9	5.2	2.8	7.6	13.9
22.5	11.2	8.4	19.0	19.2	17.4	4.4	4.4	19.4
27.6	9.1	12.4	15.8	9.3	9.9	8.9	5.1	18.4
25.8	11.8	7.8	17.9	9.6	4.2	5.5	5.5	16.3
23.9	16.3	16.3	13.6	12.8	12.3	10.5	10.7	20.7
25.1	11.6	12.4	9.0	9.9	1.9	2.8	1.7	15.1
17.3	6.6	3.6	6.1	2.9	1.4	3.1	1.4	12.4
21.1	10.7	6.5	10.8	7.2	2.6	1.6	1.7	15.3
25.9	11.0	17.5	15.9	12.4	6.2	6.4	2.9	24.8
23.7	8.9	9.0	11.5	7.9	6.2	5.7	7.2	18.2
28.3	12.4	13.6	16.1	11.4	7.2	8.1	9.2	23.5
23.7	11.4	10.0	12.1	9.4	6.6	5.5	5.8	17.6

VIII

in the Punjab since 1931-32.

(Figures in inches.)

Rawalpindi.	Attock.	Jhang.	Montgomery.	Multan.	Muzaffar Garh.	D. G. Khan.	Total.
2,16,188	2,00,904	359	20,884	40,560	58,223	6,287	12,03,518
2,16,096	2,00,657	359	21,295	40,811	48,216	6,276	12,04,201
2,15,300	2,00,651	3.9	22,811	37,903	48,111	6,858	11,98,800
2,15,059	2,00,651	359	22,659	37,903	48,030	6,858	11,96,644
2,15,149	2,00,659	359	22,035	39,025	48,125	6,858	12,01,761
2,15,280	2,00,659	359	23,034	39,025	48,113	6,858	11,99,586
2,14,980	2,00,602	359	23,044	48,495	46,831	6,148	12,05,917
2,12,066	2,00,771	359	22,982	48,515	42,359	5,793	12,05,676
2,12,066	2,00,771	359	23,282	48,515	48,354	5,793	12,04,989
2,12,066	2,00,989	359	22,282	48,515	48,879	5,792	11,82,437
2,12,066	2,00,988	359	22,193	28,463	47,382	4,371	11,78,411
2,12,066	2,00,978	359	15,706	27,692	47,989	4,371	11,66,907
2,12,066	2,00,976	359	17,842	21,434	46,840	4,371	11,66,493
2,12,066	2,00,443	359	17,841	19,925	47,594	4,344	11,48,215
2,12,066	2,00,443	359	17,832	19,925	57,601	4,344	11,49,200
2,12,066	2,00,443	359	15,155	19,925	47,890	4,344	11,46,806
2,12,066	2,00,443	359	15,155	19,925	23,222	3,472	11,21,427
2,12,066	2,00,443	359	15,155	19,725	34,186	4,344	11,47,626
2,12,066	2,00,392	14,887	15,918	19,725	47,192	4,344	11,73,478

TABLE IX. Cattle Population in the Punjab.

Category	1904	1909	1914	1920	1923	1928	1930	1935	1940	1945
Bulls ...	20,37,375	21,64,733	24,52,388	3,519	5,294	3,273	3,105	3,130	3,900	4,149
Bullocks ...	...	...	...	21,39,316	22,84,873	22,80,063	22,18,732	22,50,027	23,38,132	24,23,076
Cows ...	15,99,575	18,77,043	20,06,502	15,28,584	15,39,502	15,03,257	13,73,781	15,21,209	13,94,591	14,37,848
Youngstock calves	16,96,471*	18,41,815*	19,24,403*	15,78,734	15,11,404	16,12,479	13,78,348	16,76,137	15,85,053	14,89,587
TOTAL ...	53,33,421	58,83,591	63,83,293	52,50,153	53,40,073	53,99,072	49,73,966	54,50,503	53,21,676	53,54,660
Male Buffaloes...	3,43,005	3,86,961	3,37,575	2,69,200	2,60,801	2,42,624	2,31,249	2,87,635	2,79,418	2,36,815
Cow "	5,46,842	10,88,566	13,44,542	13,59,968	14,68,996	15,22,698	15,34,304	16,97,295	17,99,940	19,36,540
Youngstock Buffalo & calves	Included above.	in Young stock calves	9,02,498	10,62,902	11,21,021	10,99,055	13,33,849	14,78,161	15,45,301	
TOTAL ...	11,89,847	14,75,527	16,82,117	25,31,666	27,92,699	28,86,343	28,64,608	33,18,779	35,57,519	37,18,656
Sheep ...	29,53,215	32,61,788	33,79,507	28,73,664	31,31,303	33,15,243	32,65,759	34,84,866	39,09,592	31,87,564
Goats ...	28,42,525	22,29,821	25,14,183	17,25,910	25,81,250	23,47,162	20,92,181	24,25,415	17,45,438	21,29,033
TOTAL ...	57,95,740	54,91,609	58,93,690	45,99,574	57,12,553	56,62,405	53,57,940	59,10,281	56,55,030	53,16,597
Horse ...				74,182	66,618	76,343	77,510	77,550	58,449	51,906
Mares	1,73,871	2,28,381	2,71,083	1,41,624	1,49,873	1,60,281	1,59,011	1,53,750	1,18,109	1,14,394
Youngstock colts & Fillis.	Included	in Horses	and Mares	43,110	44,295	56,473	52,520	44,319	49,043	42,353
Mules ...	13,999	23,211	18,700	19,855	18,512	19,981	21,186	18,183	19,431	21,309
Donkeys ...	3,46,773	4,08,822	4,97,716	4,46,314	4,58,475	4,89,629	4,60,335	4,98,948	4,97,311	4,56,819
Camels ...	1,74,604	1,85,805	2,24,397	1,41,998	1,72,703	1,95,771	1,84,562	2,04,498	1,78,567	1,73,166
TOTAL ...	7,09,247	8,46,219	10,11,896	8,67,083	9,10,476	9,99,478	9,55,124	9,97,248	9,20,910	8,59,947
G. TOTAL	1,30,28,255	1,36,96,946	1,49,70,996	1,32,48,476	1,47,55,801	1,49,47,298	1,41,51,638	1,56,76,811	1,54,55,135	1,52,49,860

* This includes Youngstock (Buffalo Calves).

APPENDIX A

*Results of the Experiments Conducted at Nurpur and Banni
Research Stations Regarding Loss of Soil*

**Nurpur Research Station
(1939-40)**

Particulars	Grass Cover (Trays 1 & 2)	Grass and Bush (Trays 3 and 4)	Bare Soil Grass Clipp- ed Every 8 Days (Trays 5 and 6)
A.—(i) Percentage of rainfall which ran off on 63 wet days for the total rainfall of 42.26" from 1st April, 1939 to 31st March, 1940	10.3	10.1	59.5
(ii) Weight of soil (in lbs.) lost per acre during 63 storms from 1st April, 1939 to 31st March, 1940	1,343	1,214	24,455
B.—Weight of soil (in lbs) lost per acre during 198 storms from 9th July, 1937 to 31st March, 1940	6,204	6,192	68,630

It is clear that the run-off from bare soil was about six times the run-off from grass or grass-and-bush-covered soil, while the loss of soil from bare land was about 18 times that from grass and 20 times that from grass-and-bush-covered soil. Since the installation of the trays, the bare soil had lost some 68,630 lbs. of soil per acre in about 33 months which is about 11 times the soil lost under grass or grass-and-bush-cover. The bare area has thus lost soil at the rate of 2,000 lbs. per acre per month. This loss was, however, recorded only on one experimental farm.

The run-off and soil-wash data for the year 1940-41 were collected from the date of the installation of the trays which is given below :

Particulars	Grass Cover 80 % (Trays 1 and 2)	Grass and Bush Cover 90 % (Trays 3 and 4)	Bare Soil Grass Clipped Every 3 Days (Trays 5 and 6)
A.—Percentage of rainfall which ran off on 58 wet days for total rainfall of 43.26" from 1st April 1940 to 31st March, 1941,	7.5	8.5	62.5
Weight of soil, (in lbs.) lost per acre during 58 storms from 1st April, 1940 to 31st March, 1941.	1,025	1,560	17,961
B.—Weight of soil (in lbs.) lost per acre during 256 storms from 9th July, 1937 to 31st March, 1941	7,230	7,753	86,590

The run-off from the bare soil was nearly 9 times the run-off from the grass-covered soil. The total soil lost from the bare area was about 12 times the soil lost from the grass-covered soil since the beginning of the experiment. The total loss from the bare soil works out to about 23½ maunds per month per acre.

The run-off and soil data were collected up to June, 1941. Further recording was discontinued as statistically no further data were required. Moreover, soil conditions in two trays had strikingly changed while a considerable part of the soil had been washed away leaving a mantle of pebbles on the surface. The following table summarises the results upto 30th June, 1941 :

Particulars	Grass Cover 80 per cent (Trays 1 and 2)	Grass and Bush Cover 90% (Trays 3 & 4)	Bare Soil Grass Clipped Every 3 Days (Trays 5 and 6)
Percentage of rainfall which ran off on 18 wet days for total rainfall of 9.85" from 1st April to 30th June 1941	5.5	10.1	52.5
Weight of soil (in lbs.) lost per acre during 18 wet storms from 1st April to 30th June, 1941	178	281	5,217
Weight of soil (in lbs.) lost per acre during 274 wet storms from 9th July, 1937 to 30th June, 1941	7408	8,034	91,808

The run-off from the bare soil was again nearly 9 times the run-off from the grass-covered soil. The total soil lost from the bare area was over 12 times the soil lost from the grass-covered soil since the beginning of the experiment. In the course of 4 years, the bare soil lost 1,120 maunds of soil per acre or 280 maunds per year per acre.

BANNI RESEARCH STATION

A similar battery of erosion trays was installed at Banni in the Pabbi Hills and the data collected for the year 1939-40 is given below :

Particulars	Grass Cover (Trays 1 & 2)	Grass and Bush (Trays 3 & 4)	Bare Soil Grass Clipped Every 8 Days (Trays 5 & 6)	
Percentage of rainfall which ran off on 52 wet days for total rainfall of 21.92" from 1st May, 1939 to 31st March, 1940		20.1	18.1	47.5
Weight of soil (in lbs.) lost per acre during 52 storms from 1st May, 1939 to 31st March, 1940		7,262	6,328	32,752

The above summary reveals that soil loss from bare soil was five times the loss from grass and bush-covered soil and was about 3,000 lb. per acre per month. The data collected for the year 1940-41 from the Banni Experimental Farm is summarised in the table below.

Particular	Grass Cover 80 % (Trays 1 and 2)	Grass and Bush Cover 90 per cent (Trays 3 & 4)	Bare Soil Grass Clipped Every 3 Days (Trays 5 & 6)	
A.—Percentage of rainfall which ran off on 48 wet days for total rainfall of 24.82" from 1st April, 1940 to 31st March, 1941		21	18.5	47
Weight of soil (in lbs.) lost per acre during 48 storms from 1st April, 1940 to 31st March, 1941		9,353	7,194	61,046
B.—Weight of soil (in lbs.) lost per acre during 100 storms from 1st May, 1939 to 31st March, 1941		16,615	13,522	93,798

The soil lost from bare surface was about 7 times the loss from the grass-covered soil. The total loss from the bare soil works out at 49.7 maunds per month per acre. The results of the experiments for the year 1941-42 at Banni are tabulated below.

Particulars	Grass Cover 80 per cent (Trays 1 & 2)	Grass and Bush Cover 90 per cent (Trays 3 and 4)	Bare Soil, Grass clipped Every 3 Days (Trays 5 & 6)
A.—Percentage of rainfall which ran off on 58 wet days for total rainfall of 43.77" from 1st April, 1941 to 31st March, 1942	46.4	20.2	64.5
Weight of soil (in lbs.) lost per acre during 58 wet storms from 1st April, 1941 to 31st March, 1942	29,398	11,372	130,362
B.—Weight of soil (in lbs) lost per acre during 158 wet storms from 1st May, 1939 to 31st March, 1942	46,013	24,894	224,160

The commulative soil loss from bare surface during the year 1941-42 was about 5 times the loss from grass-covered soil. The total loss from the bare soil works out to nearly 911 maunds per acre against 187 maunds for grass-covered and 100 maunds for grass-and-bush-covered soil per year.

APPENDIX B

(Extracts from the Report of the Pakistan Agricultural Inquiry Committee, 1951-52.)

Control of Erosion

53. This work is of vital importance. We recommend that the Agricultural Development Council suggested by us should prepare detailed projects for tackling these problems efficiently. At present erosion is gaining ground and though good work is being done with 10 or 12 tractors working at present it only touches the fringe of the problem. The big scheme would require about a thousand tractors of 50 H.P. and above.

54. Besides the large scale problem of anti-erosion in Rawalpindi Division there are several areas in Campbellpur, Attock, and other districts where land affected by erosion is in private hands. In such areas there is room for several projects involving the hiring of tractors. According to the views expressed to us by officers of the Reclamation Department the hiring of tractors would be a paying proposition and of considerable assistance in solving the problem of land erosion. We again stress the importance of a proper survey and initiation of well considered projects in this area. There is work similar to the above required to be done in Baluchistan, Muzaffargarh District (Punjab), and parts of the N.-W.F.P.

Dry Farming and Moisture Conservation

55. The rainfall in large tracts of Rawalpindi Division is from 14" to 25" per annum, but owing to partial erosion and uncertainty of rainfall the cattle and cultivator population is sparse. In these areas, rapid cultivation and sowing after the rains would ensure a crop and for this tractors would be invaluable.

56. Where cropping is dependent on rain timely ploughing and sowing of the land is vital and this can be more effectively secured by tractors than by bullocks. In irrigated and flooded areas also timely ploughing and sowing would secure a good crop produced under the best conditions.

On State Lands and For Anti-Erosion

92. These are areas where tractors can be introduced at once to help in quick development and as quick method of absorbing surplus labour available in other areas. A programme of mechanisation both for development and cultivation, should, in our opinion, be prepared at once for New Canal Colonies. A programme for anti-erosion work should also be drawn up and a regular annual expenditure provided. From these two measures we could expect a rapid increase in food and cash crops within the next few years.

Deterioration of Land

138. Though new land is being brought under cultivation by irrigation scheme and otherwise, land already cultivated is deteriorating. Water-logging and salting have already affected 2.5 million acres and soil erosion continues to be a grave menace. If the lessons of the past and the experience of other countries are not to be forgotten, measures should be adopted to guard against the inherent fertility of the land being lost through its misuse or through the misuse of irrigation water.

One of the main factors causing soil erosion is the destruction of forests. *Pakistan's forest land covers only about 4.5 per cent. of the total area ; this is nearly the lowest percentage in the world. It is estimated that for a properly balanced use of land in dry areas, especially where timber is used for fuel, the land requires nearly 25 per cent. forest cover.*

Classification of Area

366. The area, according to village records, is classified into 5 heads :—(i) Forests ; (ii) Area not available for cultivation ; (iii) Other cultivated land excluding current fallows ; (iv) Current fallows ; and (v) Net area sown during the year.....Still the classifications are not free from ambiguity. For instance, the maximum period for which the land left uncultivated is treated as 'fallow' varies from province to province according to local conditions and practices. This should be definitely fixed for the sake of uniformity. At the expiry of this period, the land, if still left uncultivated, should be included, for statistical purposes, under the head "Culturable Waste".

367. The total area is also classified into irrigated and unirrigated, the source of irrigation being shown. The number of acres irrigation under different crops is shown, as also the areas sown more than once.

368. *Forest.* "Forest" means any land classed or administered as forest under any enactment dealing with forest. Any province, however, is free to exclude any cultivated area which may exist within such forests and to enter it under the heading "Net area sown during the year". The purpose of this note is evidently to make agricultural returns free from legal or administrative considerations as much as possible. But instead of permissive action in transferring such areas, as suggested, these transfers should be made obligatory in order to secure uniformity in the returns from all provinces/States and to make the returns conform more closely to the actual agricultural position.

369. Uncultivated land may form part of a forest or may be occupied by buildings, water, roads, etc., or may be current fallow. A portion of this area may, however, be definitely known to be cultivable. This is shown in a separate head "A", which reads "Cultivable Area". Areas under bamboos and thatching grass (when not forming parts of forest areas), as also groves not classed in sown area, are included in this head. This appears misleading. The purpose of agricultural process or culture is to grow something useful or something that can have a money-value. Culturable area included in head 3 seems to imply that such land is not profitably utilised, but in point of fact, bamboos, thatching grass or trees may not be necessarily less lucrative than food crops or jute, cotton, etc., grown on it. Moreover, the point arises as to whether ratoon crops, such as sugarcane, in the third year should or should not be included in this category. In a sense, bamboos, tea, thatching grass, and other perennial crops may be regarded as ratoon crops not requiring cultivator's attention every year and the area concerned may properly be included under cultivated area.

APPENDIX C

Summary of Erosion Control Methods Classified by Functions

Functions	Methods
A. To improve existing plant cover on all unploughed land	
(i) through grazing control	1. Reduction of surplus cattle.
(ii) through village organisations	2. Closures, complete and rotational.
(iii) through forest protection and afforestation.	3. Partition of shamlat (common) land.
(iv) for wind erosion measures, see under J below.	4. Co-operative management of grass lands.
B. To build up soil fertility in ploughed land	5. Better management of existing forests.
C. To reduce the exposure of bare soil particularly during monsoon	6. Village plantations.
D. To increase surface storage and infiltration.	7. Manuring and green manuring.
E. To increase infiltration into the deeper layers.	8. Preserve stubble and crop residues.
F. To prevent run-off gaining a cumulative velocity	9. Consolidation of holdings.
(i) by control of field drainage	10. Improve tenancy conditions.
(ii) by control of drainage outside fields	11. Choice of crops and crop rotations.
G. To divert excess water of natural channels.	12. Strip cropping.
	13. Reduce bare fallow.
	14. Restrict cultivation of steep slopes.
	15. Cover crops and mulching.
	16. Contour ploughing.
	17. Contour ridging and watbandi.
	18. Bench terraces.
	19. Subsoiling.
	20. Trenching.
	21. Basin listing.
	22. Grassed ditches.
	23. Masonry outlets in field bunds.
	24. Contour bunds set out with a side slope so that water is led off fields quickly.
	25. Live hedges & contoured hedgerows.
	26. Gully plugging & check dams.
	27. Reclamation of ravined land.
	28. Control of snow melting in high catchments.
	29. Diversion bunds.
	30. Diversion ditches.

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|---|---|
| | 31. Deliberate water-spreading by flooding of overflow meadows. |
| | 32. Water tanks. |
| | 33. Road drainage control and recovery of land-slips. |
| H. To head back accumulations of water in the river bed itself. | 34. Small water-holding bunds in multiple along torrent beds. |
| | 35. Major reservoirs. |
| I. To confine the torrent of river to a planned channel. | 36. Canalising smaller torrents by vegetational control. |
| | 37. River bank consolidation in major streams. |
| J. To reduce wind erosion | 38. Fixation of sand dunes. |
| | 39. Shelter-belts and wind-breaks. |
| | 40. Improve dry-farming practice. |

Source : "Soil and Water Conservation in the Punjab" by R. MacLagan Gorrie, 1946.

APPENDIX D

Erosion Control Proposals Summarized*

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Ploughland

1. Wat-bandi and terracing; improve where already in use and introduce where unknown.
2. Remission of revenue to encourage wat-bandi.
3. Consolidation of holdings to facilitate planning of field layout.
4. Planning and proper terracing of field drains.
5. Co-operative loans for land improvement.
6. Use of live hedge plants and proper alignment of hedges.
7. Capture and use of road run-off.
8. Encourage use of compost manure and use of green-manuring crops.
9. Rotation of crops and strip cropping with soil-binding crops.
10. Find legume or grass crop to sow on fallow.
11. Gully-plugging to stop deep erosion in and between fields.
12. Improve cultivation of wasteful crops such as potatoes.
13. Restriction of cultivation on very steep slopes.
14. Refuse 'nautor' sanctions on vulnerable slopes.
15. Provide fuel supply to eliminate burning of cowdung.
16. Patwaris and district civil staff to be given short courses in erosion control.

Livestock and Fodder

1. Encourage voluntary and rotational closures.
2. Legislation to extend application of Chos and Minor Canals Acts to other closures
3. Partition of shamlat (common lands)
4. Panchayat or co-operative management of grass-lands.
5. Replace grazing by grass cutting and stall-feeding
6. Grass-land improvement by wat-bandi and water catching
7. Develop grass and hay markets
8. Green fodder crops and silage
9. Emergency fodder crops—e.g. spineless prickly pear
10. Planting of fodder trees
11. Rotation of lopping fodder trees
12. Control migratory flock movements and reduce percentage of goats in flock
13. Application of cattle or livestock tax to encourage good type of milch and plough cattle and eliminate useless scrub animals
14. Reduction of surplus livestock
15. Grading up of flocks and herds by maintaining stud animals and segregating male goats, castration, etc
16. Determine palatability of local grasses and fodders
17. Feed mineral salts as "licks" to compensate for deficiencies in local fodders
18. Search for improved strains of grasses both local and foreign
19. Improve watering arrangement with dams, tanks, wells, etc
20. Develop market supply and humane killing in slaughter houses
21. Improve grading and marketing of hides.

Afforestation and Other Works

1. Reclamation of ravined lands for fuel and fodder production
2. Reclamation of flat lands in torrent beds by stream training
3. Establish shelter-belts where advisable
4. Village plantations for fuel, timber and fodder
5. Planting of fodder trees in grass-land and rotation of lopping
6. Control of 'nautor' grants in village waste and scrub jungle
7. Protection of existing forests
8. Encourage village co-operative society as the unit for organizing forest improvement and protection schemes
9. Special legislation for control of vitally important catchments
10. Run-off control and contour trenching and water-catching bunds in forest land
11. Closure of dangerous landslips and their vicinities

* "Land Management in the Punjab Foot-hills" by R. MacLagan Gorrie.

APPENDIX E

*Co-operative Soil Conservation Societies in Rawalpindi Division***(A) Rawalpindi District***Kahuta Tehsil*

1. Abad Pur
2. Arazi Sohail
3. Bhaun
4. Bishandot
5. Balhar
6. Berot
7. Chhaper
8. Chebutra
9. Dhok Mahli
10. Dhok Bengial
11. Dhok Baba Faiz
12. Dahu
13. Ghazan Abad
14. Geder Galla
15. Khenada
16. Luni
17. Manianda
18. Miana Mohra
19. Mirgala Maghral
20. Nadna Jatal
21. Nadna Mangral
22. Pindora Hardu
23. Pandori
24. Samot
25. Ser Sube Shah
26. Sada Khambal
27. Tekal
28. Terail
29. Phalina
30. Mohra Hiran
31. Mohra Murid
32. Sahut Saddar
33. Jochha
34. Choa Khalsa
35. Dhok Baba Baland
36. Nambal
37. Arazi Khas
38. Adwala
39. Baniwala Mohra
40. Basanta
41. Blakher
42. Champa Kirpal
43. Chulo
44. Chaprali Herdu
45. Dhok Dhamial
46. Dhok Jaba
47. Darial
48. Guff
49. Gehdar

50. Kahuta
51. Kamili Sadiq
52. Mohra Nagerial
53. Maira
54. Mohra Dhmaial
55. Mohra Terkhana
56. Numb
57. Nothia
58. Pir Grotha
59. Roper
60. Saljur
61. Sahut Budhal
62. Sahib Dhamial
63. Thanda Pani
64. Mohra Bakhtan
65. Mak
66. Mohra Rupal
67. Maira Sangal
68. Darkali Mamuri
69. Darkali Mamuri Patti Chauderian
70. Dhok Zaman Ali Jaswala
71. Sathwani

Rawalpindi Tehsil

1. Arazi Sohail
2. Atial
3. Badia Rustam
4. Bhedana Kalan
5. Bhangril
6. Chuher
7. Chak Madat Khan
8. Chak Pakhral
9. Dhok Saidu
10. Dhok Makhan
11. Dhok Kumaran
12. Dhok Jiwan
13. Dheri Shahan
14. Dadhuchha
15. Dadan Nijjar
16. Dhokheri
17. Golra
18. Gangu Jumma
19. Gider Kotha
20. Jagiot
21. Jodh
22. Kot Hathial
23. Karamwal
24. Kalinjer
25. Katarian
26. Khuram Gujjar

27. Khana Dak
28. Kirpal
29. Lakhu
30. Lakhwal
31. Mohra Jumma
32. Mohra Jafer
33. Mohra Noor
34. Mughal
35. Malka
36. Mal Pur
37. Noon
38. Narela Khurd
39. Nurpur Shahan
40. Ohjerian
41. Phul Geran
42. Pind Begwal
43. Pindora
44. Shah Pur
45. Sihala
46. Sambal Kark
47. Shaker Parian
48. Said Pur
49. Ternaul
50. Tahlian
51. Terlai Kalan
52. Jhamat
53. Jhatha Hathial
54. Rewat
55. Kaliyam Teli
56. Dhok Raja Bostan
57. Mohr Chauderian
58. Mankiala
59. Sagri
60. Jherki
61. Sohan
62. Jasial
63. Dhamial
64. Malukra
65. Takhti

Gujjar Khan Tehsil

1. Adra Nagerial
2. Bewal
3. Binjial
4. Berki Budhal
5. Bhatta
6. Bucha
7. Buchial
8. Bajjar
9. Chakri Vakilan
10. Changa Maira
11. Chura
12. Dora Budhal
13. Dhok Gondal
14. Dhok Zaman Ali

15. Dara Kial
16. Dhok Gakhar
17. Dhok Amir Ali
18. Dhok Hayat Bux
19. Darkali Kalan
20. Datta Bhatt
21. Dera Kanial
22. Bagwal Dergahi
23. Guliana
24. Gurah
25. Hedo Jagi
26. Hechiari Dolal
27. Jand Nijjar
28. Karauli
29. Kahli Klhinger
30. Kaliyam Awan
31. Kurzada Maliaran
32. Kurzada Sawan
33. Kuri Dolal
34. Kalial
35. Kala Phida
36. Kariali
37. Kanyat Khalil
38. Laddar
39. Lode
40. Mankila Brahmanan
41. Muhri
42. Muhri Barsal
43. Muhri Karnali
44. Mohra Dhamial
45. Mohra Amin
46. Matua Bangira
47. Machhia
48. Mari Bir
49. Pharwal Saru Khan
50. Pherwal Bangial
51. Paka Khan Pur
52. Rayan Gorsian
53. Rama
54. Sihal Khinger
55. Sangori
56. Satho
57. Soga Datt
58. Suj Bahadur
59. Sukho
60. Tal Khalsa
61. Thurjial
62. Turkwal
63. Darkal
64. Changa Bangial
65. Darhala Khaki
66. Dera Bakhasian
67. Tapiali Khurd
68. Pind Payan
69. Panj Girain Khurd
70. Narali Jabair

- | | |
|-----------------------|-----------------------------|
| 71. Terhala Kalial | 34. Bafahid |
| 72. Hakim Chhatha | 35. Dheri Kot |
| 73. Arjan | 36. Barazi |
| 74. Juliari Bhay Khan | 37. Dhok Ahmed Khan Dekhali |
| 75. Banth | Jalla Banian |
| 76. Natha Dolal | 38. Sagra Brahma |
| 77. Kajo | 39. Hissar |
| 78. Mohra Muqadam | 40. Baryar |
| 79. Mandra | 41. Bhedian |
| 80. Mohra Roshan Ali | 42. Golara |
| 81. Kund | 43. Kaccha |
| 82. Suhr | 44. Barotha |
| 83. Mothu Khinger | 45. Jahan Abad |
| 84. Jhuliari Guljri | 46. Kamra Kalan |
| 85. Nur Dolal | 47. Chechian |
| 86. Jand Guj r | 48. Mari |
| 87. Malakwal | 49. Langer |
| 88. Rukhia | 50. Sohail |
| 89. Jermot Khurd | 51. Pirana |
| 90. Wasla Bangiai | 52. Thoha |

(B) Campbellpur District

1. Dhok Siloo
2. Ratwal
3. Chauntra
4. Langer
5. Bahtar
6. Dhurnal
7. Magian
8. Chohan
9. Khalara Kalan
10. Multan
11. Tarap
12. Kot Sarang
13. Singwala
14. Chinji
15. Mirjan
16. Dhudial
17. Naka Kanut
18. Pira Fatial
19. Shah Muhammadi
20. Chatwal
21. Traggar
22. Wah
23. Salar
24. Islam Garh
25. Malak Mala
26. Ghorghasti
27. Dhok Umra Dekhali Jasian
28. Babarki
29. Labh Thathu
30. Fatullah
31. Ghazi Kohli
32. Kohlian
33. Nikoo

(C) Gujrat District*Gujrat Tehsil*

1. Khokhar Gharbi
2. Dharowal
3. Khapranwal
4. Kot Bela
5. Tibba Bute Shah
6. Ahli
7. Malikpur Chehra
8. Miana Kot
9. Uggowal
10. Doulat Nagar
11. Lakkanwal Khasa
12. Mota
13. Mongowal Sharqi
14. Jhamat Abad
15. Bhoian
16. Jindar Khurd
17. Malowal

18. Karianwala
19. Sarhali Khurd
20. Ghural
21. Chak Budha
22. Kot Ranjah
23. Santal
24. Handa
25. Jalalpur Sobtian

Kharian Tehsil

1. Chechian
2. Rashidpur
3. Dhoke Murid
4. Bawali Khurd
5. Bawali Kalan
6. Kullewal Gujran
7. Damun Chak
8. Aima Shah Ji
9. Gullian Patti Umar
10. Gullian Patti Gujran
11. Khawaspur
12. Bhag Nagar
13. Dhauro
14. Gill
15. Qasba Karyali
16. Bangial
17. Batur
18. Qazi Baqir
19. Khanpur Gujran
20. Baganwala
21. Dak
22. Maira
23. Bhaddar
24. Sidh
25. Chak Sikandar
26. Kotla Arbab Ali Khan
27. Jagal

(D) **Jhelum District***Jhelum Tehsil*

1. Bajwala Dattan
2. Chakrai Rajgan
3. Chhappar Sayadan
4. Naka Kalan
5. Nakki
6. Phulra Sayadan
7. Dhok Khabbal
8. Khookha
9. Daiwal
10. Darapur
11. Said Hussain
12. Doyan

13. Akra Mohra
14. Jhelum Distt. S/c Socy,

P. D. Khan Tehsil

1. Dhariale Jalap
2. Makhial
3. Nalli
4. Haranpur
5. Pinnanwal
6. Baghanwala
7. Choa Sadan Shah
8. Waula
9. Dhariale Kahun
10. Badshapur
11. Da'wal
12. Chhappar Saidan Shah
13. Lehri Sultanpur
14. Pidh
15. Chunbi
16. Dandot

Chakwal Tehsil

1. Dhok Sarang Khan
2. Khai
3. Bhaun
4. Satwal
5. Mohra Thanil
6. Dhudha
7. Chak Maluk
8. Chak Kharak
9. Jangah
10. Shah Pur Sayadan
11. Munde
12. Hattar
13. Khokhar Zer
14. Trimni
15. Kalo Jo
16. Bhalla
17. Chakral
18. Chakwal
19. Chakwal Sharqi
20. Nurwal
21. Kalas
22. Bhikhari Kalan
23. Kajli
24. Chak Naurang
25. Jabbair Pur
26. Sua
27. Murid
28. Chohan
29. Lohaser
30. Adhwal

APPENDIX F

Comments on Soil Erosion, its Causes, Effects and control by Mian Shamim Ahmad P.S.E. and Dr. Mohammad Abdullah Khan Ph. D., Directorate of Erosion Control and Soil Conservation Rawalpindi.

Soil deterioration results from menaces like erosion, water logging, salinity and exhaustion through continuous crop removal. Soil erosion is as old as agriculture. It commenced when, on the virgin land, the pre-historic man made the first furrow and exposed it to the abrasive action of wind and water. It has been going on ever since. It has, thus, been brought about as a result of human interference with the normal equilibrium existing between soil building and soil removal and continued by his apathy to restore this balance or make amends for it. Wherever land surface is bared of protective vegetation as it must be when under cultivation, soil is subjected directly to the action of erosive elements. Transposition processes of an extremely rapid nature are set in motion and the soil is bodily displaced much faster than it can be formed. Unless adequate measures are taken to guard against this abnormal highly accelerated phenomenon of soil removal, it assumes the form of the most potent single factor contributing to the deterioration of productive land.

Soil erosion is one of the most serious problems facing Pakistan. Large areas in all parts of the country have been destroyed and thrown out of cultivation as a result of severe erosion. Areas which are suffering from moderate to slight erosion and whose productivity is on the decline are larger still.

Forms of Erosion

Erosion is caused by wind and water. Both differ in the nature of their action and in their outward manifestation but are similar in the sense that both remove and transport surface soil. Under the action of wind storm the small particles of soil are thrown up in a spinning motion, and subsequently fall at a distance 4 to 5 times the height they were projected. Large particles bounce along the surface and may be carried farther in this creeping motion. Very fine particles are suspended in air and are carried over longer distances. 93% of the total soil moved by wind is known to be on account of saltation and creep and is generally below a height of 12 inches, the rest being through suspension.

The action of water, however, is two-fold. When the drops fall on the exposed land surface, they tend to detach and transport the soil particles. As the water gains in amount and velocity, its cutting and carrying capacity is increased. Theoretically, a doubling of the velocity enables water to move particles 64 times larger, allows to carry 32 times more material in suspension and makes the erosive power in total four times. Thus, if the velocity of a stream increases 10 times, its carrying capacity becomes a million times and the erosion increases 100 times. Water erosion takes three forms-sheet, rill and gully. Two or more of them may occur simultaneously in the same field. One may develop into another. In a way, these in fact represent three stages of the same process.

Sheet Erosion :—Sheet erosion is the more or less even removal of soil in thin layers one at a time, over an entire segment of the level or sloping land. It is the least conspicuous and the most extensive and insidious type of erosion. It is frequently accompanied by a gradual change of soil colour from dark to light as the humus laden top soil is replaced by humus deficient subsoil and a consequent decline in crop yield.

In the absence of soil cover and poor physical condition, beating action of rain causes surface sealing. Small particles plug the small openings in the soil. Clods and soil lumps are broken down forming a pasty mass. These hinder free penetration of water and favour runoff. The vulnerability of any field to sheet erosion is conditioned by the inherent erodibility of soil itself. Soils with a shallow layer of surface soil over-lying a dense sub soil of low permeability are particularly susceptible to this form of erosion. It also prevails on soils of high silt content, fragile sandy soils, stiff clays and all soils deficient in organic matter.

Rill Erosion :—Rill erosion is characterised by small incisions irregularly dispersed on the land surface by the cutting action of water concentrating in streamlets of sufficient volume and velocity to generate cutting power. This form is more apparent than sheet erosion probably in newly planted or fallow fields. The small incisions are easily obliterated by ordinary tillage operations and are thus under-rated for the damage that it can bring about.

Rill erosion is most common in areas of rather intense precipitation and on lands of low permeability. Soils with high silt content are especially susceptible though the process is apt to occur on all lands having loose soil overlying dense sub-soil.

Gully Erosion :—Gully erosion results either from cuts in the land surface caused by concentrated run-off in sufficient volume and velocity or continued cutting of the same incision long and deep enough to develop a gully. Usually gullies follow sheet erosion or arise from neglect of rills. Frequently, they make their beginning in slight depression of the land surface, ruts left by the wheels of wagons driven up and down the hill, livestock trails or furrows made along the slope.

The shape of gullies depends upon the relative stiffness of the soil strata and the underlying rock material. Where the soil strata offers resistance to cutting, U-shaped gullies develop. V-shaped gullies are common in areas where this resistance is present. There may thus be a combination of U-and V-shaped gullies in the same field consequence upon heterogeneity so prevalent in our fields.

Factors Affecting Erosion

The intensity and rate of erosion depends on specific factors. Those of importance are discussed below :

Rain Fall :—Of the two phases, amount of total rainfall and its intensity, the later is usually the more important. A heavy annual precipitation received gently may cause little erosion while a lower annual rain fall received in torrential showers may result in tremendous damage. High intensity rain of short duration will do more damage than low intensity rain of long duration. Drop volume, size of drops and the seasonal

distribution of precipitation are also critical in determining soil erosion losses. Drop size and velocity produce the necessary impact required for detachment, surface sealing and run-off. Rain received at a time when there is no cover is apt to cause more damage. This is why monsoon rains in the upland districts which usually come with heavy intensity and at a time when the soil is almost bare, bring about enormous losses of soil and water.

Slope and Topography :—The greater the degree of slope, other conditions remaining constant, the greater the erosion due to increased velocity of water flow. Also more water is likely to run off. Percent slope, however has little effect where detachment is a limiting factor, but, where transportation is limiting, the increase in percent slope will increase soil losses.

The length of slope is of prime importance since greater the extension of the inclined areas, the greater the concentration of the flooding water. Any time there is concentration of water into rills or gullies, soil losses will increase in length. This influence of slope is of course modified by the size and general topography of the drainage area and the physical condition of the soil. Clay in poor physical condition undergoes more loss with increased slope length but, these losses are stabilized when physical condition improves.

Land Cover :—Land cover provides protection against beating action of rains through interception, breaking impact force and thus reducing detachment. Forests and grasses are about equal in their effectiveness in this connection. Their influence varies. For instance, a forest with heavy organic matter and dense undergrowth is markedly superior to open woods with little organic accumulation. Again, the kind of grass, the thickness of stand and the vigour of its growth greatly affect erosiveness. Perennial grasses have more soil building and protective value. Field crops also vary in their influence. Close growing crops provide better canopy effect and mechanical check to run off than the intertilled crops. Goodstands of wheat, oats, *chari*, alfalfa, cow peas, *moth* etc., offer considerable obstruction to surface wash. Legumes in pure stand or in mixture with cereals exercise a stabilizing effect on soil building and soil removal.

Rotations and Management Practices :—Sequence in which crops are grown has a marked affect on erosion losses. If this sequence reduce the period of fallow and provides cover of desirable quality and amount during rainy season, it reduces soil and water losses. The common rotation in the crop land districts is *rabi-kharif-fallow-fallow*. Thus, half the amount in each holding is kept fallow and continuously tilled for one year thereby aggravating the erosion hazard. This rotation needs a change either in the intensity of cropping or in its management so as to provide complete or partial cover on land when it is most needed.

Faulty cultivation up and down the slope, unscrupulous number of tillage operations regardless of its exposure to erosive elements during the fallow period, sowing across the contour, burning of dung rather than its application to the crop, grazing of stubbles, overgrazing of ranges and pastures and reckless felling of trees are wasteful practices, calculated to enhance the erosion hazard. Management practices should aim at establishing good stand of crops, proper tillage, proper manuring and proper utilization of the product.

Soil Characteristics :—Texture, structure, organic matter content and depth of top and sub-soil, surface intake and permeability of the sub-soil greatly affect erosiveness. Generally, light textured soil overlying dense sub-soil or heavy top soil with impeded drainage are easily erodible. Structure exercises a healthy influence. Aggregated light textured top soil will resist erosion like granulated clay. Organic matter not only acts as a sponge for local absorption of rain drops but also supplies binding material for aggregation. Content of colloidal clay, aluminium and iron oxides and calcium exercise binding influence, help granulation and tend to reduce soil losses. A deeper column of light textured top soil overlying dense clay will have a different reaction as compared to a shallow top on similar sub-soil. The latter, other conditions being similar, is more deleterious. Impeded surface intake or permeability of the sub-soil induces run-off and consequent losses.

Soil temperature also has a modifying influence. Higher temperature is conducive to decomposition of organic matter and thus tends to increase soil losses. Low temperature is protective causing freezing of land but heavy intensity rain received after thawing leads to more damage.

Effects of Erosion

Losses of Plant Food and Water :—The accelerated erosion of soil taking place with unwise agricultural practices has increasingly deleterious effects on the physical body of land. The magnitude of this problem can be visualized from the fact that together wind and water are known to remove not less than 5 billions tons of soil from the crop land and associated pastures every year throughout Pakistan. This 5 billion tons of waste soil contains the equivalent of 5,250,000 tons of N.P.K. and 269,000,000 tons of calcium and magnesium. The nutrient elements of N.P.K. alone work out to an annual loss from soil equivalent to 17,296,000 tons of commercial fertilizers—400 times more than ammonium sulphate distributed by the Agriculture Department, Punjab, during 1952-53. To give an idea of the enormity of water losses as run-off from unconserved fields, a foot hill deforested and heavily grazed in the Punjab is known to lose 16,000 cubic ft. of water per second per square mile. against 60 cubic ft. from a terraced rice field.

More important than the loss of plant food constituents, however, is the soil itself. Erosion removes the entire physical mass of land, the mineral particles, the microscopic organisms and all other constituents. Crop, on the other hand, extracts only diminutive portions of the soil leaving the bulk of the material which may subsequently be improved. Erosion, if not checked, removes all leaving nothing to be improved. No other process or combination of processes is so destructive of valuable soil, its nutritive constituents and water as erosion.

Productivity Reduced and Economy Upset :—It is proverbial that any process which destroys the essential productivity of soil can exercise only an adverse effect on an economy that depends fundamentally upon the soil. Erosion is such a process. Other factors being equal, its adverse effect on agricultural economy is being reflected in the progressive deterioration of productive land and lower farm returns.

Agriculture Departments in various provinces have been actively engaged since inception on increasing the agricultural output per unit area. To achieve this, they have introduced better implements, more effective cultural practices and better yielding crops. Taking Punjab as an example, where persistent endeavours have been made in the past, the goal does not appear to be in sight. Based on total sown area and the total production in the Punjab, co-relation, co-efficients between per acre production and years have been worked out for the period 1942-43 to 1951-52 (Appendix 1). These co-efficients do not present a happy situation. The food crops like barley and maize and cash crops like cotton register a negative relationship. Three years observations made at a model farm of the Forest Department speak of a similar story. It does not, however, negate the good work done by these Departments, but, it only brings to light the fact that the increase in yield brought about by the improved agriculture has been more than offset by the canker ceaselessly eating into the vitals of soil.

With decrease in soil fertility and productivity not only the crop yields are affected, but the quality also suffers. Apart from inherited characters the quality depends upon the absorption of nutrient ions and their availability in soil. Erosion diminishes the latter and thus the former is automatically lowered. This in turn affects animal nutrition which lowers the quality of their products.

Such are the effects on level land which are subject to surface wash alone. The severity of the effect will be alarming on sloping land for which no authentic data is available.

Through the ages soil erosion has exerted a tremendous influence on the course of civilization. Man owes his sustenance to the products of soil and thus, his struggle for existence resolves into wresting land from nature. Man's conquest of land has frequently led to extreme impoverishment or complete destruction of the soil resource on which he himself depends. Unchecked erosion eventually may lead to sub-marginality, abandonment, rural migration, disruption of tax base, general community disintegration and similar maladjustments of an economic and social nature. True, civilization rises and falls when land fails to produce.

Under-ground Water Supply Impaired :—When a part or whole of the top soil is eroded taking away with it the organic matter, the land no longer remains spongy and absorptive. Also in the absence of any mechanical check to run off, resultant on the lack of cover, the water flows off as soon as it falls on the soil surface thus minimizing local absorption. Consequently, the replenishment of the sub-soil water does not take place, and the underground water supplies are diminished. These effects have become very prominent in Baluchistan and the upland districts of the Punjab. In the latter the water level is going down and in karezes of the former the water supply is on the decline.

How far soil conservation helps in this direction is obvious from the work done by the Forest Department in Gujjar Khan Tehsil of Rawalpindi District. In certain tracts where terracing and embanking of the ravined fields was undertaken the water level rose many feet.

Floods Intensified :—With denudation, the absorptive capacity of the catchment area has been much reduced. Unchecked run off increases flow in water ways which with progressive sedimentation in their beds are reduced in capacity for this flow. The water thus spills over their banks into the adjoining low land. The increasing number of engineering works such as weirs and bridges across the rivers, canals, roads and railway embankments provided with insufficient cross drainage obstruct the flow of this water thus intensifying the flood hazard.

Communications Damaged :—Soil erosion undermines the compactness of the ground and often leads to land slides in hilly tracts which block roads and rails. Threat to communication increases manifold in monsoon season when as a result of heavy downpours and greater run-off, the rail and road tracks are submerged. The stream channels are clogged with debris. Road and railway embankments are undermined and highways covered with silt, sand and gravel. Irrigation and drainage channels are choked with mud, water supply, power reservoir, rivers and harbours are silted up and need dredging operations at an enormous subsequent cost.

Climate and Games Affected :—Natural vegetation exercises a healthy influence on climate and affords natural protection and nourishment for games. Indiscriminate felling of trees and denudation caused by overgrazing tend to raise the atmospheric temperature. Lower relative humidity and decreased precipitation. With thinning out of forests, the wild animals retreat to remote forest reserves causing shortage of game animals.

Wind Erosion a Nuisance to Plant and Human Life :—Low sweeping winds that drive dust and sand before them are more destructive as they attack the land with more regularity. They blow silt and sand over thousands of acres of range and crop land smothering plant life and killing whatever chances there may have been for a harvest or a cover of grass. Often the abrasive force of these wind driven soil particles slices off plants at their roots. In many instances the shifting blowing sand has covered highways and formed troublesome drifts, dunes that are a constant menace to adjoining farm lands. In all its forms wind erosion has become a twofold destructive process in removing fertile soil from fields where it is needed and in depositing relatively infertile soil on lands where it is neither needed nor welcome.

To the people, the process is both economic and a social menace. It is not only impairing or destroying the basis of their major industries, agriculture and grazing, but, also blanketing homes, offices and merchantile establishments with dust, covering sheds and other small buildings with sand and destroying agriculture machinery.

Erosion Control and Soil Conservation

Many individual farmers especially in the rural part of this country-grew conscious of the problem much earlier and some tried remedies of their own. Concern grew with knowledge and the Government through the Forest and Co-operative Departments began to study the process of soil washing and methods looking to its control or prevention. Unfortunately, early efforts to control erosion largely tended to lean on a single method of control. Erratic efforts towards afforestation or terracing were

regarded as complete defence against erosion. Occasionally spillways were made and bigger gullies blocked with huge dams at selected places involving enormous expenditure for ponding up resultant run-off for inducing sedimentation. The upper reaches were kept constantly stirred for accelerating this process. In this way, a few acres were reclaimed at the foot of the dam. Such a process of reclaiming is highly questionable on economic and technical grounds. Vegetative methods of erosion control were given scant attention. The use of mechanical and vegetative measures in support of each other was infrequent. The fallacy of reliance on temporary or piecemeal methods of conservation, haphazardly applied, thus failed to produce the desired effect.

Soil conservation is essentially different from soil reclaiming and involves adoption of a new and conservative system of land use. The modern approach to erosion control through a planned system of land use in the entire catchment area involving the coordinated application of a variety of control measures devised by a team of experts in the fields of Agronomy, Soil Science, Agricultural Engineering and Forestry has proved fruitful in other countries and shows considerable promise under our conditions. The pre-requisite to such an approach is a real recognition of soil erosion as a national problem and its wide understanding by the politician, the legislator, the educator and the cultivator alike. Upon such an understanding will depend not only the incentive to act but the ability to act intelligently. Demonstrations of sound conservation, land use practices carried out in problem areas through the collaboration of Government agencies and the individual cultivator prove of immense educational value. These might ultimately be extended to all vulnerable land. Discussion is given below on soil conservation programme in line with a modern approach.

A Proper Land Use :—Like living beings every piece of land is born with a different capability and is thus suited to a specific use. In order to determine this, land capability classification is done keeping in view the characteristics of top and sub-soil, topography, erosion and inhibiting factors like wetness, overflow stoniness, etc. Based on this, the land is separated into two major groups; fit for cultivation and not fit for cultivation. The former group of land is fit for arable farming. These groups can be further subdivided into four classes (I, II, III, IV) each differing in the intensity of limitations, in use and hazards in maintenance and thus requiring a variety of agronomical and engineering practices for conservation use. Likewise, the latter group of land is only fit for permanent vegetation. The character of which may vary with the classes (V, VI, VII, VIII) into which this group may be similarly subdivided. However, land under this category accompanied by certain water spreading and water control devices may support forest stands, ranges, pastures and wild life with advantage. It is thus apparent that the use which can be assigned to a particular piece of land will take into consideration its limitations and hazards in addition to the farmers' requirements and will be according to a certain plan drawn out for the entire catchment. Such a use will not only give the maximum utility of its inherent capability but will also guard it against the inroads of erosion.

Soil Cover :—The maintenance of continuous vegetative cover is essential to intercept dashing rain, break impact force and thus check detachment. The cover affords a mechanical check to run-off, thereby increasing infiltration. The plant roots exercise binding influence on soil particles, add organic matter, help aggregation and increase absorptive capacity of soil.

The nature of this cover may vary with land classes. Forest and grasses form the best cover on land not fit for cultivation. Wherever this cover has been removed, it needs to be re-established. On crop land however, a crop cover is preferred. The cover crop should be faster in growth and less hard on soil. Such a cover has to be devised keeping under consideration the environments, farmers' economy and the adaptability of the cover crop.

In the upland districts, the general rotation followed on the crop land areas is *rabi-kharif-fallow-fallow*. This leaves half the holding without a cover of any kind for one year fully exposed to erosive agencies. To aggravate conditions, the bare soil is kept continuously stirred thus making it easier to succumb to abrasive forces. In order to help save the situation, the long period during which the soil remains bare has to be cut down by growing some sort of a cash crop. Ground nut (*Arachis spp.*) *mash* and *mung* (*Phaseolus spp.*) and cow peas (*Vigna spp.*) appear to be promising in this respect.

Management Practices :—Tilling up and down the hill, sowing in rows running along the slope, removing the entire growth at harvesting, keeping a long fallow and indiscriminate tillage, are some of the popular, though faulty, practices in vogue. These require to be modified keeping in with the conservation requirements.

In place of indiscriminate number of cultivations it would be highly desirable to cut this down to an extent which will not adversely affect the performance of the following crop. If necessary, breaking sod may be combined with slight application of fertiliser to recoup fertility. During the rainy season, contour tillage is necessary. On slope, contour listing which essentially consists in making a ditch and a ridge should be resorted to. Each ditch and ridge will check run-off and aid local absorption. This should be followed by sowing on the contour and if possible the fields should be subdivided into small compartments by making contour levees. The check to run-off by the crop stand entailed by levees will enable the crop up and down the slope to benefit equally from subsequent rains.

Our soils are very deficient in organic matter. This deficiency has not only told upon the physical condition of the soil, but also the absorptive and water holding capacity and plant performance. As a result of low capacity for water absorption and holding, the water runs off in larger volumes and causes more losses. In order to remedy this state of affairs the following steps may be suggested :—

1. Addition of farmyard manure.
2. Green manuring,

3. Provision of legume crops in the cropping system,
4. Leaving a part of the matured stalk at harvesting as stubble mulch.

Farmyard manure supply with zamindars of upland districts is very limited. For want of other fuel, a part out of this has to be burnt for meeting household needs. This quantity can be saved by growing green hedges of *arhar* (*Cajanus* spp), *jantar* (*Sesbania* spp), *sankukra* (*Hibiscus* spp.) around the field. These plants, to a certain extent, will serve their fuel, fibre, and vegetable needs.

Due to moisture problem caused by erratic rainfall in the upland districts, the scope of green manuring is limited unless the land after burying green manure is left fallow for one season or some technique to hasten decomposition of organic matter is found out. The provision of a legume crop in the cropping system and leaving a part of the mature stalk as stubbles are practical anti-erosion measures meriting consideration.

In areas subject to erosion, overgrazing is common. This is partially due to low fodder supplies. In order to divert the pressure on grazing, fodder crops have to be raised, pastures and ranges improved and controlled grazing introduced.

Engineering Devices :—It is, some how, maintained in certain quarters, that levelling of sloping land is essential for arable farming. It is not only expensive and laborious but uneconomical and non-practicable enterprise. Without it, arable farming is possible if suitable engineering practices are undertaken on sloping land.

Suitable engineering devices supplementing the programme are very essential. For efficient and quick results they have to be necessarily combined with agronomical practices. Terraces correctly laid out and combined with contour sowing cut off the run-off very efficiently. There are a number of terrace designs available. Different designs are meant for meeting different situations but all aim at cutting the length of slope and affording a regular check to run-off.

While laying out a terrace, the capacity of water shed has to be assessed and a diversion ditch provided for conducting the surplus water safely into the water-way. Waterways for an individual holding or a number of holdings in the catchment area have to be carefully designed. This design will depend upon the amount and velocity of run-off. In case of a smaller run-off of non-erosive velocity, a grass water way would be adequate. A grass which grows prolifically withstands drought and overflow, and forms a thick mat which be highly desirable. A spur may be needed if the velocity of run-off increases. Construction of spillways will become essential if the velocity or amount are otherwise uncontrollable. The spillways, however, should be carefully designed keeping in view the run-off requirements.

To stop further damage, gully plugging is very essential. The velocity of the run-off has to be reduced. To achieve this, cross-bands of a bunch type, quick and tall growing grasses, drought resistant and

not susceptible to overflow should be planted at regular intervals along the gully and its fingers. *Sarkanda* (*Saccharum* spp.) *nara* (*Arundo-dona* spp.) and *Ipomia* species meet this requirement under different conditions. The same plants can be used for stabilizing gully banks. Suitable tree species should be planted in the gully beds and banks by a suitable technique to ensure success. Protection of the existing grass vegetation in the entire gully area will exercise a healthy stabilizing influence. In certain places, where absolutely necessary, small check dams of a suitable design may be built.

Wind Erosion :—In controlling wind erosion, the stabilization of sand with a vegetative cover and growing of shelter belts are needed. Regular shelter belts of the type desired for fighting this menace dispersed throughout the wind borne area may not be a practical proposition in view of the scattered holding and tenancy. However, if the borders of each field are provided with a green hedge of *sarkanda* or *nara* and strips of tall growing crops like *chari*, and *bajra* systematically laid out against the prevailing wind direction in summer when blowing is optimum, it will check wind velocity and reduce the hazard. To add to efficiency strips of stubbles at least 2-4 ft. high should be left at the time of harvesting. Listing sandy areas, when bare, against the prevailing wind direction will prove of a definite avail.

APPENDIX

Coefficients of correlation between years and crop yield in the Punjab.

Name of crop	Coefficient of correlation	Sr.	Required for significance at		Significant or non-significant
			5%	1%	
Wheat	+ 0.078	0.377	0.666	0.798	0
Barley	- 0.394	0.346			0
Maize	- 0.615	0.299			0
Gram	+ 0.276	0.363			0
Cotton	- 0.019	0.378			0
Sugarcane (<i>gur</i>)	+ 0.233	0.348			0

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GLOSSARY OF TERMS

ANNA	...	One-sixteenth of a rupee (Abbrev. A. or As.)
BANJAR	...	Land which has gone out of cultivation. Unproductive cultivable land.
BARANI	...	Depending on rainfall.
BUND	...	An embankment built of stone or earth.
CANAL	...	The name given to a large area brought under
COLONIES	...	cultivation as a result of canal projects.
CHO	...	A torrent of sand or boulders.
DARRAR	...	A ravine.
DISTRICT	...	The most important administrative unit of area in Pakistan.
GULLY- PLUGGING	...	Dams or obstructions erected in a stream bed or rivulet in the hills.
GUZARAS	...	Village forests.
KACHCHA	...	In case of weights applied to local as distinguished from standard ones; for wells the term denotes those which are unlined by bricks and for houses those made of mud only; for roads denotes unmetalled conditions.
KAS	...	Sandy torrent outflow bed.
KHAL	...	Water channel.
KHARKHANA		A variety of long grass with small prickly surface.
KHARIF	...	Autumn harvest, monsoon or summer crops.
LAKH or LAC		A hundred thousand.
MAUND	...	A standard weight of 40 seers used in Indo-Pakistan sub-continent: equals to 82-2/7 lbs. (Abbrev. Md.)
NARA	...	A long tropical grass with thick and hard stem.
PARTITION	...	The division of Indian sub-continent into Bharat and Pakistan under the Indian Independence Act of 1947. The provinces of Punjab and Bengal were also partitioned by the Radcliffe Award in August 1947 under the same Act.
PUCCA	...	Sound; perfect; complete; fixed; applied to weights and measures it denotes those recognised by Government as distinguished from those

having local sanction; for wells and houses implies the use of kiln-baked bricks in their construction, for roads those which are metalled.

- RABI ... Spring harvest or winter crops.
 RAKH ... Forest.
 RUPEE ... A standard coin of Pakistan. (Abbrev. Re. or Rs.)
 SEER .. One-fortieth of a maund, equals to 32.9 oz. or 933.1 grammes (Abbrev. Sr.)
 SHAMLAT ... Village common pasture.
 TEHSIL ... Revenue sub-division of a district with a separate administrative staff.
 WATBANDI ... Contour ridging in plough land, the practice of erecting embankments around fields.
 WATT ... An embankment round a field built to pond up rainwater.

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