

STUDY
ON
WASTELANDS
INCLUDING
SALINE, ALKALI
AND
WATERLOGGED LANDS
AND THEIR
RECLAMATION MEASURES



COMMITTEE ON NATURAL RESOURCES
PLANNING COMMISSION
NEW DELHI
1963.

**STUDY ON
WASTELANDS INCLUDING SALINE,
ALKALI & WATERLOGGED LANDS
AND
THEIR RECLAMATION MEASURES**

**Committee on Natural Resources
Planning Commission
New Delhi
1963.**

49 PC-1

CONTENTS

Foreword	. . . . .	(ii)
Introduction	. . . . .	(iv)
CHAPTER I	Wastelands in India:	1
	(1) Soil	1
	(2) Land utilisation statistics	2
	(3) Concepts in land utilisation statistics	2
	(4) Causes of culturable land lying waste	4
	(5) Land going out of cultivation due to soil erosion and	5
	(6) Survey of wastelands	5
CHAPTER II	Kans infested wasteland	7
CHAPTER III	Saline and alkali soils, extent, location, reclamation measures suggested for prevention of extension of such areas.	10
CHAPTER IV	Problems of coastal saline soils.	53
CHAPTER V	Review of the work done in the survey of ground water, demarcation of areas of sweet and saline ground water.	61
CHAPTER VI	Suitable trees, grasses and crops for saline and alkali soils.	95
CHAPTER VII ✓	The extent of water-logged lands, their classification and rate of change.	105
CHAPTER VIII	Problems of surface drainage.	109
CHAPTER IX	Problems of sub-surface drainage	118
CHAPTER X ✓	A review of work done in some states to tackle the pro- blem of water-logging with suggestions for future work.	125
CHAPTER XI	Suitable trees and grass species for water-logged areas	135
CHAPTER XII	Crops suitable for water-logged areas and fish culture in paddy fields	142
CHAPTER XIII	Review of work on soil conservation and reclamation done during First and Second Plan periods and schemes of Third Plan	149
CHAPTER XIV	Use of aerial photography in soil mapping and land use classification with particular reference to waste lands including saline and alkali and waterlogged lands.	160
CHAPTER XV	The economics of reclamation of waste lands.	164
CHAPTER XVI	Recommendations	172
BIBLIOGRAPHY	. . . . .	179
REFERENCES	. . . . .	186
APPENDIX I	Study Groups which have carried out studies on different aspects of wastelands, including saline, alkali and water-logged lands.	187
APPENDIX II	Tables of waste lands for States—Districtwise.	189

FOREWORD

One of the ways of stepping up agricultural production is through extension of area under cultivation by reclaiming wastelands for cultivation wherever such reclamation can be carried out economically. The total area classified as "other uncultivated lands excluding fallows" and "fallows other than current fallows"—the two categories of land in which wastelands are known to be available—during 1958-59 was 127·4 million acres, out of which 50·9 million acres has been estimated as "culturable waste." The Wastelands Survey and Reclamation Committee of the Ministry of Food and Agriculture which was entrusted with the task of locating large blocks of wastelands and suggesting suitable reclamation measures in the different States has completed its survey of 13 States, namely, Punjab, West Bengal, Bihar, Mysore, Andhra Pradesh, Madhya Pradesh, Kerala, Madras, Uttar Pradesh, Jammu & Kashmir, Maharashtra, Orissa and Gujarat. In these States, the area of wastelands available for cultivation in blocks of 250 acres or more is reckoned at nearly 2 million acres. The total area of wastelands in such large blocks for the entire country is likely to be more than 3 million acres as large blocks of wastelands are known to be available in Rajasthan and Assam also, reports in respect of which have not been completed by the Committee. The Committee has expressed the view that the mere collection of statistics under the head "culturable waste" can serve little purpose and has recommended collection of detailed information about the location and types of wastelands in each State, the ownership of such lands, their availability in sizeable blocks and the cost of reclamation measures by rapid reconnaissance. The Planning Commission has approved of an expenditure of Rs. 69 lakhs in the Third Plan for survey of wastelands in blocks of less than 250 acres. Several States have taken up this survey work. It is essential to have information of the location of all these categories of wastelands in the States in small blocks as also in large blocks and the economics of their reclamation measures for increased agricultural production. The social aspects of this problem has also to be kept in view as the problem of utilisation of wastelands involves not merely the adoption of agricultural techniques but also appreciation of the problem of the settlement of agricultural labour. Unless this information is urgently collected, the limited resources of the country cannot be fruitfully utilised for land reclamation and settlement.

(iii)

The present report on the "Study on Wastelands of India, including Saline and Alkali and Waterlogged Lands and their Reclamation Measures" prepared by the Committee on Natural Resources of the Planning Commission contains valuable information on the different categories of wastelands and their reclamation measures and will be very useful to the State Governments in their work of land reclamation and resettlement. The recommendations made in the report have special significance from the resource point of view regarding proper utilisation of marginal lands which are at present under cultivation with low productivity and may become waste in due course.

The recommendations made in the report are of practical importance. Some of them should, as far as possible, be implemented during the Third Plan. The remaining recommendations should be given due consideration in the formulation of the Fourth Plan.

NEW DELHI,
January 7, 1963.

SHRIMAN NARAYAN,
Member,
Planning Commission.

INTRODUCTION

The Committee on Natural Resources at their meeting held on 26th December 1961 approved a study on water-logged, saline and alkali lands and wastelands of India. The Technical Committee on Land, on 3rd January 1962, set up a Working Group with membership as below to carry out this study:

1. Dr. B. N. Uppal, Agricultural Adviser, Punjab.
2. Shri R. D. Dhir, Chief Engineer (Flood control), Central Water and Power Commission, New Delhi.
3. Dr. R. V. Tamhane, Soil Conservation Adviser, Ministry of Food and Agriculture, Department of Agriculture.
4. Shri K. P. Sagreiya, President, Forest Research Institute, Dehra Dun.
5. Shri U. S. Madan, Director, Soil Conservation, Central Water and Power Commission (co-opted).
6. Dr. S. P. Raychaudhuri, Senior Specialist, Land Resources, Planning Commission (Convener).

The main object of this study was to collect all the existing information on the occurrence of saline, alkali and water-logged lands, to examine all the reclamation measures for such lands and to analyse the data available with a view to suggesting policy measures. The economics of reclamation of such areas by the application of different methods was also to be studied.

The Working Group met at Chandigarh from 21st to 23rd April, 1962. Sub-groups of experts were set up to study the relevant problems. For each sub-group a convener was appointed to collect and coordinate all the information which became available. On the basis of the information so collected, a draft report was prepared and discussed at a meeting held on the 29th December 1962 in which the representatives of the Planning Commission, the Ministry of Food and Agriculture, Ministry of Irrigation and Power, Indian Council of Agricultural Research and a few State Governments took part. The study is, therefore, the collective work of a large number of experts including economists, soil scientists, engineers and soil conservation and forestry experts from the Government of India as well as the States. The major brunt of the study fell on the shoulders of

Dr. S. P. Raychaudhuri, Senior Specialist (Land), who with his indefatigable industry, co-ordinated the entire material in its present form.

Chapter I of the present study deals with land utilisation statistics of India, concepts in land utilisation statistics and soil map and areas under each soil group.

Chapter II deals with the survey of wastelands. The Wastelands Survey and Reclamation Committee has grouped the following three categories of land and designated them as "other uncultivated land excluding fallow lands":—

- (i) Permanent pastures and meadows;
- (ii) Areas under miscellaneous trees and crops; and
- (iii) Culturable waste.

The category "Culturable waste" has been defined to include all lands available for cultivation but not taken up for cultivation or abandoned after a few years for one reason or the other. In addition to the above three categories, land classified as "fallow other than current fallows" has also been included in the wasteland category by the Wastelands Survey and Reclamation Committee. The Committee has further pointed out that the concept of "other uncultivated lands excluding fallow lands" was not yet clearly understood. Land which were classified as "culturable waste" at the time of settlement some years ago still cannot continue to be classified as such in the revenue records even though they cannot be made culturable after incurring any reasonable expenditure. Similarly, some of the lands which were culturable continue to be classified as barren and unculturable or pasture land. In some cases, pasture lands have been included in the category of "culturable waste". The Committee has, therefore, come to the conclusion that the areas included in the two categories, namely, "other uncultivated lands excluding fallow lands" and "fallow lands other than current fallows" may not truly represent the actual extent of culturable wastes in the country. For the purposes of the report, however, the Wastelands Survey and Reclamation Committee has utilised the data furnished to them by the revenue and agricultural agency of each State under the above two heads.

In the present study, in addition to the above two categories of land, saline and alkali lands and also water-logged lands which may be producing some crops but of low yield, have been included.

Chapter III gives a brief review of the work done on the reclamation of wastelands caused by erosion and weed infestation.

Chapters IV to VII deal with the saline and alkali lands including coastal salines, their locations, extent, problems of reclamation, and demarcation of areas with sweet and saline ground water table. Trees, grasses and crops suitable for growing in such lands, and techniques evolved for the reclamation of saline and alkali lands are also described.

Chapters VIII to XII deal with water-logged lands, their extent, location, variations of depths of water-table, trees, grasses and crops suitable for growing in such lands, methods of reclamation of such lands, and utilisation of such areas for deep-water paddy and pisciculture.

The review of work done on soil conservation and reclamation during the First and Second Five Year Plan periods is given in Chapter XIII along-with a mention of the schemes of the III Plan. In Chapter XIV use of aerial photography in soil mapping and land-use classification with particular reference to saline, alkali and water-logged lands is stressed. The recommendations which emerge from this study are dealt with in Chapter XVI.

The detailed break-up of land classification statistics of States have been included as Appendix II. Maps and photographs have been included to illustrate the points made out in the text.

Substantial information has been collected in this study which can lead to policy measures for reclamation of such lands in the Fourth and subsequent Five Year Plans.

M. S. RANDHAWA,
Adviser (Resources).

New Delhi,
January 5, 1963.

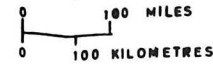
Study Team

In this study on wastelands, including saline and alkali lands, and water-logged lands, the following participated.

- | | |
|-------------------|----------------------------------------------------------------------------------------------|
| M.S. Randhawa | . Adviser (Resources), Planning Commission. |
| B.N. Uppal | . Agricultural Adviser to the Govt. of Punjab. |
| Mukhtar Singh | . Deputy Agriculture Commissioner, Indian Council of Agricultural Research. |
| R.D. Dhir | . Chief Engineer, (Flood Control) Central Water and Power Commission. |
| M.M. Anand | . Suptdg: Engineer, Western Jamuna Canal. |
| Jatinder Singh | . Chief Engineer (Irrig.) Punjab. |
| D. Mukherjee | . Chief Engineer (Irrig.) West Bengal. |
| B.S. Dina | . Chief Engineer (Irrig.) Punjab. |
| P.C. Raheja | . Director, Central Arid Zone Research Institute. |
| R.R. Agarwal | . Director, Agriculture, Uttar Pradesh. |
| M.L. Wahi | . Director, Central Design Irrigation, Punjab. |
| K.L. Vij | . Director, (H.E.), Central Water and Power Commission. |
| H.L. Uppal | . Director, Irrigation Research, Punjab. |
| U.S. Madan | . Director, Soil Conservation, Central Water and Power Commission. |
| S.K. Mukherjee | . Joint Director, Agriculture, West Bengal. |
| A. D. Khan | . Joint Director, Agriculture (Soil Conservation), Uttar Pradesh. |
| N.C. Shah | . Deputy Director, Agriculture (Engg.), Gujarat. |
| U.S. Dalal | . Deputy Director, (Reclamation) Irrigation Research, Punjab. |
| J.S. Kanwar | . Agricultural Chemist, Punjab. |
| K.M. Mehta | . Agricultural Chemist, Rajasthan. |
| D.V. Krishna Rao | . Agricultural Chemist, Andhra Pradesh. |
| H.G. Pandey | . Agricultural Chemist, Gujarat |
| D.V. Ballal | . Agricultural Chemist, Maharashtra |
| B. Ramamoorthy | . Physical Chemist, Indian Agricultural Research Institute. |
| M.S.V. Rama Rao | . Soil Conservation Adviser, Deptt. of Agriculture, Punjab. |
| H.T. Khemchandani | . Deputy Soil Conservation Adviser, Min. of Food & Agri. |
| Jagdish Singh | . Silviculturist, Punjab. |
| Waheed Khan | . Silviculturist, Forest Research Institute. |
| G.S. Dhillon | . Chief Conservator of Forests, Punjab. |
| G.C. Chatterjee | . Incharge Ground Water Division, Geological Survey of India. |
| Satwant Singh | . Nasirpur Farm, Punjab. |
| A.S. Venugopalan | . Secretary, Wastelands, Survey and Reclamation Committee, Ministry of Food and Agriculture. |
| K.D. Sharma | . Research Officer, Planning Commission. |
| S.P. Raychaudhuri | . Senior Specialist (Land Resources) Planning Commission, Convener. |

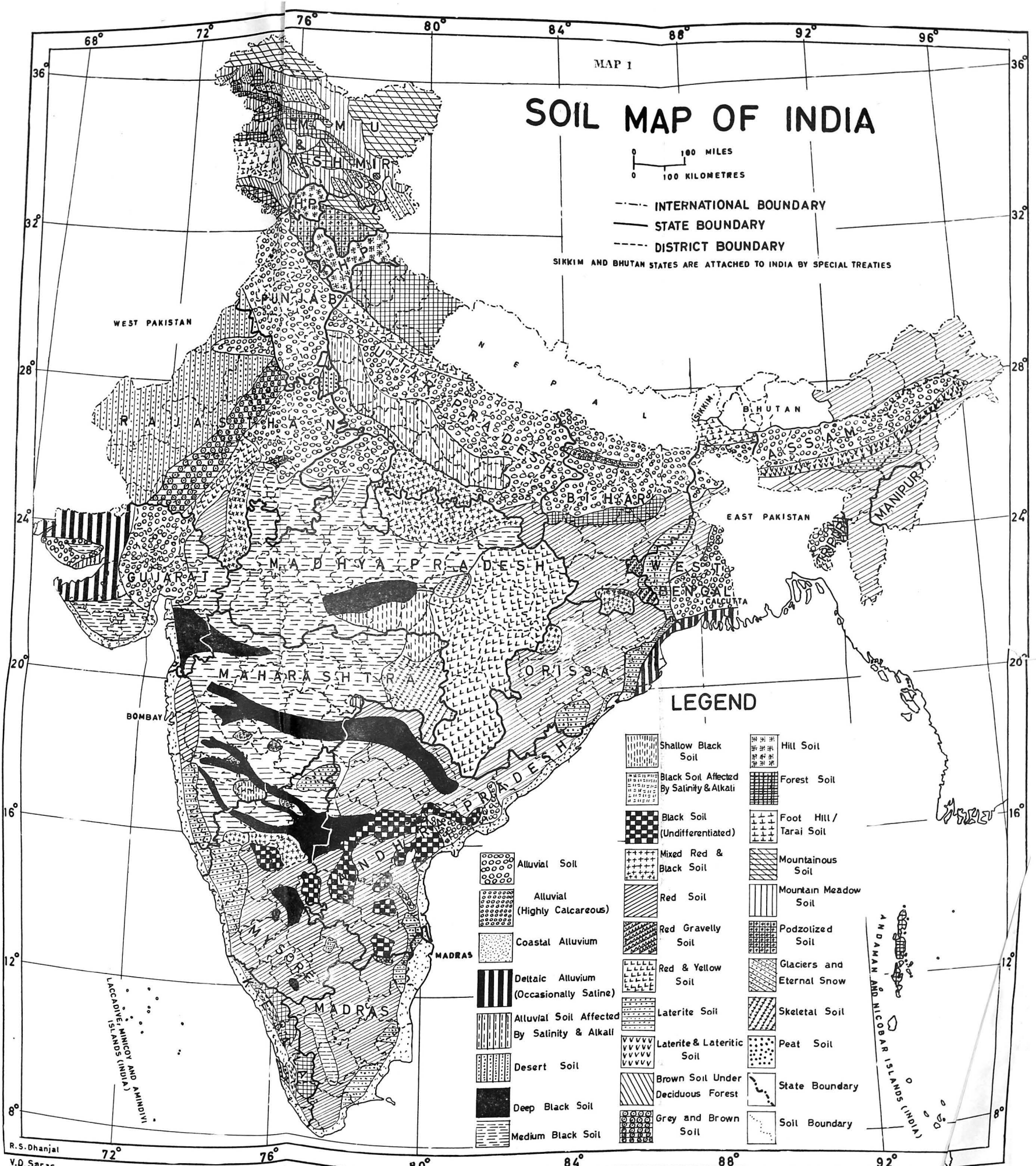
SOIL MAP OF INDIA

MAP 1



- INTERNATIONAL BOUNDARY
- STATE BOUNDARY
- - - DISTRICT BOUNDARY

SIKKIM AND BHUTAN STATES ARE ATTACHED TO INDIA BY SPECIAL TREATIES



LEGEND

- | | | | |
|--|---------------------------------------------|--|---------------------------|
| | Shallow Black Soil | | Hill Soil |
| | Black Soil Affected By Salinity & Alkali | | Forest Soil |
| | Black Soil (Undifferentiated) | | Foot Hill / Tarai Soil |
| | Alluvial Soil | | Mountainous Soil |
| | Alluvial (Highly Calcareous) | | Mountain Meadow Soil |
| | Coastal Alluvium | | Podzolized Soil |
| | Deltaic Alluvium (Occasionally Saline) | | Glaciers and Eternal Snow |
| | Alluvial Soil Affected By Salinity & Alkali | | Skeletal Soil |
| | Desert Soil | | Peat Soil |
| | Deep Black Soil | | State Boundary |
| | Medium Black Soil | | Soil Boundary |
| | Mixed Red & Black Soil | | |
| | Red Soil | | |
| | Red Gravelly Soil | | |
| | Red & Yellow Soil | | |
| | Laterite Soil | | |
| | Laterite & Lateritic Soil | | |
| | Brown Soil Under Deciduous Forest | | |
| | Grey and Brown Soil | | |

R.S. Dhanjal
V.D. Saras

Prepared at the Indian Agricultural Research Institute, New Delhi - 1961

PLANNING COMMISSION
C M U / N 4 8 / - 3 - 6 3

CHAPTER I

Wastelands in India

1. *Soils.* The soil map prepared at the Indian Agricultural Research Institute shows that there are twenty-seven broad soil classes excluding glaciers and eternal snow (Map 1). Approximate areas of the twenty-seven broad soil classes and of the glacier and eternal snow are shown in Table 1.

Table 1

S.No.	Approx area in million acres.
1. Alluvial soil	250.0
2. Alluvial soil, highly calcareous	22.0
3. Coastal alluvium	21.0
4. Deltaic alluvium (Occasionally saline)	42.0
5. Alluvial soil, affected by salinity and alkalinity	17.0
6. Desert soil	36.0
7. Deep Black soil	17.0
8. Medium black soil	46.0
9. Shallow black soil	12.0
10. Black soil affected by salinity and alkalinity	17.0
11. Black soil undifferentiated	31.0
12. Mixed red and black soil	26.0
13. Red soil	75.0
14. Red Gravelly soil	4.0
15. Red and Yellow soil	44.0
16. Laterite	25.0
17. Laterite and lateritic soil	5.0
18. Brown soil under deciduous	4.0
19. Grey and brown soil	9.0
20. Hill soil	6.0
21. Podsollic soil	9.0
22. Forest soil laterised	16.0
23. Foot hill/Terai hill	14.0
24. Mountain Meadow soil	29.0
25. Mountainous soil undifferentiated	16.0
26. Skeletal soil	6.0
27. Peat muck, very humose and humose soil, also called bog soils, organic soils and half bog soils	0.6
28. Glaciers and eternal snow	10.0
TOTAL	805.6

2. *Land utilisation statistics.* The total geographical area of India is about 806 million acres, of which reporting area is about 721 million acres and net area sown in 1958-59 was 323.6 million acres. The broad features of the present pattern of land utilisation during 1950-51, 1955-56, 1957-58 and 1958-59 is set out in the Table below:

Table 2: Land utilisation in 1950-51, 1955-56, 1957-58 and 1958-59

	(area in million acres)			
	1950-51	1955-56	1957-58	1958-59
(i) Forests	100.0	125.6	128.1	128.1
(ii) Land not available for cultivation—				
(a) barren and unculturable lands	..	..	83.1	82.1
(b) land put to non-agricultural use	117.4	118.7	33.0	33.5
(iii) Other uncultivated land excluding fallows—				
(a) culturable waste	56.7	54.8	52.2	50.8
(b) permanent pasture and other grazing lands	26.5	28.4	31.9	32.4
(c) land under miscellaneous tree, crops and groves	49.0	13.9	14.5	14.2
(iv) Current fallows	69.5	29.5	32.2	29.4
(v) Fallow other than current fallows	..	30.9	31.2	30.0
(vi) Net area sown	293.4	318.2	317.9	323.6
(vii) Area sown more than once	32.5	44.4	41.3	48.6
(viii) Gross area sown	325.9	362.6	359.2	372.2

Availability per head of cultivable land in India is about 0.82 acre as against 0.42 in U.K., 0.48 in Germany, 0.17 in Japan, 0.50 in China, 2.68 in U.S.A., 2.59 in U.S.S.R. and 50.75 in Canada.

3. *Concepts in land utilisation statistics.* The lands classified under categories iii(a), (b) and (c) have been grouped together by the Wastelands Surveys and Reclamation Committee and designated as "other uncultivated lands excluding fallow lands". The category "culturable wastes is defined to include all lands available for cultivation but not taken up for cultivation or abandoned after a few years for one reason or the other. Such lands may be fallow for more than five years and may be covered with shrubs and jungle. They may be assessed or unassessed and may lie in

isolated patches or blocks or within cultivated holdings. Lands reserved as pasture for grazing are not included under "culturable waste". Similar fallows of one year are classified as "current fallows", while those of 2—5 years are classified as "fallows other than current fallows". Lands left for growth of miscellaneous tree like bamboo, casuarina, fuel trees, etc. are not classified as "culturable waste".

As would be clear from the concepts explained above, wastelands for purposes of extension of cultivation, can be found only from the categories "other uncultivated land excluding fallows" and "fallows other than current fallows".

It will be observed that the total area during 1958-59 classified as "other cultivated land excluding fallows" is 97·4 million acres whilst the area classified as "fallows other than current fallows" is 30·0 million acres. The total area under these two categories during 1958-59 will be 127·4 million acres.

The distribution of wastelands in different States is shown in Table 3 below:

Table 3

State	(Million acres)		
	Other uncultivated land excluding fallows	Fallows other than current fallows	Total wastelands.
Assam	3·66	0·41	4·07
Rajasthan	21·57	9·29	30·86
Andhra Pradesh	8·31	2·19	10·50
Bihar	2·83	2·01	4·84
Orissa	6·46	0·74	7·20
Gujarat	4·66	0·63	5·29
Himachal Pradesh	1·64	0·01	1·65
Jammu & Kashmir	0·76	0·15	0·91
Kerala	1·06	0·20	1·26
Madhya Pradesh	17·97	4·02	21·99
Madras	3·38	1·64	5·02
Maharashtra	6·57	2·52	10·09
Mysore	7·07	1·18	8·25
Punjab	2·25	0·01	2·26
Uttar Pradesh	6·57	3·63	10·20
West Bengal	1·51*	Not known	1·51

* Other uncultivated lands excluding current fallows.

The Report of the Working Group on Land Use Planning of the Ministry of Food and Agriculture has discussed the maladjustments in broad lands use categories for the years 1950-51 to 1955-56. According to this Committee, during the period 1950-51 to 1955-56, the Reporting area increased by 17.0 million acres from 702.5 million acres to 719.5 million acres. This increase in the reporting area renders these figures rather incomparable from year to year. For example, although the actual figures relating to net area sown shows an increase of 24.8 million acres from 293.4 million acres to 318.2 million acres, a part of this increase is attributable to the larger coverage of the latter figure. However, as the reporting area increased by about 17.0 million acres only while the net area sown figures show an increase of 24.8 million acres, there has obviously been some increase (which may roughly be put between 15 million acres and 17 million acres) in the net area sown in the country during the First Five Year Plan period. Discussing further, the Report of the Committee mentions that though it would appear that there is very little scope for expansion of arable farming in the country, a certain amount of land shown under "culturable waste" and "old fallows" can be brought under profitable use if suitable efforts are made to locate these lands and reclaim them for agriculture, forestry or pasturing. However, ten million acres might be the upper limit of the additional area that might become available for arable farming itself out of the existing culturable waste during the period of about fifteen years beyond 1960-61. But because of extension of irrigation, we should be able to achieve a greater intensity of cultivation and the gross cropped area might go up substantially even by about 50 million acres—during the period 1961-76.

4. *Causes of culturable land lying waste.*—The total wasteland in the entire Union is about 127.4 million acres. The culturable wastelands if brought under cultivation, can be one of the important factors for augmenting the country's agricultural production. The chief reasons for leaving such lands uncultivated are:

- (i) Deep-rooted grasses and weeds
- (ii) Unhealthy conditions chiefly due to malaria
- (iii) Lack of drainage
- (iv) Low fertility of the soil
- (v) Lack of water supply
- (vi) Salinity and alkalinity
- (vii) Damage by wild animals.

5. *Land going out of cultivation due to soil erosion.*—Every year millions of tons of top soil is washed away during the monsoon. It has been calculated that the loss of top soil per acre in the course of

one year in the absence of soil conservation measures could be 10 to 15 tons per hectare. The area affected by the *chos* in the highly fertile soils of the Punjab has increased from 7 sq. miles to 700 sq. miles within the last century. No complete survey of the ravines in the alluvial plains of North India has been made, but it is estimated that in U.P. alone 3.5 million acres of land have been completely ruined by ravines and another 5 million acres of land are in the grip of acute erosion. Similar areas are being lost due to the formation of ravines in the States of Madhya Pradesh, Rajasthan and Gujarat on the banks of Chambal, Kali Sind, Mahe and Sabarmati. Unless steps are taken to stop further damage, more and more valuable crop lands will be lost to the ravines. It is estimated that in all about 200 million acres of land in the country require protection by soil conservation measures.

6. *Survey of wastelands.*—Agricultural production can be stepped up through extension of area under cultivation by cultivating wastelands, double cropping of single crop areas, and other measures of intensive farming. According to the available land utilisation statistics, the area under culturable waste in 1958-59 amounted to about 50.8 million acres. In June 1959, the Government of India constituted a Committee to make a survey of land classified as "other uncultivated land excluding fallow lands" and "fallow lands other than current fallows" and to locate areas where large blocks of land are available for reclamation and resettlement. The Committee has completed its survey of thirteen States, viz. Punjab, West Bengal, Bihar, Mysore, Andhra Pradesh, Madhya Pradesh, Kerala, Madras, Uttar Pradesh, Jammu & Kashmir, Maharashtra, Orissa and Gujarat. In these, the area of wasteland available for cultivation in blocks of 250 acres or more is reckoned at nearly 2 million acres. The Committee's findings regarding the present statistics of wastelands are of considerable importance. On the whole the existing data are not sufficiently reliable, and lands classified as culturable waste at the time of settlement often continue to be shown as such in the revenue records, long after they have come under cultivation. In the view of the Committee, the mere collection of statistics under the head 'culturable waste' can serve little purpose and detailed information should be available about the types of wastelands in each State, the ownership of such lands, their availability in sizeable blocks and the cost of reclamation measures. The Committee, has, therefore, recommended that rapid reconnaissance surveys should be conducted for collection of such information.

Typical wastelands in each State were visited by the Committee and were classified according to certain broad categories like water-logged lands, saline and alkali lands, eroded lands, lands infested

with thick growth of bushes in jungles and char lands. After studying the type of soil, rainfall, natural vegetation etc. suitable reclamation measures have been suggested for bringing the areas under cultivation. In addition, wherever necessary, resettlement schemes which would be needed for keeping the areas under cultivation have also been suggested. Suitable cropping patterns that should be followed in the various areas as also the economics of reclamation of these areas have been discussed. Finally, priorities have been given between various categories of reclaimable lands.

If the recommendations of the Wastelands Survey and Reclamation Committee are to be implemented during the Third Plan period, it is necessary that suitable provision should be made in the plans of different States. In particular, it may be mentioned that provision for reclaiming the areas which have been accorded a high priority by the Committee should be made by the States unless it has been done already. These areas are reported to be capable of increasing the agricultural production to a considerable extent at an economic cost. Following the recommendation of the Wastelands Survey and Reclamation Committee, the Planning Commission has sanctioned a scheme for survey and categorisation of wastelands in blocks measuring less than 250 acres and has made a provision of Rs. 69 lakhs for the purpose. So far the Ministry of Food and Agriculture have received schemes from States of Madhya Pradesh and Madras for the year 1961-62 and States of West Bengal, Assam, Orissa, Punjab and Himachal Pradesh have forwarded their schemes for the financial year 1962-63. The Madras Government scheme envisages to localise wastelands in blocks of 15 acres and above in 10 districts. The other State Governments also have similar schemes. The Ministry of Food and Agriculture have approved almost all the schemes of localising wastelands in blocks of similar size and have also agreed to reimburse the actual expenditure subject to a ceiling of Rs. 23,000 per district. The remaining States have been reminded to expedite formulation and submission of their schemes. A budget provision of Rs. 12.00 lakhs has been agreed to by the Ministry of Finance for 1962-63. (Ref: Maps 2 to 10).

The wastelands for the purposes of the present study have been differentiated under the following three broad categories:

- (i) Kans infested wasteland.
- (ii) Saline and alkali lands.
- (iii) Water-logged lands.

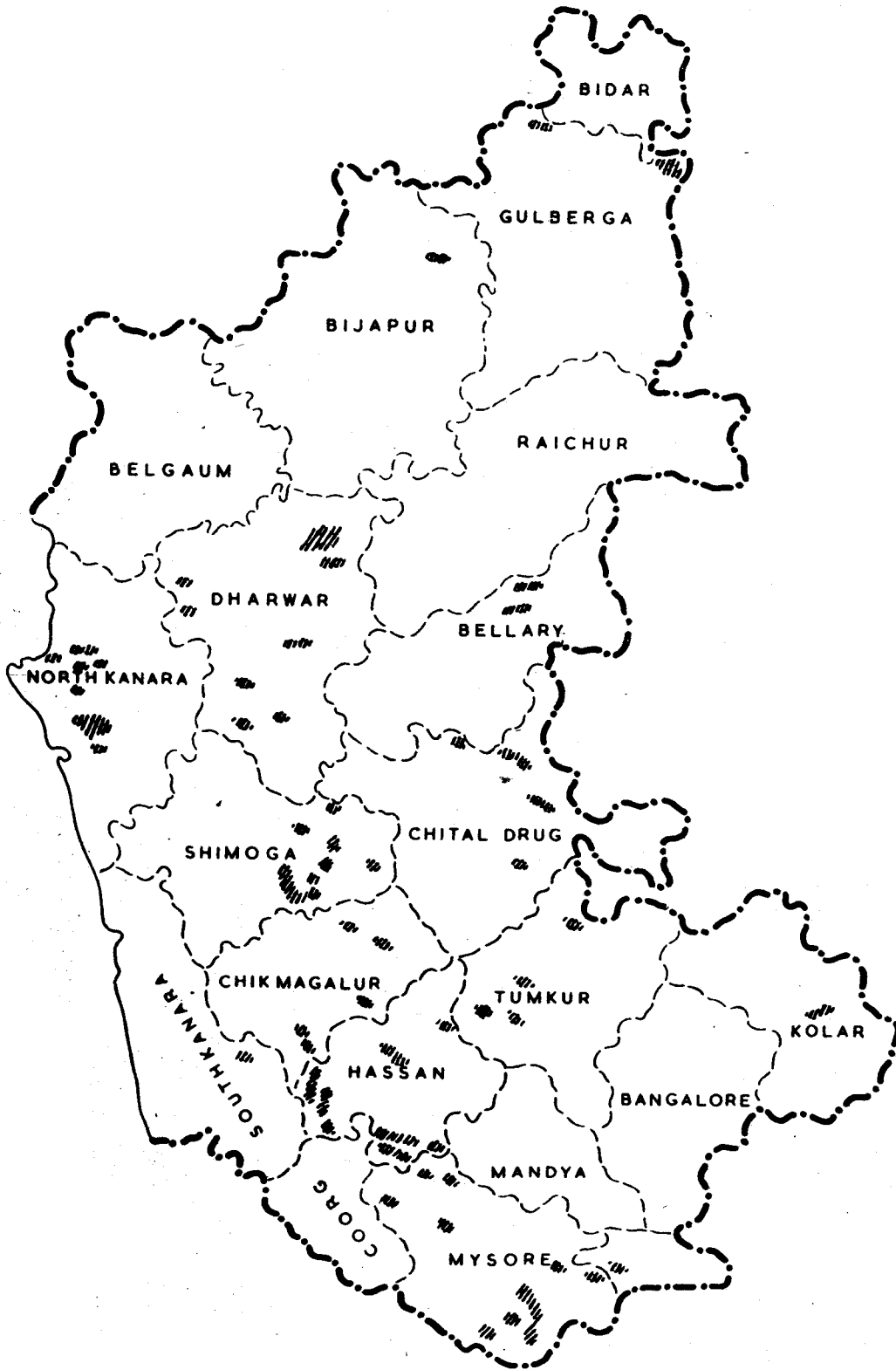
The study includes areas of very low productivity in addition to areas lying waste, particularly in respect of saline and alkali and water-logged lands.

MAP-2

BIHAR

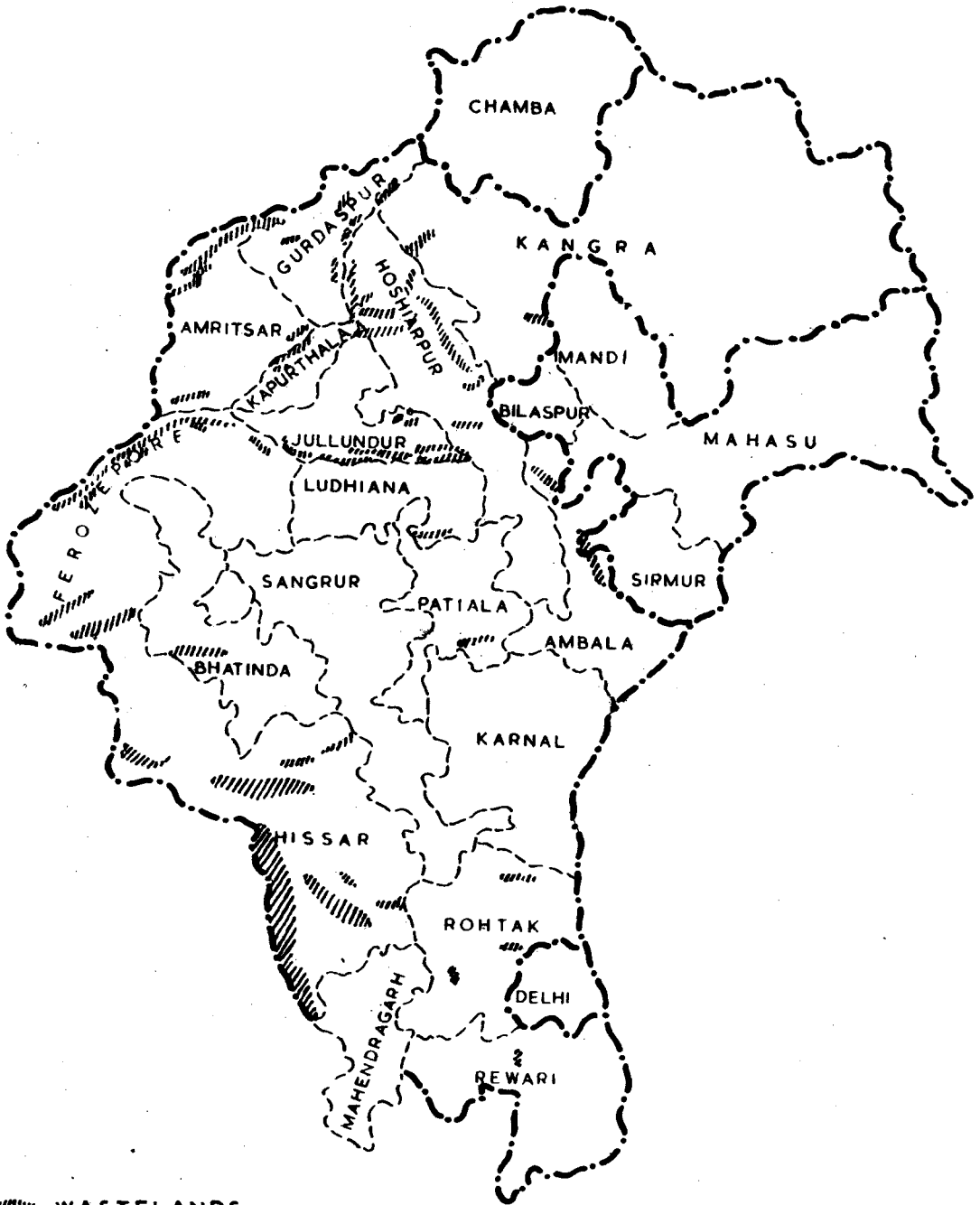


MAP-3
MYSORE



WASTELANDS
(IN BLOCKS OF 250 ACRES
OR MORE)

MAP-4
PUNJAB



WASTELANDS
(IN BLOCKS OF 250 ACRES OR MORE)

MAP - 5

MADHYA PRADESH



WASTELANDS
(IN BLOCKS OF 250 ACRES OR MORE)

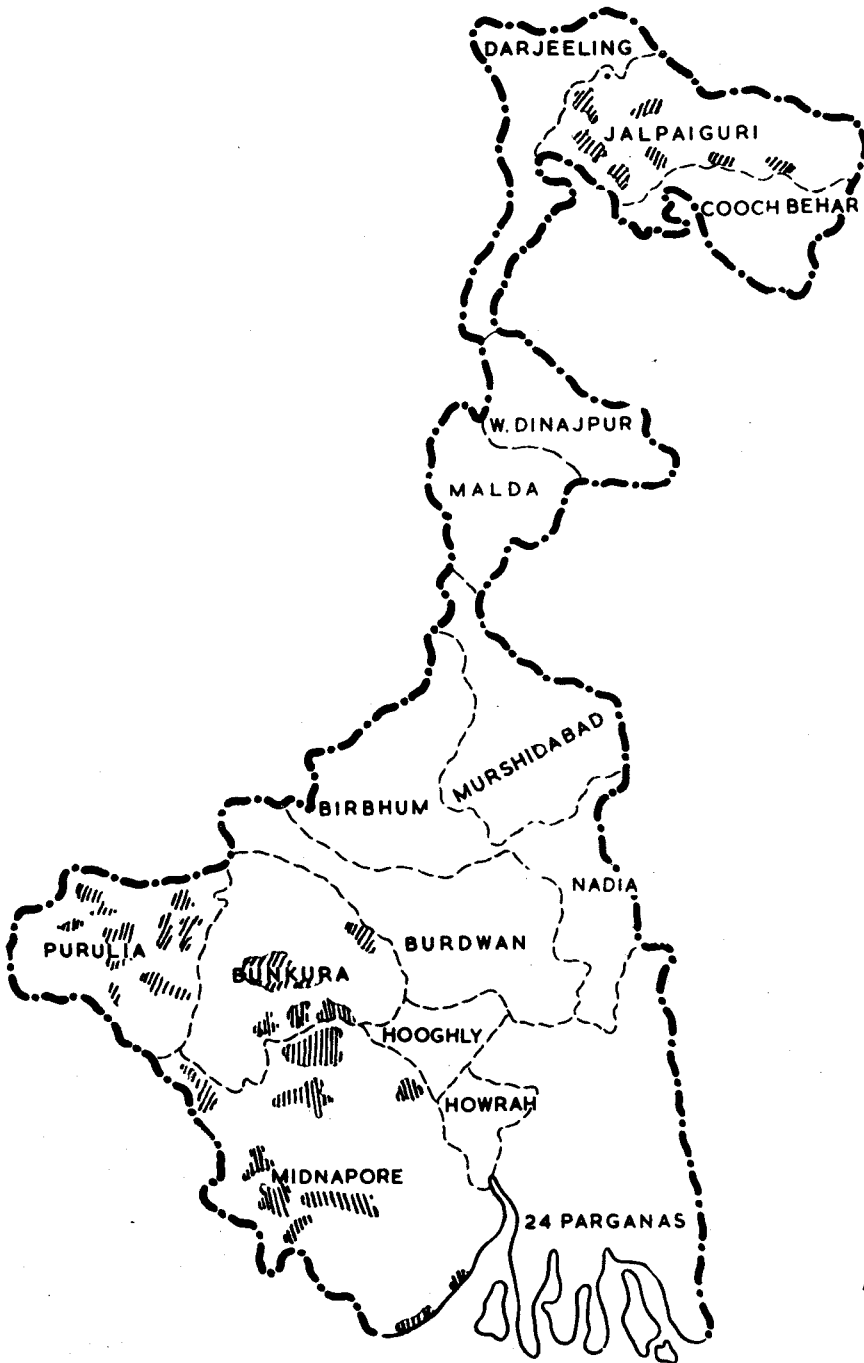
MAP-6

ANDHRA PRADESH



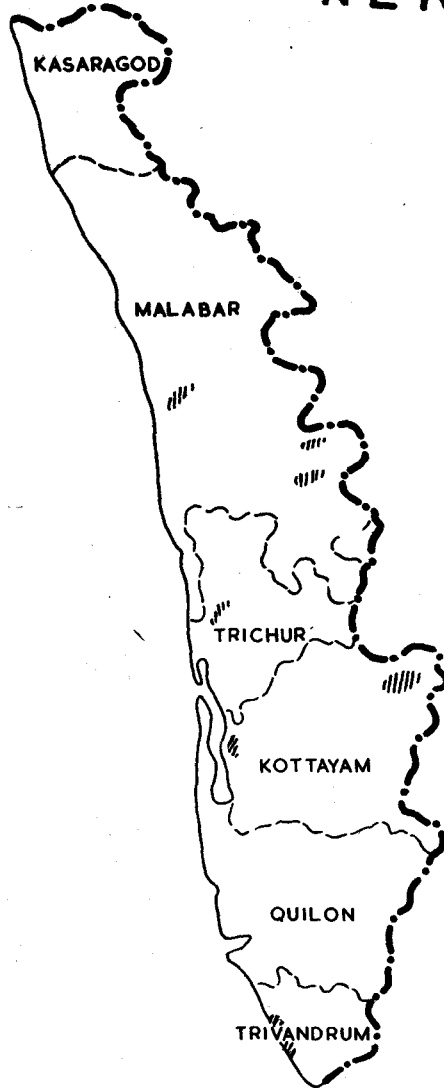
MAP-7

WEST BANGAL



WASTELANDS
(IN BLOCKS OF 250 ACRES
OR MORE)

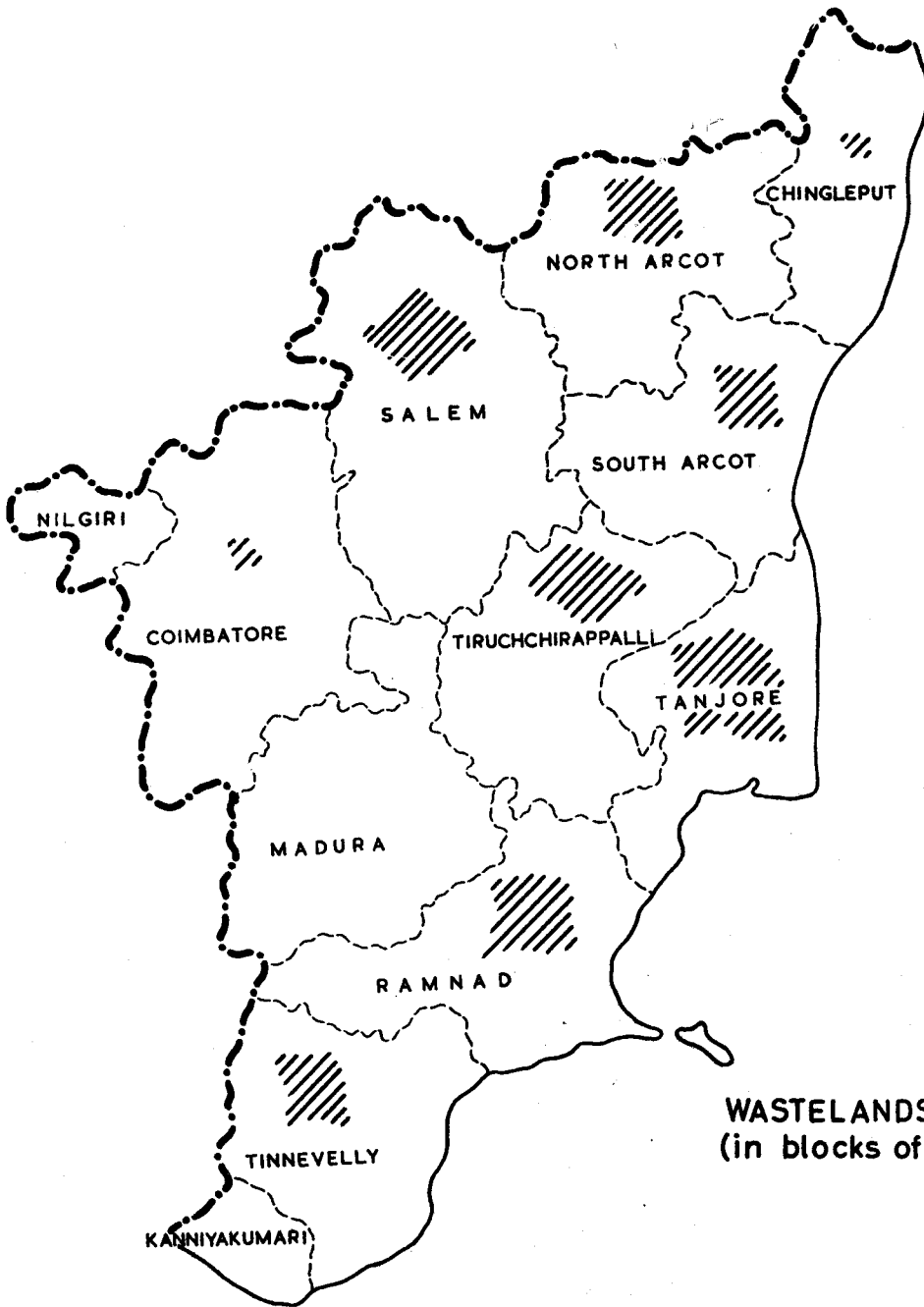
MAP - 8
KERALA



 WASTELANDS

MAP - 9

MADRAS



WASTELANDS
(in blocks of 250 acres or more.)

MAP-10

UTTAR PRADESH



WASTELANDS
(in blocks of 250 acres or more)

CHAPTER II

Kans Infested Wastelands

The extent of total waste lands including other uncultivated land excluding fallows and fallows other than current fallows (1958-59) in different States in India are given in Table 3.

The lands covered with jungles and shrubs cannot be brought under cultivation without the aid of adequate labour and capital. The deep-rooted grasses like kans cannot be eradicated without the assistance of tractors, and the draining of marshy lands is frequently an expensive operation. Provision of irrigational facilities involves heavy capital outlay and there is a limit to the rate at which open wells and tube-wells can be constructed. Due to lack of suitable fencing and fire-arms, protection against wild animals presents difficulties. In addition to these, unhealthy tracts provide problems difficult to tackle.

Cultivable wastelands are covered either with a scrub jungle or with deep-rooted weeds like kans. The weed-infested areas are spreading out every year and these are either entirely out of cultivation, or are producing progressively less and less according to the degree of infestation. Ten million acres of such land has gone out of cultivation in Madhya Pradesh, Bihar and Rajasthan. Normally such land is capable of yielding 9 to 19 maunds of foodgrains per acre, whereas on account of kans-infestation, the yield hardly exceeds 2½ maunds. Such lands can be rendered free from weeds only by heavy tractors.

Nearly 10 million acres of culturable waste lands roughly distributed as below before reorganization of States were projected to be reclaimed by tractorisation.

Table 4

Culturable wastelands projected to be reclaimed

Punjab	. . . . .	500,000	acres
U.P.	. . . . .	1,000,000	”
Bihar	. . . . .	200,000	”
Assam	. . . . .	3,000,000	”
		to	
		4,000,000	”
Ori sa	. . . . .	1,000,000	”

Madhya Pradesh	.	.	.	.	.	.	1,000,000	acres
Rajasthan	.	.	.	.	.	.	1,500,000	"
Madras	.	.	.	.	.	.	1,000,000	"
TOTAL								10,000,000 acres approximately.

The Foodgrains Policy Committee recommended that 3 million tons of additional foodgrains could be obtained by reclamation of 9 million acres of weed-infested and jungle lands. On account of the general shortage of trained personnel and difficulty of obtaining the requisite heavy machinery, the Central Tractor Organisation aimed at reclaiming 2.5 million acres of wasteland within a period of five years with the help of 375 heavy tractors and other necessary equipment, as a first instalment of work in the scheme. Besides, 100,000 acres of wasteland per annum was to be reclaimed with the aid of 180 rehabilitated tractors of the Central Tractor Organisation.

During 1948, more than 400,000 acres of land spread over Bihar, Uttar Pradesh, Madhya Pradesh, Assam, Madras and Punjab were reclaimed for cultivation. By the end of June, 1949, the Central Tractor Organisation reclaimed over 70,000 acres of weed-infested wasteland. The scheme was confined to blocks with an area of 10,000 acres and above only.

The Uttar Pradesh Government also brought under plough nearly 50,000 acres of Khadar land near Hastinapur and another about 100,000 acres in the Tarai region. An experimental plantation of 4,300 acres in the Tarai area yielded a crop of 34,000 maunds of paddy. The yield from the reclaimed Ganga Khadar area was 30 maunds of paddy per acre as compared with the average yield of about 10 maunds per acre in Uttar Pradesh.

The areas reclaimed by tractors offer a great opportunity for initiating soil conservation practices. It is unfortunate that the Central Tractor Organisation had to be wound up. The State Governments wanted the reclamation by tractors to be carried out by themselves instead of paying to the Central Tractor Organisation. The heavy cost of repairing the tractors was also one of the reasons for winding up the organisation. Since then it seems that the State Governments found the operation expensive and uneconomic and, therefore, not much progress has been made. It is desirable that the State Governments should be addressed to find out what work in this direction has been carried out, and what are the difficulties encountered, so that the future plan of work for reclamation of kans infested land is drawn up.

It is desirable that while breaking up wastelands ploughing should be done on the contour where slopes are more than two per cent. The question of leaving sufficient areas unploughed to meet the grazing needs of cattle of the cultivators needs careful consideration. It is suggested that boundary embankments as also field embankments on the contours should be put up. This will prevent soil losses and at the same time preserve moisture. In addition these bunds will hold monsoon water which will suppress the growth of kans. There is every likelihood of the weeds reappearing after five or six years if proper precautions are not taken. In that case ploughing operations by tractors may have to be repeated. On higher slopes terracing on the contours will be needed and suitable kharif ground crops will have to be used in rotation. Green manuring should also be practised wherever feasible.

Good plough bullocks should be made available in time so that the broken up land does not become re-infested with kans. The individual cultivators possessing large holdings may be encouraged to use tractors of 25 or 30 horse power for the 'follow up' cultivation. Tractors will incidentally be of considerable importance where seasonal farming is practised. In some cases, it would be necessary to maintain light tractors units suitably equipped for 'follow up' cultivation.

CHAPTER III

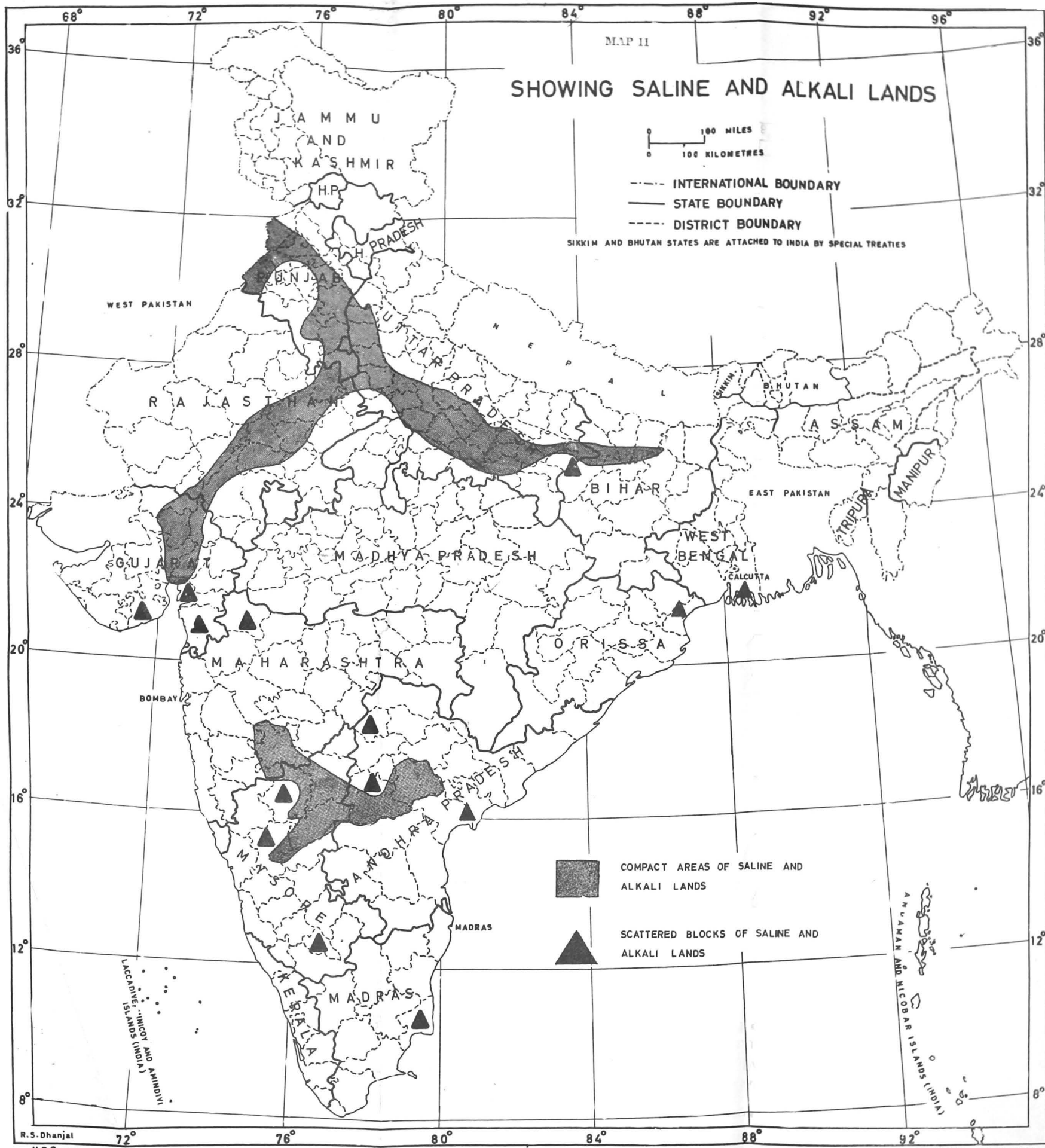
Saline and Alkali Soils, extent, location, classification and reclamation measures

General Occurrences

The saline and alkali soils are found in almost all normal (Zonal) soils. There are about 15 million acres of such soils in the States in India. They are characterised by high salt concentration and or high alkaline reaction. The introduction of irrigation through canal system in the arid and semi-arid regions, e.g. Punjab, U.P and Bombay-Deccan, brought about an increase in such unproductive areas amounting to several thousand square miles due to accumulation of salts in the surface soil. The principal areas are (i) Punjab and Rajasthan, (ii) the Ganga Valley, West of about 80° E in Delhi and Uttar Pradesh, (iii) the uplands of the Deccan Plateau especially between the Tapti, Godavari and Bhima rivers, (iv) the saline marches of the sea-coast and of the deltas of the Ganga, Cauvery and Mahanadi, and (v) the coastal salt flats along the Rann of Kutch. Map 11 shows broadly the occurrences of saline and alkali soils in the country.

Causes of origin

Leather⁴¹ showed that injurious salts in saline and alkali soils which are the decomposition products of igneous rocks under natural weathering process, are present in the soil profile itself and that they become evident on the surface layers under certain pre-disposing conditions like (i) arid or semi-arid climate, (ii) an impervious sub-soil or hard pan, and (iii) temporary abundance of humidity in the soil interspersed with dry periods. He included the saline and alkali soils of the Punjab, U.P., Gujarat and Bombay-Deccan under the common term "*usar*" derived from the Sanskrit word "*Ushtra*" meaning barren or sterile. Similarly, a poor drainage and high water table, which usually go hand in hand, are the two important factors which lead to salinity of soil. This is very clearly illustrated by the deterioration of extensive areas of lands commanded by the newly opened canals in the Bombay-Deccan constructed towards the end of the nineteenth century. No provision was made for the drainage of surplus water, and irrigation was introduced without any regard to the suitability of these soils for irrigation. Within three years of the opening of the Nira Left Bank Canal, very heavy



R.S.Dhanjal
V.D.Saras

PLANNING COMMISSION
C.M.U./NO 50/-4-63

damage had been caused to the rich sugarcane lands commanded by the canal. The same is the story in the Punjab and to a smaller extent in Uttar Pradesh.

Local Names

Saline and alkali soils are known by different names in different parts of India, such as *thur, reh, kallar, rakar, usar, karl* and *chopan*. Besides, their origin in the soil itself, the salts in the soil, which are usually sulphate and chloride of sodium with some calcium and magnesium salts, are introduced by river and sea water. In many parts of the world alluvial plains where effective underground drainage is lacking, the salts become concentrated, and capillary action during the summer months brings them to the surface where they form a white efflorescent crust. Under certain conditions the sodium salt give rise to sodium carbonate and bicarbonate.

Extent and Location

In the Punjab, about 4.29 lakh acres in the canal irrigated area and about 2.24 lakh acres outside it have been recorded as damaged by salt accumulation. It is, however, considered that over 3 million acres in the State are either visibly affected by salts on the surface or contain enough salts to lower crop yields.

It is estimated that, in Uttar Pradesh, about 3.1 million acres are lying waste because of saline or alkali soils and that the State has an equally large area of arable land suffering from soil salinity. The comparatively more arid, central and north-western districts of the Uttar Pradesh on the left bank of the river Ganga, contain largest extent of saline and alkali lands.⁶⁸

In the south, saline and alkali soils are found in Maharashtra, Gujarat, Mysore, Andhra Pradesh and Madras. About 75,000 acres of land were reported in 1938 to have become unproductive in the canal area of the former Bombay State as a result of salt infestation. In addition, about 6 million acres round the sea coast and estuaries of rivers are affected by sea tide carrying salt laden deposits⁶⁵. This latter category would include 35,000 acres of peaty saline soils in Kerala locally known as *kari* soils which have originated as a result of accumulation of large amount organic matter in the soil. The coastal saline tract of the West Bengal which remains practically submerged in the tidal water is of the order of 2.1 lakh acres⁶³, such soils are also found along the Maharashtra coast (25,000 acres) and the Rann of Kutch (82,000 acres). Saline and alkali soils also occur in patches in Rajasthan (about 1 million acres), in some parts of the sugarcane tracts of North Bihar (about 10,000 acres) and in areas commanded by canals in Deccan, Gujarat and Karnatak tracts (about 3 million acres).

General classification

Saline and alkali soils found in India can be classified into three major types, viz., (i) saline, (ii) saline-alkali and (iii) alkali soils depending on the salt content and the percentage of exchangeable sodium present in them.

(i) *Saline soils*.—Saline soils are generally known as *reh* or *rehals* in Uttar Pradesh and *thur* in the Punjab, and is recognised by the presence of extensive white or greyish white or ash-coloured fluffy deposits on the surface. Such soils occur extensively along the west coast in Maharashtra and in parts of north Gujarat and Saurashtra region and soils are loam to sandy loam in texture and there is usually no hard pan or *kankar* layer in the subsoil. They usually occur in the vicinity of rivers or streams or near canals with an obstructed natural drainage. On such soils during the monsoon months when the salts are washed down, many varieties of salt-loving grasses thrive. During dry periods, however, no vegetation exists.

In the saline lands there is decline in productivity ranging from 10% to 50% or more because of the salt influence. The plants growing on these areas may not show any evidence of salt in the form of surface crust and the cultivators may be totally unaware that the salts are reducing the yields but may think that some other factor like loss of soil fertility, is the cause of low yields.

(ii) *Saline-alkali soils*.—Saline-alkali soils are called occasionally *reh* and more generally *usar* in Uttar Pradesh and *kallar* in the Punjab. Outwardly the soil presents the characters of saline type, but the sub-soil is hard and is more or less impermeable to water. There may or may not be salt efflorescence or deposit on the surface. The hard clay pan in the lower layers of the profile may vary from a few inches to sometimes three feet. There may also be a *kankar* pan, but the size of *kankars* in the pan is usually small, being about the size of peas. The soils have moderate to low salt content.

(iii) *Alkali soils*.—This type of soils is the typical *usar* of Uttar Pradesh. It is known as *rakkar* in the Punjab and *Chopan* in Bombay-Deccan. In this type, hard and compact soils of clay to clay loam texture are found resting on heavier, indurated or hardened columnar sub-soil which restricts upward movement of water by capillary action and the downward flow of water by percolation under force of gravity.

All irrigation water contains some salt which is leached down below the root zones and finally into the ground water. If, however,

the ground water be near the surface within 5 ft. the salts return to the root zone or to the surface by capillary action. This may be avoided firstly by adopting good drainage system, and secondly by good farming methods like levelling of land, applying water uniformly and in sufficient quantities, use of sufficient organic matter and by building up soil fertility by good system of rotation of crops. In case of alkali soils, the addition of chemical amendment like gypsum has been established to be very beneficial for the base exchange reaction in the replacement of exchanegable sodium and use of dhaincha as green manure which contributes to the reclaiming action of gypsum by restoring the physical condition and enriching the soil in nitrogen and organic matter. Addition of gypsum, leaching, flushing and growing of salt resistant crops are some of the chief methods usually adopted for the reclamation of saline alkali soils.

General Methods of Reclamation

The general methods of treatment of different classes of saline and alkali soils for reclamation are indicated below—

1. Saline soils with efflorescence of salt at the surface.
 - (i) by scraping of the surface salts.
 - (ii) by flushing with water to wash away the excess salts.
2. Saline soils with high concentration of soluble salts up to great depth but with low water table.
 - (i) by impounding rain or irrigation water for leaching out injurious salts to a safe limit inside the soil.
 - (ii) by trenching coupled with flushing to remove the salts by surface and sub-surface drainage.
3. Saline soils with high concentration of soluble salts up to great depth but with high water table.
 - (i) by lowering of water table through pumping of water or through wells and tube-wells.
 - (ii) by improving underground drainage through sub-soil and tile drain to facilitate rapid removal of salts.
4. Saline soils with diffused or compact clay or *kankar* pan in the sub-soil by deep ploughing to break the pan.
5. Hard alkali soils
 - (i) by treating with chemical amendments like gypsum calcium chloride, sulphur, etc.,

- (ii) by adding organic material such as farm yard manure mollasses, crop residues, green manuring crops like *Sesbania aculeata*, etc.
- (iii) by leaching with water to remove the products of reaction,
- (iv) by deep ploughing or trenching to break any hard pan for improving drainage.

Yadav and Agarwal¹⁰⁰ have shown that alkali soils inherently containing gypsum can be easily reclaimed by merely impounding rain water and leaching out salts, but such soils are of very limited occurrence in the country. On the other hand, the alkali soils usually met with are associated with the presence of calcium carbonate as an integral part which may play an important role in their reclamation if rendered soluble.

Pasture Development and Afforestation (General)

Some *usar* areas which may be considered unfit for agricultural purposes can be utilised for pasture development or afforestation. If such lands are properly enclosed to exclude reckless grazing, they can support some types of beneficial grasses constituting initially a mediocre type of pasture and better grasses will establish themselves in due course. Such areas should be protected from grazing in July and August of each year, and opened to rotational grazing from September to June in blocks. The incidence of grazing should not be high. Under such conditions, the grasses grow tall enough and are fit even for cutting as hay. However, on stiff clay type *usar* the growth of grass and fodder is extremely slow⁸⁸.

Khar usar (*Sporobolus arobious*) and *usrants* (*Chloris urigata*) are the usual grasses which grow on *usar*, but die out after the rains. In low-lying patches and in areas remaining moist for longer periods of time, *dub* (*Cynodon dactylon*) and *gandar* (*Andropogon squarrosus*) can also grow. Whereas, *usar* grasses are characteristics of *usar* areas, *dub*, (*Aragrestis cynosurfides*) *dub* (*Cynodon dactylon*), and *gandar* (*Andropogon squarrosus*) are suggestive of better spots.

For successful afforestation of *usar* land having hard *kankar* pan below the surface, *Deep Thala* system is adopted. In this system, holes, three to four feet in depth and two to three feet in diameter are dug out regularly in the areas according to the number of trees needed to be planted. The depth is usually such that the compact

stratum or the *kankar* layer can be pierced through. The soil from this hole is completely removed and used for making a ridge round the hole. Good soil free from alkali is brought from outside and the holes filled with it. Seedlings are thereafter transplanted. With proper nursing they grow into healthy trees. If further protection from the harmful effects of salt-laden seepage water is desired, about a basketful of gypsum can be added per hole with the good soil at the time of filling it. By this technique the young trees in the process of growth would extend their root system extensively throughout the sub-soil and will shatter the hard pan, making the land more porous and permeable to water**

A mechanical method has been devised in Uttar Pradesh for digging these holes with a post-hole auger mounted on a tractor. The auger digs as well as brings out the soil and the cost of this operation is considerably less. Some plantings made in Uttar Pradesh by this technique in the early decade of the present century, have grown into good forests, yielding a fair revenue to the State.

The use of most of the measures of reclaiming saline and alkali soils is costly and may not prove profitable in developing pasture, forestry or village wood lands. In such cases attempt should be made to grow salinity and alkali resistant species by using suitable sowing or planting techniques which may include perforation of the underlying impervious pan, use of imported soil and application of manures or chemical fertilisers for ensuring quick establishment. After the tree seedlings are well-established, most of the soil moisture is absorbed by the roots to meet the transpiration loss and comparatively little quantity moves upward through capillary action to compensate for evaporation loss. Thus the chances for upward rise of soluble salts are greatly reduced and the salt concentration is maintained at a safe level. The incorporation of organic matter and binding action of tree root system promote a favourable soil structure and thus bring about beneficial physical conditions. Similarly the production of organic and inorganic acids helps in the transformation of the insoluble calcium carbonate into soluble calcium bicarbonate, calcium replacing the harmful sodium in the exchange complex. Of the various types of plantations which have been tried on saline and alkali soils, *Acacia arabica*, *Prosopis juliflorad*, *Albizia procara*, *Azadirachta indica* and *Zigypus jujuba* seem generally to flourish well in non-irrigated areas whilst in irrigated areas *Azadirachta indica*, *Tamarindus indica* and *Albizia procara* showed generally the best performance.

Work done on the reclamation of saline and alkali soils in the different States is given in the following account.

Work on Saline and Alkali Soils in Uttar Pradesh

In Uttar Pradesh vast stretches of saline and alkali lands popularly known as *usar* and *reh* are lying waste and uncultivated. The total area of *usar* in the State was estimated at 2.2 million acres in 1938; but a more recent survey made in 1957 placed this figure at 3.1 million acres, registering thereby an increase of 50 per cent within a period of less than 20 years. At this rate the state is about to lose 5 million acres of land within the next 100 years. The situation is indeed alarming and calls for immediate attention both in regard to the reclamation of the area under *usar* as well as to check further spread of alkalinity to culturable lands.

Salt problem in U.P. was recognised as early as 1876 when the 'Reh' Commission was set up to investigate into the causes of deterioration of soils soon after the introduction of the Ganga canal in the Aligarh and Etah districts. It is now known that extensive areas of *usar* occur in Uttar Pradesh, west of about 81 degree E longitude. The districts affected most are those of Aligarh, Moinpuri, Kanpur, Fatehpur, Unnao, Etah, Etawah, Rae Bareli and Lucknow. Though the Commission could not base their findings on any previous scientific research, yet their report gave an impetus to the future line of action in tackling the problem. The Commission recommended deeping the canals to lower the water table, prevention of over irrigation and draining out surplus sub-soil water.

The 'Usar' Reclamation Committee of U.P. (1938-39) reviewed the technical work done on such soils and reported that alkaline conditions were mainly due to sodium carbonate and bicarbonate to the extent of 0.1 to 0.4 per cent, the exact quantity of which differed according to the nature of the soil and sub-soil, presence of *kankar* (CaCO_3 concretions) beds and high water table. The alkaline layer extends on an average to a depth of 3-4 feet. Although the distribution of saline soils is comparatively less yet the area is not negligible. These soils are characterised by presence of sodium chloride and sulphate, very little Na_2CO_3 or NaHCO_3 and 'open' texture, and exist in a state of flocculation.

From the textural point of view, the alkali soils either at the surface or at some depth below, within the zone generally occupied by roots were found to be impervious. The profiles of these soils were generally associated with *kankar* or a definitely hard pan which restrict the upward movement of water by capillary action and the downward flow of water by percolation under force of gravity.

In 1912 Leather 42 investigated scientifically the question of spread of *usar* in U.P. with canal irrigation. He selected a line of country as similar as possible in respect of soil and hydrological conditions in the district of Etah where sterile *usar* patches occurred in arable fields. He selected a number of such patches, which were accurately mapped to obtain a survey plan and soil samples were collected in sections of 6 inches from each patch. The position of the point from where samples were obtained was accurately marked on the survey plan. This was done so that a future comparison of the selected *usar* patches and their soil condition may enable a dependable decision as to whether canal irrigation caused spread and intensification of *usar*. These patches were again visited in 1952 after a lapse of 40 years of canal irrigation and the area and intensity of *usar* patches increased in 9 out of the 12 fields examined, but that the intensity of *usar* expressed by the term volume salt-concentration showed increase in 10 and decline in 2 sites. On the basis of the data it was concluded that although the quality of irrigation water had been good, the increased intensification of *usar* is primarily due to soil factors, chief of which are nearness of water table and/or impence of drainage due to the presence of an indurated layer of clay or *kankar* pan in the sub-soil. This obviously shows that the chief causative factors of the creation, spread and intensity of soil alkalinity in this state lie in the soil itself and all solutions for checking the spread or reclaiming the land must be sought in the soil.

A systematic survey of *usar* tracts in large blocks of over 200 acres each, is in progress in Uttar Pradesh in nine districts where the intensity of such areas is maximum and where about 50 per cent of the total *usar* area in the state is encountered. These nine districts are Kanpur, Fatehpur, Aligarh, parts of Mainpuri, Unnao, Etawah, Rae Bareli, Ratangarh and Azamgarh. Based on these surveys, *usar* land is being demarcated into the following classes:

- (i) land which is suitable for cultivation without any special treatment,
- (ii) land which can be made fit for cultivation after it is properly treated, and
- (iii) land which is totally unfit for cultivation.

The surveys carried out in the districts of Kanpur, Fatehpur, Aligarh, Mainpuri and Unnao have revealed the existence of over 2.8 lakh acres of *usar* land in blocks of 200-acres or more. The total extent of such lands in large-sized blocks has been estimated to be 6 lakh acres in the state.

Studies on saline alkali soils of U.P., under a scheme on soil survey and soil work of the state Government have made considerable progress during the last few years (Agarwal and Mehrotra 3, 4 Agarwal, Mehrotra and Gangwar, 6). The *usar* soils are generally distributed in the low-lying and ill-drained areas of the state, for example in the district of Aligarh where all the factors which together contribute to soil salinisation and alkalisiation, e.g., arid climate, poor drainage and alkaline nature of high ground waters are co-existent. In the district of Kanpur, besides a tract similar to Aligarh condition, there is another tract of *usar* land with a level topography which has been rendered unculturable due to impeded drainage as a result of hard clay pan in the subsoil. Morphological studies of *usar* soil profiles reveal formation of hard solonetz like structure at the top. For salinity appraisals laboratory examination of profile soil samples from a large number of *usar* tracts of the state has been made under the scheme. The salinity and alkali status of a typical *usar* soil profile is given in Table (5) below:—

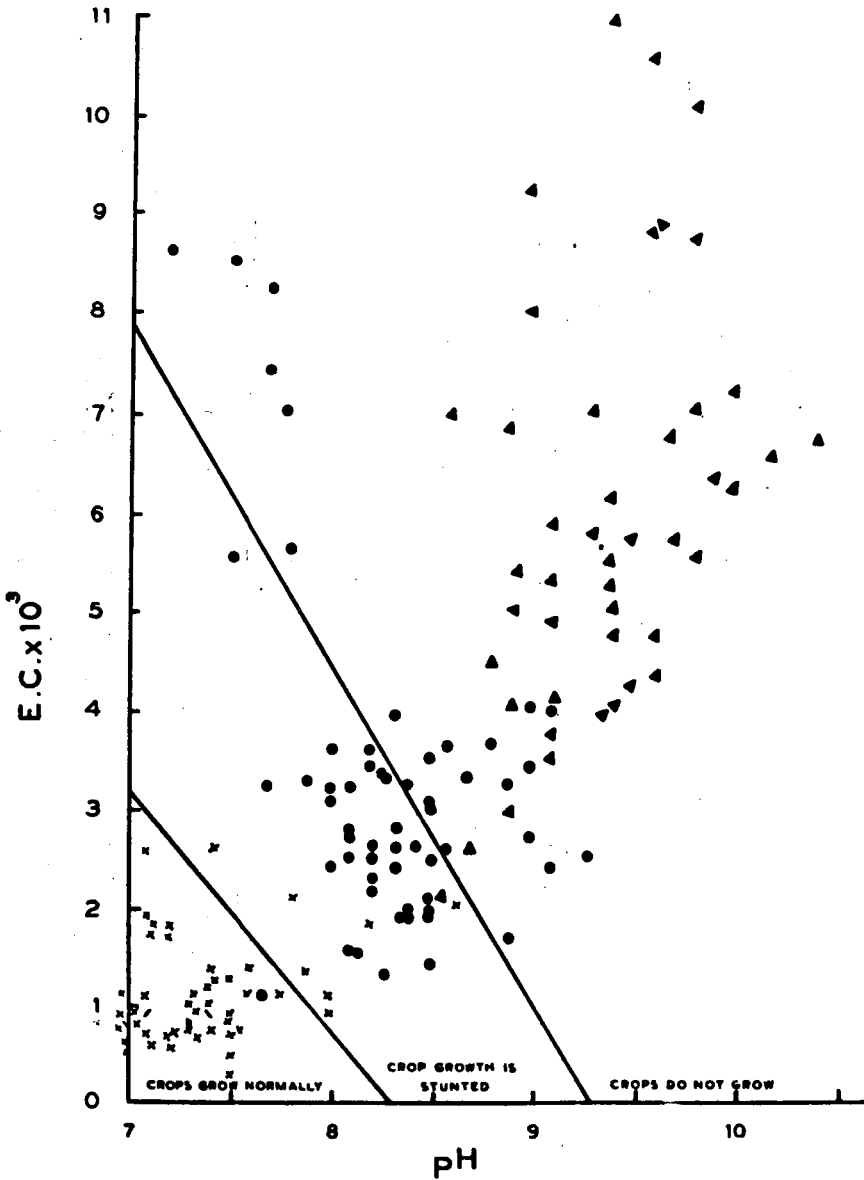
Table 5

Salinity and alkali status of a typical *usar* soil profile of Uttar Pradesh.

Locality	Local name	Horizon	TSS p.c.	Carbonate as Na ₂ CO ₃ %	Bicarbonate as NaHCO ₃ %	Chlorides & sulphates of sodium %	pH	C.E.C. m.e.%	Ex.bases m.e.%		Na-Saturation %
									Ca	Na+K	
Pachpera,	Usar	1st	1.61	0.39	0.40	0.74	9.6	10.2	..	10.2	100
Aligarh District, U.P.	Rch	2nd	0.50	0.11	0.16	0.20	9.5	20.76	1.0	19.6	94.4
		3rd	1.23	0.33	0.29	0.58	9.3	15.32	1.0	13.3	86.9
		4th	0.32	0.09	0.14	0.03	9.4	13.44	1.4	11.84	88.1
		5th	0.23	0.03	0.15	0.01	8.2	10.44	2.6	7.04	67.4

The *usar* soils as in the above table are found to have attained the last stage of alkalisiation the exchange complex of the soil at the surface or at some depth below having been fully saturated with sodium. The pH value and salt content are highest at the top decreasing with depth. From textural and structural point of view, the alkali soils at the first and second horizons are found to be impervious and the profiles of these soils are generally associated with *kankar* or a hard clay pan restricting the upward movement

Fig-1



SALINITY AND ALKALI SCALE TO EVALUATE SALINE ALKALI SOILS

- × CROPS GROW NORMALLY
- CROPS GROWTH IS STUNTED
- ▲ CROPS DO NOT GROW

or downward flow of water. Utilisation of such soils for agricultural purposes is extremely problematic. There are other milder types which are expected to respond quickly to the corrective methods of reclamation. Development of a planned system of drainage is considered pre-requisite of all projects of reclamation of such soils (Raychaudhuri and Datta Biswas⁶¹).

An attempt has been made to determine whether the diagnostic techniques for saline and alkali soils proposed for American soils can be used for similar soils on the Indo-Gangetic alluvium developed under entirely different climatic and environmental conditions (Agarwal and Yadav⁶). Systematic investigations conducted by these authors, demonstrated that the pH value, electrical conductivity of saturation extracts, cation-exchange capacity using sodium acetate and the degree of calcareousness of the samples should form workable criteria for salinity and alkali appraisals of Indo-Gangetic alluvial soils. These determinations can, therefore, be used as a basis for mapping alkali soils in any large-scale soil survey operations in areas where salts or alkali may be a problem. From similar information on a large variety of soils, a salinity and alkali scale to evaluate saline alkali soils for crop rating was evolved in which both salinity and alkali in soils have been taken into account (Agarwal and Yadav⁶). The scale is reproduced in Fig (1). In this method with the help of the simple estimations on soils, viz., pH values and electrical conductivity of the saturation extract it is possible to quickly diagnose the salinity and alkali status of the soils and evaluate them in terms of crop behaviour. This scale may be given wider trial in saline alkali areas in the country with necessary modifications for different soils regions.

Reclamation Measures

The reclamation of *usar* soils of Uttar Pradesh had been successfully carried out near Kanpur and Allahabad by application of heavy doses of molasses (at 10-15 tons per acre). Dhar and Mukherjee²⁰ expressed the view that molasses which contains 2 percent lime and 60-70 percent of carbohydrate when added to the soil, creates acidic condition in the soil due to production of carbonic acid or organic acids like acetic, propionic, butyric, etc. in the early stages of decomposition. The acids so produced neutralise the alkali of the soil and the carbonic acid produced in large quantity from the decomposition and oxidation of carbohydrates convert sodium carbonate into bicarbonate. Escape of excess CO² from the molasses improves soil porosity and tilth. The calcium added to the soil by dint of its presence in the molasses helps converting the sodium soil into a calcium

one, that is, a normal soil. Dhar further stressed the beneficial effect of molasses by saying that the carbohydrate material present in molasses encourages the growth of nitrogen fixing bacteria like *Azotobacter* in the soil which is thus eventually made richer in total nitrogen.

In milder category of *usar* soils where exchange complex is only partly saturated with sodium and where sub-soil induration is due to the presence of a hard clay pan, at a depth not exceeding 36 inches, recourse to mechanical shattering of the clay pan beyond the induration depths without upturning the soil supplemented with leaching and use of organic matter yielded highly encouraging results at the Government Usar Reclamation Farm, Chakeri, Kanpur. The experiment was started over an area of 400 acres. The entire land has been reclaimed and normal salt tolerant crops like paddy and barley are now being grown year after year without any additional treatment. This single method can succeed where similar types of soil are available and there is provision for the supply of organic matter and good quality irrigation water.

The treatment of soil with gypsum at a rate of the gypsum requirement of the soil (3 to 5 tons per acre) followed by flushing with plentiful supply of good quality irrigation water and growing a crop of *dhaincha* (*Sesbania aculeata*) as green manure and transplanted paddy also gave marked responses under average cultivators' conditions in U.P. (Agarwal¹). From these treatments the average grain yields increased three folds by the combined action of gypsum and *dhaincha*.

Experiments for the reclamation of *usar* land in Uttar Pradesh by leaching with water are being carried out at the State Usar Reclamation Farm, Dhakauni (Hardoi) Rehimabad and Katiar (Lucknow) for several years past. So far 2700 acres of saline and alkali lands have been reclaimed at these state farms. As a result of studies it has been established that the reclamation of saline-alkali (*Usar*) soils is largely a physical problem. It has been found that where the water table is not high enough to be within the effective range of active capillary action or where the sub-soil is not totally impermeable on account of the presence of *kankar* pan or indurated clay pan or where the clay fraction in the soil or sub-soil is not deflocculated to such an extent as to prevent infiltration completely, *usar* soils can be reclaimed for agriculture or afforestation purposes by leaching with water alone or preferably by leaching preceded by application of paddy straw or other undecomposed bulky organic matter.

Presence of *kankar* nodules, provided these do not make the soil totally impermeable, is not likely to come in the way of its reclama-

tion. The addition of chemical amendments as gypsum or bulky organic substances as molasses, farm yard manure, compost, green manure, paddy straw or paddy husk correct the physical condition of the soil and help in increasing its infiltration capacity. However, these operations alone by themselves can by no means get rid of the excess salts which can only be done through leaching with water.

*Reclamation of Saline and Alkali Lands at the Banthra Farm,
Lucknow*

The principle of reclamation followed by Prof. K. N. Kaul at the Banthra Farm consists in (i) digging of ditches around the fields with formation of embankments to hold the rain water, (ii) addition of organic matter in the form of powdered *Argemone mexicana* (or powdered leaf mould) and (iii) provision of irrigation water by cavity tube wells. In this area, there is clay layer in the subsoil up to the water table which is at about 80 ft. below the surface. This sub-soil condition has been taken advantage of in constructing cavity tubewells at a cost of about Rs. 5,000/- per tubewell with a discharge of 13,000 to 14,000 gallons per hour. Each tubewell controls about 25 acres of land. *Argemone mexicana* powder is added at the rate of 24 maunds per acre. In an experiment on adjacent similar land of 215 acres in the Karauni Farm under the ICAR Scheme, with the weed *Argemone mexicana* added as a treatment, yield of paddy at the rate of 20 maunds, was obtained as against 2.1 maunds of paddy under control. The results at the Banthra Farm on the comparative study of the relative efficacy of cow-dung, *Argemone mexicana* and gypsum in bringing down the pH of the alkali soils indicate that the *Argemone mexicana* brings down the pH from 10.0 to 7.8 within a period of 10 days after its application, but later on, the pH increases to 8.5 within a period of about a month, whereas in the case of gypsum, the pH decreases gradually and remains steady at 8.1 within a period of about a month. The efficacy of cow-dung in decreasing the pH is, however, less.

The analysis of *Argemone mexicana* indicates that the weed contains 2% N, 15% P₂O₅ and 0.35% K₂O and about 4.2 per cent water soluble organic acid. Prof. Kaul has suggested that the decrease in the alkalinity could be due to the constituents of plant providing good culture medium to the growth and activity of soil microbes. It may be mentioned in this connection that leguminous green manure plants like *Sesbania aculeata* will be just as suitable for lowering the pH and for the reclamation of alkali lands as *Argemone mexicana*. In fact, *Sesbania aculeata* is likely to prove better for this purpose as it yields larger quantity of organic matter than *Argemone mexicana*.

Method of Reclamation followed by Shri Bishan Man Singh at Bilanda and Habeeb Farms, Fatehpur

The method followed by Shri Bishan Man Singh at Fatehpur, U.P. in reclaiming *usar* land at Fatehpur was to construct low bunds on the land to hold rain water to leach out injurious salts from the soil. Large quantities of undecomposed organic matter were also applied to the land. In the partially reclaimed lands salt-resistant trees like *ber*, *neem*, *shisham*, etc. were planted on the trench and ridge system. The land was reclaimed in about 10-12 years. Two farms *viz.* Bilanda Farm (320 acres) and Habeeb Farm (125 acres) have been developed on the most unpromising soil, and the land now grows fruit trees, paddy and other crops. Other cultivators in the same area followed Bishan Man Singh's method, and have reclaimed areas of *usar* lands into paddy fields.

The classification of reclaimable saline and saline-alkali soils which occur in the Uttar Pradesh is given below:—

Class I— Easily reclaimable	Where the water table even during the rainy season is beyond 10' from the surface and the permeability is at least 0.05 inch per hour. Soils having considerably less than 40% clay.
Class II —Reclaimable with slight difficulty	Where the water table is beyond 10' during the summer but within six feet during rains, and the permeability is at least 0.05 inch per hour. Soil having considerably less than 40% clay.
Class III—Reclaimable with moderate difficulty	Where the permanent water table is well above 10' or the soil profile is very little permeable due to some restriction by way of <i>Kankar</i> or indurated clay pan in the sub-soil (within 6 ft.) or both soil having less than 40% clay.

The reclamation methods recommended for the above classes of soils are as follows:—

- Class I.*—(i) Making the land into convenient sized plots and bunding.
- (ii) Levelling in order to obtain a uniform spread of water.
- (iii) Application before rain of easily decomposable organic matter, *e.g.* paddy straw, paddy husk, press mud, molasses, dried leaves and *Argemone maxicana*.
- (iv) Leaching with rain water during rains.
- (v) Transplanting and growing of paddy for a few years until a good crop is obtained.
- (vi) Green manuring followed by a rabi crop.

Class II.—All the practices described in Class I above with the additional provision that leaching will be done by irrigation water during the summer months from April to June.

Class III.—These soils can be permanently reclaimed by establishing an adequate system of internal drainage, either through open drains or tile-drains. In addition, all practices described under Classes I and II above will be followed.

The following measures have been suggested for prevention of extension of the above three classes of areas:—

- (i) Intensive pre-irrigation soil surveys should be carried out. The main feature of these pre-irrigation surveys should be the mapping out of the sub-soil characters in regard to permeability and salt content and should indicate areas where water table is expected to rise so that this factor may be taken into account while designing the irrigation system, such as lining sections of the channels where the soil is excessively porous and the sub-soil is impermeable or semi-permeable.
- (ii) In areas under canal irrigation where there is a tendency for the water table to rise, it is suggested that such areas may be excluded from canal irrigation and tubewells may be installed to lower ground water level.
- (iii) Deep drainage cuts may be provided at regular intervals in canal irrigated areas where there is a tendency for water table to rise.
- (iv) Extensive drainage projects in the Second Five Year Plan and in the Third Five Year Plan are almost entirely restricted to main drainage channels. This often results in the main drains running much below their capacity though the country side is extensively water-logged. Equal attention should be paid to the provision of laterals, so as to bring water from the field to the main drains.
- (v) Construction of wider culverts on road and railway embankments in order to help in the quick disposal of excess rainfall.

It may be mentioned that complete closure to grazing and construction of contour bunds so as to ensure retention of rain water will by themselves go a long way in ameliorating, in course of time, the condition of all the types of soils described above. The land

which is to be reclaimed should be made up into convenient sized plots and substantial field embankments should be raised around each plot. The plots should then be got levelled in order to get as uniform a spread of water as possible. Thereafter they should be thoroughly ploughed during early summer (end of March or beginning of April). It should be determined in advance whether the soil has adequate infiltration capacity. Ordinarily the presence of *reh* is an indication that the infiltration capacity would be reasonably good. After being satisfied on this point the plots are filled with water. The process would be very much quickened and very good yields obtained in the 1st or 2nd year if it is possible to apply paddy, straw or other undecomposed bulky organic matter uniformly in the field at 200-300 mds. per acre depending on availability. When the water begins to dry up, more water is added. This process continues until July when paddy (preferably a late variety) may be transplanted in the plots. This process may have to be repeated for 3 years in succession depending on conditions. By this time alkalinity and excess salt content would have been reduced to allow a reasonably good crop of paddy. In the 4th year (or earlier if possible) *dhaincha* is sown in April and ploughed down in the soil in June, and is followed by transplanting of paddy. It is expected that in the 4th year a good crop of paddy would be obtained. Paddy is immediately followed by gram or peas. If it happens to be clay soil then the rotation paddy-gram or paddy-peas will be permanently followed. In lighter soils *dhaincha* is sown in the normal Kharif season and is ploughed down at the proper time *i.e.* in the second fortnight of August. It is hoped that by this time the land would be completely reclaimed. *Dhaincha*, green manure, is followed by wheat in order to test the condition of soil. If wheat succeeds then the land may be taken as fully reclaimed and normal farm operations may be followed thereafter. In case a reasonably good crop of wheat is not obtained then such salt resisting crop as barley, oats, paddy or mustard etc. may be taken for a few years more. However, great stress should continue to be placed on green manuring and addition of other bulky organic manures in order to help in fully reviving the microbiological life of the soil.

If the soil is pure alkali with no *reh* on it, and if infiltration is very restricted and the soil gets puddled by addition of water then gypsum will have to be applied. The quantity of gypsum to be applied will depend on the chemical status of the soil. After addition of gypsum the sequence of the rest of the operations will be followed just as described above.

A scheme of reclamation of saline and alkali soils has been started in U.P. wherein some N.E.S. Blocks of selected districts have been earmarked for this purpose, and the cultivators are being induced

there to take up *usar* reclamation work. Cost of irrigation for leaching and for raising paddy crop for first three years is being entirely subsidized in this scheme. Under certain conditions, payment of rent on this land is also exempted for first three years. During the year ending December 31, 1960, and the year ending December 31, 1961, total bunding was done on 469·16 acres and 538·27 acres respectively and paddy was transplanted on 341·91 acres and 548·22 acres respectively, the average yield of paddy during both the years being 5.26 mds. per acre.

There is hardly any information available on the cost of reclamation of *usar* land of different types in Uttar Pradesh. However, for the lands which have a low water-table and are not impervious to water and in areas where the underground water resources are adequate and where less intractable types of *usar* are found in large-sized, compact blocks, the cost of reclamation of *usar* land has been worked out by the Wastelands Survey and Reclamation Committee as under:—

Table 6

	Cost per acre
	Rs.
(a) Harrowing twice	20
(b) Levelling	50
(c) Bunding	30
(d) Irrigation	150*
(e) Compost manure	75
TOTAL	325

*Includes Rs. 30 towards cost of construction of channels.

Work on Saline and Alkali Soils in the Punjab

About 3 million acres of the Punjab is affected by salinity or alkalinity or both. These soils are locally known as 'kallar', 'Kal-rathi', 'reh', 'usar', 'thur', etc. According to Punjab Irrigation Department standard the land was recorded as *thur* when the damage to land was more than 20 per cent. The classification is done as (i) uncultivated *thur* (*thur kohna*), (ii) ex-cultivated *thur* (*thur nau*), (iii) cultivated *thur* (*thur juzvi*) pH values about 9·0, total salts above 0.2 per cent and clay above 17·9 per cent were considered to be the factors contributing towards deterioration of land. Based on the

results of analysis the area was divided into four categories as follows: (H.L. Uppal, 1962):

- (i) area having high salt content and of high pH value near the surface;
- (ii) Area having high salt content with or without high pH value at some depth in the profile.
- (iii) Area exceedingly sandy with normal salt content and pH value;
- (iv) Land good in all respects.

According to H.L. Uppal⁸⁷ total area affected by salts and alkali (*thur and kallar*) including all stages of deterioration in the Punjab as revealed by Thur Girdwaries and scientific soil survey is estimated to be of the order of 3 million acres as shown below:—

Table 7

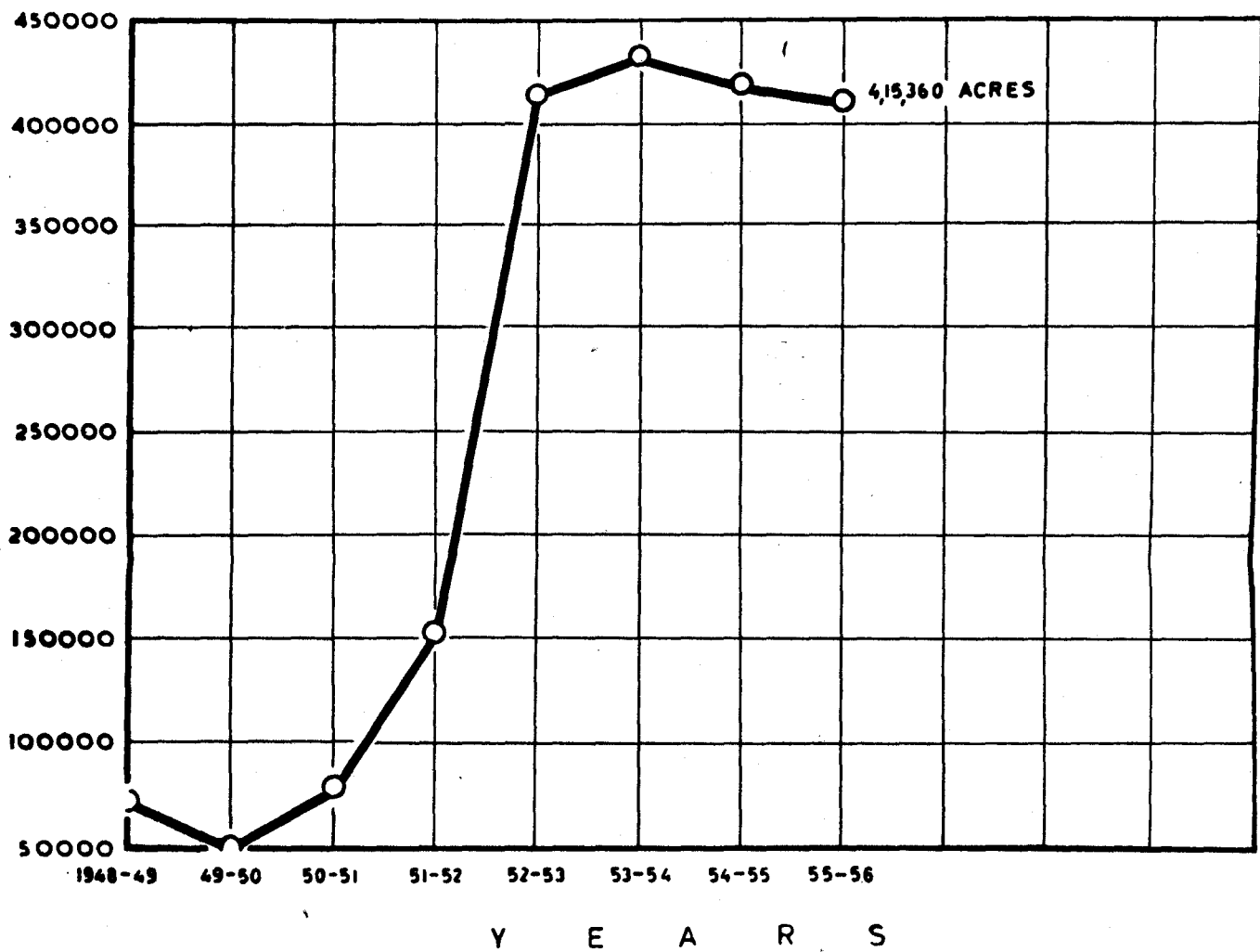
	(acres)
(i) Thur recorded by Irrigation Branch within the irrigation boundary as a result of visual Test Thur Girdwar (1958-59)	4,83,427
(ii) Thur recorded by the Civil Department outside Irrigation boundaries, Thur Girdawari (1957)	1,38,219
(iii) Area found in various stages of deterioration as a result of 33 lakh acres surveyed by Bhakra Scientific Soil Survey	9,93,000
(iv) Do. 10,24,466 acres surveyed in erstwhile Pepsu Bhakra area	3,23,414
(v) Do. 26,94,000 acres surveyed on the old Sirhind canal in erstwhile Pepsu	8,37,025
(vi) Do. 1,71,200 acres waste area surveyed of Karnal district	1,35,000
TOTAL	29,10,085
	30,00,000 approximately.

Out of the total area of 3 million acres of deteriorated land, 12.5 lakh acres are estimated to be lying in the deep water table areas of Bhakra Canals. The remaining 17.5 lakhs acres are in the waterlogged area, mostly in Category 'A' (sub-soil water depth within 5 ft. from the natural surface) and a part in Category 'B', (sub-soil water depth within 5-10 ft. from natural surface).

In addition the extent of waterlogged area free from thur is about 19 lakhs acres. Further according to the survey carried out by the Director, Irrigation and Power Research Institute, Amritsar, about 15,000 to 20,000 acres of fertile land are going out of cultivation each year on account of salinity, alkalinity and water-logging (Fig. 2).

Fig-2

INCREASE OF THUR IN THE PUNJAB (INDIA)
IN ACCORDANCE WITH IRRIGATION BRANCH
GIRDAWRIES WITH - IN THE IRRIGATION BOUNDARY



DATTA

The saline alkali soils in the Punjab mostly contain chlorides and sulphates of sodium. Carbonates and bicarbonates of sodium are also met with, especially in Karnal district. Salt accumulation occurs in areas receiving rainfall of 30" or less. In places receiving rainfall of 20" or less the concentration of salts is due to poor and restricted drainage. The restricted drainage of soils is due to the presence of a high ground water table or to low permeability of soil or both. Low permeability is due to unfavourable soil texture or structure and sometimes due to the presence of hard pan, which may be clay pan or deposition of calcium carbonate (*Kankar layer*).

Soils containing excess of salts occur extensively under natural conditions in the Punjab but normal soils become frequently salted as a result of irrigation.

If the agriculture is of such a type that the amount of water used for irrigation is just sufficient to counter balance that lost by transpiration of the leaves and evaporation from the surface zone, the accumulation will tend to remain stationary or to move down to a lower layer. In these conditions, the salt zone never come up the surface to make the land saline. If, on the other hand, the quantity of irrigation water is insufficient to balance the losses due to transpiration and evaporation and if the zone is within ten feet from the surface, then the salt zone tends to move upwards.

Due to the increasing pressure of population on land, the cultivator wants to irrigate a wider area with the same quantity of water available to him. With the increase in the intensity of irrigation there is a corresponding decrease in the volume of water used. An examination of the acreage irrigated by the Lower Chenab Canal in undivided Punjab reveals that the intensity of irrigation during the kharif season had increased from 26 per cent in 1907 to 44 per cent in 1936, which means an increase of 79 per cent in irrigation (within a period of about 20 years) with the same water supply. There was, therefore, a consequent decrease in the depth of water used for irrigation of the kharif crops from 4.6 feet in 1907 to 2.5 feet in 1936. These figures show that a much smaller quantity of water was used for maturing the crops than what was used in the early years. Under this system of agriculture, the tendency for the zone of salt accumulation is to move upwards. When this zone finally appears at the surface, the salts come up and crystalize there as an efflorescence, and the land becomes saline. The depth of the zone of accumulation or the salt bearing layer in the soil varies from point to point in the field. This zone is continuous, but not necessarily so in horizontal plane on the

surface. The upward movement of this layer from varying depth accounts for the efflorescence of salts in patches. As the salt zone from the lower depth reaches the surface, the size of the salt patch increases and may spread over the soil surface.

Irrigation water may also contain considerable amount of salts and such waters, if frequently used, result in accumulation of salts. Irrigation water may contain salts from 0.1 ton to as much as 5 tons of salts per acre foot of water and the annual application may amount to 5 feet or so. From the use of brackish waters large areas in Ferozepur, Gurgaon, Rohtak and Hissar districts have been rendered unsuitable for agriculture by the use of excessive irrigation or when the natural drainage is impeded in the areas irrigated by the canals. The water table rises to within 5 to 6 ft. of the soil surface resulting in accumulation of salts on the surface. This process has resulted in the accumulation of salts in Amritsar district, Batala and Dehra Baba Nanak tehsils of Gurdaspur district and Karnal and parts of Hissar districts. When these salts react with the exchange complex of the soil, it results in the replacement of divalent bases like calcium and magnesium by sodium. Such soils have high pH values, are impervious, sticky and hard or in other words these have got defective structure as well as high alkalinity. The failure of crops on such soils is, therefore, attributed to the following three causes:

- (i) Defective and unfavourable structure.
- (ii) High alkalinity which may be toxic to plants and
- (iii) high alkalinity may indirectly render the important nutrients like N and P unavailable.

The results of analysis of typical saline and sodic soils of the Punjab (Kanwar and Bhamkela²⁴) indicate that these soils have high pH, quite high salt concentration and high percentage of exchangeable sodium. The results of analysis are given in Table 8 below:—

Table 8

Localities	Depth in inches	Saturation percentage	pH	Electrical conductivity saturation extract m/m	Exchangeable sodium percentage
Kamma	0—8	31	9.4	7.39	77
	8—24	30	10.0	11.70	87
	24—43	37	9.4	4.09	82
	43—72	31	8.9	1.53	..

Localities	Depth in inches	Saturation percentage	pH	Electrical conductivity saturation extract mm	Exchangeable sodium percentage
Nilokheri	0—6	45	9·8	13·3	86
	6—18	52	9·9	7·3	93
	18—33	33	9·3	3·1	78
	33—42	41	9·2	0·9	78

The anions are predominantly carbonates and bicarbonates.

Four thousands acres of saline alkali land in block of 250 acres or more with low water table have been located in the districts of Jullundur and Ludhiana while 1,59,000 acres of such land have been located in the districts of Hissar, Rohtak, Amritsar, Jullundur, Kapurthala, Ludhiana, Ferozepur, Gurdaspur and Gurgaon as shown in table 9 below (Report on the location and utilization of wastelands in India, Part I, Punjab, page 30 Sept. 1960).

Table 9.

District	Extent of areas in large blocks of alkaline/saline land	
	with low water table	with high water table
	(Acres)	(Acres)
Hissar	..	15,000
Rohtak	..	10,000
Amritsar	..	50,000
Jullundur	1,000	4,000
Kapurthala:	..	35,000
Ludhiana	3,000	35,000
Ferozepur	..	30,000
Gurdaspur	..	5,000
Gurgaon	..	5,000
TOTAL	4,000	1,59,000

N.B. The above figures are approximate.

H.L. Uppal⁸⁷ has pointed out that "assuming that the damage in waterlogged *cum* saline area is of the order of 75 per cent., that in waterlogged areas free from thur 50 per cent and that due to salinity in deep water table areas 25 per cent, total area which suffers from a complete loss of production of crop works out to be as under:—

Table 10 (in lakh acres)

	(in lakhs acres)
(i) Saline <i>cum</i> waterlogged areas	13.0
(ii) Waterlogged (free from thur)	9.5
(iii) Salinity in deep water table area	3.0
TOTAL	25.5
say	25

Annual loss to the nation in terms of money comes to 34 crores."

Reclamation of Saline Soils

As early as 1916, the methods used for reclamation of saline soils were:—

- (i) Washing down of salts.
- (ii) Flushing out of salts.
- (iii) Scraping of salts.
- (iv) Growing of salt tolerant crops.

(i) and (ii). Heavy irrigation also can remove water soluble salts from the soil surface. Continued flooding for sometime can reclaim the saline soil. This method is possible if there is natural drainage, large supply of good quality irrigation water and a low water table. In the field to be reclaimed, 4—6 inches deep water is allowed to stand on the surface for a day or so with occasional mechanical stirring after the period it is drained out of the field, thereby removing the maximum quantity of dissolved salt. Saline soils can also be reclaimed by leaching down the salts to or below a depth of 10 feet. Washed down to this depth, the salts cannot easily come up if the water table is low, or if there are sand strata in the sub-soil.

(iii). Salts accumulated on the saline soils surface could be removed by mechanical scraping with the help of a karah. If the sahnity patches are small in the field, this method is the easiest to adopt, but it is non-economical in large areas. After scraping, F.Y.M. @ 15 tons per acre should be applied and ploughed in before sowing any crop.

(iv). Proper soil management practices can reclaim saline soils, crops can be grown on the sides of the ridges, salts generally come upto the top and accumulate on the tops of ridges without affecting the growing crops. Salts from the top of the ridge can be removed

by scraping. Certain crops are more salt-tolerant than others. Hence salt tolerant crops can be grown in such soils and the salinity reduced. Sugar beet and salt bushes were tried in the salt infected areas. Sugar beet did well on such soils and reduced the percentage of salts in the soil. However, this practice could not find favour because any economic use of sugar beet crops could not be made. Growing of salt-bushes (*Portulaca eleraces*) was the common practice which was followed by cultivators. Salt bush was used for the preparation of sajji, a product rich in washing soda.

Growing of salt bushes and trees such as Kikar (*Acacia arabica*), Jand (*Prosopis spicigera*), Karir (*Capparis aphylla*), etc. can go a long way in assuaging the 'Kallar' affliction as the salts are due to their absorption by the above mentioned plants.

Reclamation of Alkali Soils

A large tract of land commanded by Lower Bari Doab canal containing considerable amount of carbonate salts was treated in the usual reclamation process for washing down salts with little success due to the impervious nature of the soils. Further studies revealed (1926-27) that these soils contained high amount of exchangeable sodium. Therefore attempts were made to replace exchangeable sodium by the application of gypsum and calcium chloride. Later on it was found that calcium carbonate present in the soil could be made use of for replacement of sodium by calcium. When salts from such soils were removed by flooding and washing and the soil was irrigated with canal water, its structure improved and the yield of crops increased. This process could be accelerated by growing of rice and berseem, the latter crop being used as green manure. Therefore, the methods evolved in the Punjab for such soils are (i) application of amendments like calcium chloride, gypsum and press mud and (ii) agronomic practice, e.g., rice-berseem rotation.

Nijhawan ⁵¹ working with such soils showed that gypsum could be successfully used for the reclamation of alkali soils. The actual procedure consisted in flooding the land to remove salts, if present. When the soil came in wet condition, gypsum in a well powdered form was applied and land ploughed up and watered copiously afterwards. This process was continued for 4-6 months. The amount of gypsum to be applied depended upon the degree of alkalinity and nature of soil but 2 tons of gypsum per acre were found to be quite sufficient to reclaim alkali soil containing 80-90 per cent of exchangeable sodium. Prior to the sowing of crop, application of F.Y.M. @ 15 tons per acre was found advantageous. Further work on the problem

carried out showed that it was not necessary to completely replace sodium by calcium but when exchangeable calcium was only 55—70 per cent of the total exchangeable bases the soil began to support a normal crop and at this concentration of exchangeable calcium there was a sudden increase in the rate of percolation of water indicating thereby the improvement of the structure of the soil.

Nijhawan⁵¹ further showed that press-mud can be successfully utilised for the reclamation of alkali soils where rice-berseem rotation is being used as the method of reclamation. Press mud besides containing about 70 per cent calcium carbonate also contains 0.4 to 0.5 per cent Nitrogen, 1.25 per cent. P_2O_5 and 8.9 per cent organic matter. The results of experiments conducted are given below:—

Table 11

Treatment]	Grain yields in maunds per acre-Paddy	
	Kachwa	Tarn Taran
1. Control	4.0	6.9
2. Gypsum @ 2 ton per acre	5.5	13.3
3. Preses mud @ 2 tons per acre	6.0	10.6

Rice-berseem rotation was used with advantage for the reclamation of saline or saline-cum-alkali soils.

Yield results of rice grown for reclamation of *bara* or *rakkar* soils:

Table 12

Year	Crop	Yield in mds. per acre:	
		Grain	Straw
1933-34	Paddy	2.35	8.2
1934-35	Paddy	7.83	18.72
1935-36	Paddy	19.75	43.12

The yield of paddy increased about eight fold in the 3rd year after which period the land became suitable for growing of other crops.

Further work carried out at Kala Shah Kaku showed that green manuring with "Dhaincha" considerably increased the yield of paddy

crop used for reclamation. The reclamation could be accelerated if gypsum was applied to the soil before putting in "Dhaincha".

The reclamation experiments at Kamma and Nilokheri indicate (Kanwar,⁸⁶) that it was possible to reclaim the saline and alkali soil of the area and bring it to normal production in paddy-barley rotation by using ordinary amounts of water and normal doses of fertiliser. The results at these centres also indicate that sugar-beet (Q.S. 75 variety) is more successful than berseem in saline-alkali soils of the Punjab. Experiments with pressmud, gypsum and fertilisers at Kamma indicate that in the case of saline-alkali soils, in the areas of low water table, the best results can be obtained by using fertiliser along with pressmud and gypsum. The use of fertiliser alone also can accomplish reclamation economically. The average amount of gypsum required for saline-alkali soils of the Punjab comes to 2.70 tons to 4.50 tons gypsum per acre. A comparison of different crop rotations in the reclamation of saline-alkali soils at Kamma also show that the best results are obtained from the recommended method which included *dhaincha* grown with superphosphate and green manured at the rate of 10 tons green matter per acre. The efficiency of *dhaincha* or *jantar* for the reclamation of saline-alkali soils may be related to the following causes:—

- (i) Its tolerance for salts and water-logging.
- (ii) Its extensive root system which opens up the compact subsoil, thus facilitating aeration of roots and leaching of salts. Application of superphosphate to *dhaincha* stimulates its growth.
- (iii) *Dhaincha* rets very rapidly when green manured and thus there is no difficulty in preparing the seed bed for the subsequent crop which is frequently paddy.
- (iv) It has more acidic sap than most of the common green manuring plants and hence it is more effective in neutralising alkalinity than others.

Successful reclamation work has been carried out on 200 acres of highly alkaline and unproductive barren lands, in the village Nissang in the District Karnal in the Punjab, in the course of about five years. The operational procedures followed in the reclamation of the land were (H.L. Uppal⁸⁴):

- (i) Initial breaking up and laying out into quarter-acre plots.
- (ii) Levelling according to contours.
- (iii) Leaching consisting of flooding, ploughing and reflooding.

- (iv) Green manuring, *jantar* in *kharif* and *senji* in *rabi*.
- (v) Raising rice in *kharif* and berseem, gram and wheat in *rabi*.
- (vi) In the post-reclamation phase, cotton, sugar-cane, oilseed and fodder have been successfully grown.

The cost of reclamation to bring it to normal is about Rs. 333 per acre.

The work on the reclamation of saline and alkali soils in the Punjab under a scheme financed by I.C.A.R. on soil samples from Gurdaspur, Amritsar, Patiala, Sangrur and Rohtak (1958-59, 1959-60 and 1960-61 Annual Progress Reports) leads to the conclusion that the application of gypsum and use of *dhaincha* as green manure give significant effect in increasing the yield of grain and straw of both paddy and barley. Sugarbeet and barley seem to be the promising crop in saline and sodic soils. The data also indicate that the two course rotation *dhaincha* (green manure)—paddy—berseem leads to the improvement of organic matter content of the soil.

The Waste Lands Survey and Reclamation Committee, Ministry of Food & Agriculture, in their Report on the Location and Utilisation of Wastelands with reference to Punjab has recommended the following methods of reclamation of saline alkali soils for general adoption by the cultivators:

- (i) Where the water-table is within 5 feet steps should be taken to drain out the excess water.
- (ii) As a first step in the reclamation of affected lands, strong bunds about 2 ft. in height should be constructed all round the fields.
- (iii) If pH of the soil is about 10, four tons of gypsum or presmud should be ploughed well into the affected land. (This quantity can be varied according to the nature of the soil).
- (iv) The field should then be heavily irrigated so as to allow gypsum to react with the soil and leach down the salts.
- (v) When the field is in water (i.e. in optimum condition of soil moisture), *dhaincha* (*Sesbania aculeata*) seed should be sown broadcast in the second week of March at the rate of 20 to 30 lbs. per acre. The seed should be soaked in water for 4—6 hours. before sowing so as to promote quick germination. About 2 to 3 maunds of sulphate of ammonia and an equal quantity of super-phosphate

should be applied before sowing. Frequent light irrigation should be given so as to avoid injury to small seedlings.

- (vi) When *dhaincha* plants are 8—10 weeks old, they should be ploughed into the field as green manure.
- (vii) About 1-2 weeks after green manuring, paddy should be transplanted in the field. Sulphate of ammonia should be applied at the rate of 3 maunds per acre at the time of transplanting.
- (viii) After paddy is harvested, a crop of *senji*, barley or berseem (as forage crop) should be grown in the field.
- (ix) Where paddy cannot be grown, *dhaincha* should be sown in the rains and ploughed in as green manure in early September. Thereafter, barley should be sown.
- (x) The above process should be repeated the next year but without the addition of gypsum or pressmud to the field.
- (xi) The soil should be analysed at the commencement of the reclamation and again after two years in order to find out the effect of the above treatment.

The application of farm yard manure to these degraded lands helps to restore their productivity. Equally good results have been obtained with fertilisers, the application of which is also economical. Crop like sugar-beet can be grown with advantage on these lands. A suitable cropping pattern for these lands is *dhaincha* (as a green manure crop) followed by rice, barley, or wheat (or sugarbeet or berseem). The old method of flooding the land in order to leach out salts followed by the cultivation of paddy has not been found effective. After reclamation, it is not advisable to grow paddy continuously as these lands have a tendency to become water-logged."

Regarding the cost of reclamation of saline alkali land in the State the estimate of the Wastelands Survey and Reclamation Committee is that the cost will be Rs. 250 per acre when water table is low; when the water table is high the reclamation cost will be as high Rs. 500 per acre because of heavy expenditure on drainage.

The Wastelands Survey and Reclamation Committee has recommended the following:

- (i) the setting up of pilot projects in the district where the salinity and alkalinity are acute so as to demonstrate to cultivators practical methods of reclaiming affected lands.

- (ii) provision for *dhaincha* seeds for green manuring and fertilisers and manures to the cultivators at subsidised rates,
- (iii) the need for research on cheap materials for drainage, depth and spacing of tile drainage and their economy, as it is felt that in areas with high water tables unless the cheap methods of improving drainage are introduced, reclamation measures may not be practised by cultivators as a regular practice.
- (iv) the necessity of the study of soils from the point of view of their structure, permeability, the nature and contents of salts in the soil profiles in connection with the reclamation of saline and alkali lands.

Work on Saline and Alkali Soils in West Bengal

Saline and alkali lands in West Bengal occur in the coastal areas in the districts of Midnapur and Twenty-Four Parganas including the Sunderbans area and in the Northern and Southern salt lakes near Calcutta. The total extent of such areas has been estimated to be 2.1 million acres (Note 16).

These soils have been formed from deposits brought by tidal currents. The original deltaic branches of the Ganges choked up because the head water had been cut off, as a result of which numerous tidal flats were formed. These were subsequently bunded to prevent ingress of the sea water. Sluice are constructed to allow the escape of rain water to dissolve away the salt from the soil. The soils have been divided into four classes viz., (i) saline soils, (ii) non-saline alkali soils, (iii) saline alkali soils and (iv) degraded alkali soils. All the soils are heavy clay (sodium clays) and alluvium and rich in organic matter and plant nutrients, the percentage of soluble salts varying between 0.09 to 1.8. When dry the saline look whitish due to the presence of salts and is not suitable for cultivation. These soils under proper management give good yield of paddy. From the report of the Wastelands Survey and Reclamation Committee on the Location and Utilisation of Wastelands in India, West Bengal, it is seen that in the category of saline lands, only two blocks comprising an area of 1,798 acres have been located in the Contai and Ramnagar Police Stations of the Midnapore district where however salinity is not very high but the lands are slightly eroded. Cost of suitable amelioration measures for the removal of salinity has been estimated at about Rs. 160 per acre.

*Coastal Saline Areas in the District—Midnapore and 24 Parganas
(including Sunderbans)*

The coastal saline area in the districts of Midnapore and 24 Parganas ⁴⁸ (including Sunderbans) occupy about 1.9 million acres. Attempts to reclaim these lands by the Government of West Bengal and private enterprises, have been made with satisfactory results. The problem is one of reclamation by suitable bunding or irrigation by washing the salts and growing salt resistant varieties of crops like paddy.

Reclamation of Northern Salt-Lakes

Calcutta has, on its eastern fringe, a large tract of low lying and swampy saline land known as "Salt Lakes" which has been divided into two parts by the Calcutta Corporation Storm Water Channel. The polygonal area of 11500 acres of low-lying swampy land on the north of the Storm Water Channel is known as the "Northern Salt Lakes" whereas an area of 9600 acres of low lying swampy land south of Storm Water Channel is known as the "Southern Salt Lakes". In these areas there are reed fields, fisheries and locally some paddy fields, fish culture being more prevalent in the Northern Salt Lakes than in the Southern Salt Lakes. The Northern Salt Lake area is proposed to be reclaimed in two parts: In the northern-most end an area of 2400 acres contiguous to the city of Calcutta is to be raised and used for city extension purpose. The filling material will be obtained by dredging the bed of the river Hooghly in the reach between Howrah and Vivekanianda Bridges. The remaining 9100 acres of area will be reclaimed and made fit for agriculture and horticulture by treating the area as a polder with a surrounding embankment. Pumping will be restored to for draining the area and by lowering the ground water table. The soils of the lake bottom are very fine, especially in the deeper layers consisting of fine ground quartz particles. Chemically, the soil is not rich; physically it will have a rather low permeability. These soils are covered with more or less brackish water which has influenced its properties. From composition and humus content of the topsoil, it may be concluded that the Salt Lake has been formed rather recently and that the soils originally did not differ much from those in the adjoining regions where the soils are suitable for wet rice fields. The salts have penetrated to depths of 7—10 feet, the percentages (on weight of dry soil) generally reaching 0.5—1 per cent, but less in the topsoil. pH varies between 7.5 and 8.2 (determined in water) and between 6.5 and 7.7 (when in KC1). In the few sub-soil samples at 7—10 feet, it amounts to 8, but in the samples at 2 feet, it varies between 6.7 and 8.1. The higher figures at

7—10 feet correspond with the higher salt percentages. The Na percentage varies between 40 and 50 which has to be lowered by leaching. As clay-minerals do not seem to be abundant, the destructive influence of Na ions on soil texture may not be important. The water samples taken in June in sewage, fisheries, drains and ground water are too high in salts. When reclaimed it will, under natural conditions, be suitable for wet rice only. If desalinization in the first years is too slow, wet rice could be grown, depending on the soil survey, but in many parts vegetable-growing may be started. In that case the separate lots will have to be drained by trenches and ditches, dividing them into small fields and afterwards being used for water-supply. In this manner thorough draining in the wet seasons and easy watering in the dry seasons would go together. Studies are being conducted in an experimental polder constructed within the area for determining the agri-horticulture possibilities. (Ref. Map 12).

Development of Southern Salt Lakes

The Southern Salt Lakes area is proposed to be developed by setting up fisheries on improved scientific lines to be worked through cooperatives of local fishermen to be capable of producing the quantity of fish not less than that which is now being produced in both the Salt Lakes area.

Work on Saline and Alkali Soils in Delhi State

Delhi State occupies an area of about 3.7 lakh acre of which 62% is under cultivation. Of the cultivated area nearly 20% (about 46000 acres) is lying waste due to salinity or water-logged conditions. Except the rocky or hilly area (*Kohi*), the State suffers from acute salinity problems in the other areas viz. *Khadar* (recent alluvium on the banks of river Jamuna), *Bangar* (old alluvium) and *Dabar* (Low-lying area). Introduction of irrigation from canals has hastened the development of salinity in some areas. For instance, the introduction of irrigation at IARI has brought about high water table conditions and salt problem within a period of 20 years. Excepting one main Najafgarh drain there is no adequate natural surface drainage system. In some places when the floods are high, the drain starts flowing in the reverse direction. There are also some small drains which end abruptly and do not join any of the main drains with the consequence that flood waters accumulate in the low lying areas. From the soil studies and soil surveys carried out, the saline and alkali soils in the Delhi State may be grouped into the following four categories:—

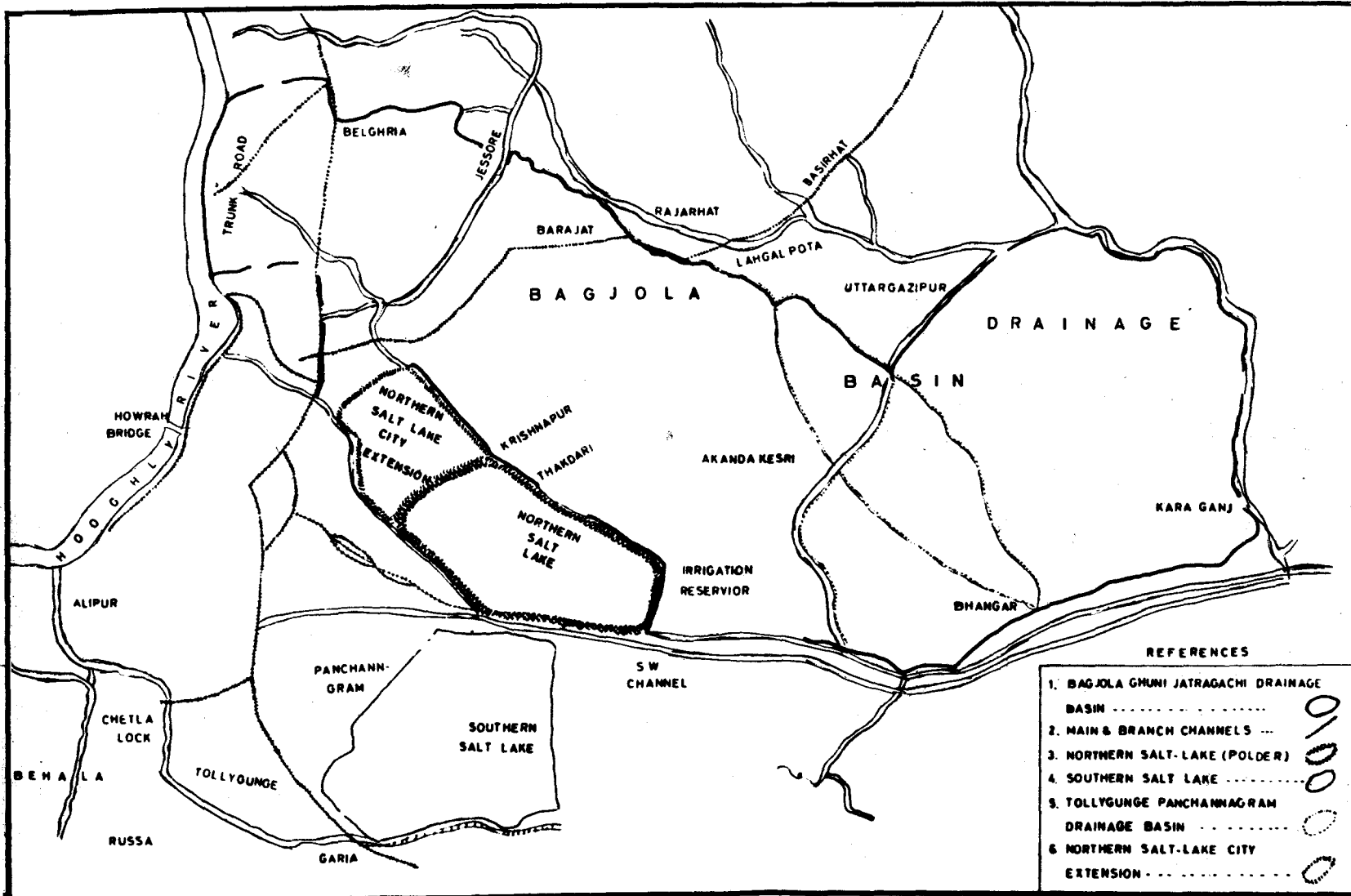
- (i) salinity and alkalinity in the *Khadar* area caused by the effects of flood water from the river Jamuna;

MAP -12

NORTHERN SALT LAKE-CITY EXTENSION SCHEME

INDEX MAP SHOWING

CALCUTTA AND THE DRAINAGE BASINS & SCHEMES ON ITS EASTERN ENVIRONS



SARAS

- REFERENCES
- 1. BAGJOLA GHUNI JATRAGACHI DRAINAGE BASIN - - - - -
 - 2. MAIN & BRANCH CHANNELS - - - - -
 - 3. NORTHERN SALT-LAKE (POLDER) - - - - -
 - 4. SOUTHERN SALT LAKE - - - - -
 - 5. TOLLYGUNGE PANCHANNAGRAM DRAINAGE BASIN - - - - -
 - 6. NORTHERN SALT-LAKE CITY EXTENSION - - - - -

PLANNING COMMISSION
PC/CMU- NO. / 5-62

- (ii) salinity and alkalinity caused by the natural drainage and high water table conditions in *Dabar* (low-lying) and *Bangar* (old alluvium) tracts;
- (iii) salinity and alkalinity caused by impermeability in the subsoil due to hard pan in the subsoil locally known as "Ratha"; and
- (iv) salinity and alkalinity caused by the continuous use of brackish well water.

In the areas affected by salinity and alkalinity the texture of the soil varies from sandy loam to loam, rather poor in nitrogen and organic matter. Total and available phosphoric acid seems to be in weak supply which varies between .09 and .03 per cent and .44 and .005 per cent respectively. The soils are also well supplied in total and available potash. The lime content varies widely generally between 0.3 per cent to 4 per cent and the pH is mainly above 8.0 and in certain saline and alkaline patches it is above 9.0. The base exchange saline and alkaline patches about 9.0 is obtained. The base exchange capacity of the soil is low, about 10 m.e. in the top layers and 15 to 20 m.e. in the lower layers. The content of exchangeable sodium is quite high. The concentration of water soluble salts in the soils varies between 1.5 to 0.1 per cent. The dissolved salts in many of the well waters in the area affected with salinity and alkalinity exceed 2000 ppm and sodium percentage is above 70. The quality of well water is normally bad and the waters are unsuitable for continuous irrigation. One major differentiating characteristic of these soils is the nature and extent of concretions development, both of calcareous and ferruginous nature, the depth of which may vary from 5-6 ft. The soils affected by salinity and alkalinity are generally charactered by high water table, the rise in water table being due to the area being under canal irrigation for a long time.

Chibber and Satyanarayana¹⁶ in an interesting experiment on the alkali soil area of the village Nilothi in Delhi State have indicated that it is possible to reclaim large areas of saline alkali soils lying waste in unirrigated tracks, making use of the rain water (20") during the monsoon season and using organic manure at the rate of 4 tons per acre and gypsum at the rate of 2 tons per acre. The results showed that under such conditions gypsum with organic manure will reduce the pH from 9.0 to 8.2 and total soluble salts from 0.35 per cent to 0.14 per cent in the surface layer within one year. The yield of wheat grain in lbs. per acre increases from 200 in the control to 450 in the plots treated with gypsum and organic manure.

The experiments at the Indian Agricultural Research Institute and in cultivators' fields on the reclamation of these soils indicate

that there are great possibilities of reclaiming these lands if proper drainage is provided to lower the water table. Gypsum will have to be applied to replace high exchangeable sodium wherever necessary followed by growing salt tolerant crops like paddy, barley and berseem.

Work on Saline and Alkali Lands in the Maharashtra State

Saline lands in Maharashtra State may be due to water-logging in heavily irrigated black soil areas or may lie within the zone along the sea coast where they are covered with sea water during normal tides. It is estimated that more than two and a half lakh acres along the west coast of the Maharashtra State have been rendered saline by the flowing in of the sea water. In addition, about 75,000 acres of the black soil area were reported in 1938 to have become unproductive in the Deccan Canal of the former Bombay State as a result of salt infestation.

Saline areas also stretch over about 1 million acres along the bank of either side of the Purna river in Vidarbha region. These soils contain high amount of fixed salts and are considered as problem areas for irrigation. The alkali soils are characterised by their low salt contents (0.2 to 0.3 per cent), very high alkalinity (pH around 9.0), very poor structure and considerable compactness of the lower horizons. Both the saline and alkali condition directly affect the plant growth by interfering with the absorption of water and nutrients by the plants. The physical condition of the soil which governs the movement of air and water is adversely affected by salinity and alkalinity. The biological activity which is responsible for transforming the inert nutrients into available forms, is also impaired and sometimes the soil is not able even to support weeds. The coastal salty alluvium, situated generally in low lying areas or subject to ingress of sea water, are deep silty loams with clay loam on the surface layer which are cloddy in structure and show extensive incrustation of salts. The soils are grey in colour and calcium carbonate is found in some quantity in the profile.

Extensive areas along the coastal districts have become unfit for the economic cultivation of the normal crops of the tract. The unfertility of these lands is mainly due to the salinity caused by their periodical inundation with sea water which enters these lands through creeks during high tides. The Maharashtra State has appointed a statutory Khar Land Development Board to carry out reclamation of the coastal soils by putting in embankments.

Though attempts have been made since ancient times to reclaim these lands by putting embankments, no scientific research appears to have been carried out in the past for their proper utilisation and reclamation. Recently a Research Station has been established at Pargaon on Panvel-Uran road—4 miles away from Panvel, a town in Kolaba district—with a laboratory attached to it. The experimental area is divided into different blocks and is protected by putting embankments to prevent entry of sea water. Another object of putting embankment is to impound rain water which, when allowed to drain out, would remove the excess salts from the soils. The position of the embankment, location of the sluice gates and their areas etc. are decided with due regard to the local conditions such as the highest tide levels, drainage conditions, salts brought into the embanked areas etc. Complete reclamation technique is being worked out by adopting chemical, mechanical and agronomical measures.

By the end of the Second Plan 59,000 acres of Khar and Khajan lands on the Western coast in Konkan have been reclaimed. This still leaves about 57,500 acres of Khar and Khajan lands which are capable of being reclaimed. The Third Plan provides for reclamation of about 38,000 acres with the outlay of Rs. 65 lakhs (Ref. 5).

Basu¹⁵ employed sulphur, gypsum and farmyard manure in alkaline regur soils for reclamation; and Talati¹⁶ conducted field experiments on the reclamation and crop management of the salt lands in Baramati region.

General remedial measures suggested to control extension of water-logged and salt affected areas caused by excessive irrigation comprise (Ref. 5);

- (i) Preventive measures; and
- (ii) Curative Measures.

Preventive measures:

- (i) Canal lining;
- (ii) Pre-irrigation soil surveys;
- (iii) Fixing intensity of perennial irrigation in relation to drainage capacities of the areas;
- (iv) Volumetric supply of water.

Curative measures:

- (i) Surface and sub-surface drainage of the salt affected areas;

- (ii) Reclamation methods to bring back the fertility of soils to grow normal crops.

Work on Saline and Alkali Soils in Andhra Pradesh .

There are two categories of saline soils in Andhra Pradesh:—

- (i) About 20,000 acres in the black soil area growing virginia tobacco;
- (ii) About one million acres in the coastal alluvium of the districts of Srikakulam, Visakhapatnam, East Godavari, West Godavari, Krishna, Guntur, and Nellore.

About 90 per cent of the total production of flue cured tobacco in India is from about 2 lakh acres of black soil in the districts of Guntur, Krishna, West and East Godavari in Andhra Pradesh. The entire area is a very flat land with slopes rarely exceeding 1.5%. Due to the flat nature of the terrain, especially along the Krishna river in Guntur district, there is great difficulty in draining the excess rain water out of this entire land. The flood waters and also the waters from seasonal streams accumulate in the low lying areas which may be about 10 per cent of black soil area growing tobacco, making cultivation almost impossible in some lands. The internal drainage in these areas is also very much restricted. All these factors taken together, along with the heavy clayey nature of the soil, have resulted in increased salinity and alkalinity of the area. A detailed soil survey of the entire area has been taken up by the Nagpur Soil Correlation Centre of the All India Soil and Land Use Survey in order to assess the suitability of these soils for growing virginia tobacco. These soils are clayey throughout the depth and have no marked differentiation. They are invariably very deep, being more than 6 ft. with very grey to dark grey brown colour throughout. The structure is angular blockly up to 20", below which it is diagonally platy. This platy structure ultimately deteriorates into small angular blocks. Lime is present throughout the profile, either in diffused form or in small concretions. The soil reaction is moderately to strongly alkaline all along the profile. Deep wide cracks are found in the soil during the dry season. The water holding capacity of these soils is high. Well water and tank waters of this area are brackish. Low lying areas which are affected with salt, and also the submerged areas, are used for paddy cultivation during the rainy season. Chillies, tobacco, jowar (grain and fodder) and pulses are taken in the rest of the area by rotation. At many places including salt affected areas virginia tobacco is grown in the same plot, year after year, following a fallow period. Although no

visual symptoms of the harmful effects of salt at any stage are seen on the tobacco plants, the colour and the burning quality of the leaf is said to be deteriorated on curing. Tobacco crop is known to suffer especially from excess of chlorides. Further studies are needed on the type of underground water, the development of such soils and fluctuations of salts due to seasonal variations.

As given in the report of the Wastelands Survey and Reclamation Committee of the Ministry of Food & Agriculture, thirtyfive blocks each of 250 acres and above of saline area, comprising a total area of 37,605 acres, have been located as below:—

Table 13

<i>District</i>	<i>Area (acres)</i>
East Godavari	500
Guntur	9,505
Krishna	27,600

The Committee has concluded that the saline lands lying waste in the districts of Guntur and Krishna can be rendered productive, if adequate irrigation is provided and, whenever necessary, the drainage is improved by widening the existing drains or constructing new ones. Protection from the ingress of salt water during high tides by the construction of bunds and provision of saline gates to control outflow of the rain-water is necessary. These lands after reclamation are capable of yielding at least 20 maunds of paddy per acre. The cost of reclamation of the saline land depending on its nature varies between Rs. 100/- to Rs. 300/- per acre.

There is a great scope for undertaking development programmes connected with reclamation of saline soils in large sized projects in Andhra Pradesh, especially in East Godavari district, where vast stretches of saline soils occur along the coast. At Tallarevu extensive saline areas are present. According to a report by the Government Agricultural Chemist, Andhra Pradesh, there is one compact block of 400 acres in the village of Polekurru, 12 miles from Kakinada which is patta land. There is a road running along one side of the block for a length of $7\frac{1}{2}$ miles. The eastern side of the farm is bound by a creek called 'Odalinali'. A flood bank (embankment) has also been made to a height of 6 ft. around the block which will prevent incursion of salt water. A channel has also been excavated for supply of fresh water from Gadimoga channel of Koringa Project in Godavari Delta. The area was subjected to periodical tidal inundations of sea water. As the area is situated at a lower contour,

there is stagnation of drainage waters also from the higher levels. The vegetation of the area comprises some salt bushes and mangrove. In view of the assured irrigation facilities with channel water, and the measures taken to prevent further incursions of sea water, it is possible to reclaim the area by leaching out the salts after incorporating paddy straw or green leaf and applying heavy dressings of superphosphate so as to supply the required soil amendment (calcium) and phosphoric acid in which the soils are highly deficient. During the course of about 3 years, such areas can be rendered fit for supporting good crop of paddy and an average yield of at least 2000 lbs. per acre can be expected from the last year onwards. The immediate reclamation work consists of the important measures like filling the gullies and creeks, laying of bunds and forming irrigation channels and drainage courses, and levelling of the land in certain areas.

Under the I.C.A.R. scheme for land reclamation in Andhra Pradesh which was in operation for a period of 5 years from 29th December, 1955 at Masulipatam where high saline soils occur and the pH ranges between 7.0 to 8.5 and the sub-soil water is exceedingly rich in salt content, chiefly of sodium salts, it was established that continued supply of irrigation water and cropping alone could check the salt content, from rising (Ref. 21). A permanent lowering of the water table also appears to be very necessary.

Work on Saline Soils in Kerala

The peaty or kari soils in Kerala which have an accumulation of large quantities of water soluble alkali salts occupy an area of about 38,000 acres. These areas are found in the taluks of Ambalappuza, Kunnathanad, Vaikom and Shertallai and are generally submerged under water during the monsoon season.

The occurrences of salts in the Kari soils could be traced to the following causes; (i) firstly, the topographical position of the different Kari areas in the State is such that all of them are subjected to tidal rise of saline waters. During summer when the salt water gets into the lands, the dissolved salts, after evaporation, are tenaciously held up by the soil which is extremely plastic and sticky and which is commonly characterised as heavy clay; (ii) there exists in each of the Kari areas sub-soil water containing salts within a few feet of the surface of the land and when water is drawn up to the surface by the force of capillaries, the dissolved salts are also slowly brought upwards. These soils contain 10 to 40 per cent of resistant type of organic matter, grey in appearance, most of which is composed of lignite. The soils are black and heavy and highly acidic, pH

sometimes being as low as 3.9. The soils contain 20-30 per cent Fe_2O_3 and Al_2O_3 . As soon as the rain ceases these lands are put under paddy cultivation. Sometimes these soils are highly toxic to plant life as they contain ferrous and aluminium sulphate in considerable amounts. Attempts at reclaiming such soils, highly toxic to plants, by the application of lime to correct acidity and improving drainage have met with no appreciable success and investigations are necessary in this direction.

Work on Saline Soils in Madras

As a result of excessive alkalinity 2,500 acres of land were lying waste in the Kulittalai taluq of the Trichinopoly district and all attempts of growing crops failed. A survey of the area showed that the alkalinity was not the result of irrigation being introduced, but was entirely due to the nature of the soils themselves, which lie in saucer shaped depressions into which the salts from the upper situations reaches within 2-3 ft. The soils of the most affected lands are sandy loams and contain 1 to 2 per cent of CaO . But they have a high pH of 10.0 in many cases, and excessive soluble salts constituted mostly of carbonate and bicarbonate of sodium. Large scale trials were conducted in the field using sulphur at 1 to 2 tons and gypsum at 10 tons per acre. Samples of soils were examined both before and after the application of the soil amendments, and it was found that the treatment ameliorated the condition of the soil a great deal, reduced the pH, washed down the soluble salts, and made the soils grow good crops of *dhaincha* and paddy. The cost of such a treatment was put at Rs. 200/- per acre.

According to the Report on Madras by the Wastelands Survey and Reclamation Committee, a total area of 8,000 acres of alkali land in one block has been located in the Pattukottai taluq of the district Tanjore. The area is highly saline due to inundation by sea water over a number of years and is swampy and only scrub jungles are found. The salinity of the land is very high, the drainage of the stagnant water from the swampy land would present a very serious problem and the cost of reclamation would be very high. The Committee has not, therefore, recommended this area for reclamation.

Work on Saline Soils in Orissa

The Coastal saline soils in Orissa occur in the districts of Balasore, Cuttack and Puri and in the area inundated by the Chilka salt lake in the Ganjam district during the rainy season. The total area of such soils in the State will be about one million acres. The annual rainfall in these areas is within 46" to 63" and is quite suitable for growing paddy with adequate protective and reclamation measures.

According to the draft Report on Orissa by the Wastelands Survey and Reclamation Committee, eleven blocks each of area more than 250 acres, comprising a total area of 10,724 acres have been located for reclamation in the districts of Cuttack and Puri. Blocks 1 to 6 comprising 7,250 acres of wastelands are located in the Mansaghai tehsil of the Cuttack district. The land is saline and is infested with scrub jungle and bushes. The annual rainfall in the area is 50 inches. The area can be brought under cultivation by the construction of protective embankments with sluice gates, so as to prevent the ingress of sea water and control the outflow of rain water. The soil is black. The cost of reclamation has been estimated at Rs. 200/- per acre. Crops like paddy, jute and ragi can be grown in the reclaimed land. In the blocks 7 to 10 comprising 3,102 acres which are located in the Benpur tehsil of the Puri district and where there is no irrigation and the rainfall is 50", the reclamation measures are the same and the cost of reclamation is estimated at Rs. 200/- per acre. The remaining block (11) of 372 acres is located in the Bhubneswar tehsil of the Puri district. The land is saline. The rainfall in the area is 50"-60" and there is no irrigation. The soil is black and red. The cost of reclamation is estimated at Rs. 250/- per acre. Part of the area has already been brought under cultivation after adopting suitable reclamation measures.

In addition to above there are large blocks of culturable wastelands in the Puri and Ganjam districts, which are subject to inundation by floods from the Chilka lake which is a salt water lake extending over an area of about 450 sq. miles. During the rains the water of the lake spreads over large acres of wastelands, a portion of which turns into low swamps when the water recedes after the monsoon. The total area of such wastelands is about 11,000 acres. The reclamation of such lands would involve (i) construction of embankments at suitable points for protecting the lands from inundation from the salt lake during rains and (ii) construction of channels with shutter arrangements to drain out flood water from these lands into the lake when the water-level in the lake goes down. After reclamation the lands are quite suitable for growing paddy. The cost of reclamation has been estimated at Rs. 250-300 per acre. The Wastelands Survey and Reclamation Committee has tentatively recommended the reclamation and bringing under cultivation the entire wasteland saline area around the Chilka lake which vests with the Government and settling there landless labourers from adjoining villages or selling out to private individuals.¹⁰²

There is scope for reclamation of saline soils in the coastal tracts of Orissa. A strip of land about 10 miles in width running along the

Bay of Bengal in Kujang and Kanika lies uninhabited. The area is full of mangrove vegetation and prairie like growth of grass. It is malarious and communications are poor. Reclamation and colonization of this area will be possible if malaria is effectively controlled and roads are developed.

Work on Saline Alkali Soils in the Mysore State

Saline areas occur in the districts of Chitaldrug, Bellary, Raichur, Dharwar and Bijapur and the coastal districts of South Kannara and North Kannara. The coastal salines may be about 5½ lakh acres whilst the total area of such soils in the States may be about one million acres. Portions of Dharwar district and of Bijapur taluks are affected by what is known as *Karl* soils which are saline and alkaline and fairly deep clayey soils. The salt lands of the Nira Valley have developed as a result of excessive irrigation given on the deep black soils of the locality. The salts were derived from the decay of trap itself. An analysis of the disintegrated rock showed the prevalence of sulphate and chloride of sodium with varying quantities of magnesium salts. One of the main properties of these soils is the relatively high sodium saturation (10 to 40 per cent). The 'A' horizon is invariably hard and compact with cloddy, nutty or laminated structure. The areas of black soils which have been irrigated with Tungabhadra water (containing 200 ppm of soluble salts) have not developed alkalinity, whereas similar soils irrigated from other sources like Chinna Hagari River developed alkalinity (containing large amounts of soluble salts). The damaged lands of the canal tract have been studied by Talati and classified into (i) mixed saline soil, (ii) saline soil, and (iii) alkali and strong alkali soils. The mixed saline soil contains a mixture of calcium, magnesium and sodium salts, but sodium salts showed tendency to increase with depth. The saline soils mostly contain sodium salts with pH higher than the mixed saline soils. The accumulated salts are difficult to leach. Alkali soils have low salts at the top. These are very stiff soils with varying degrees of alkalisation, between 20 and 60 per cent. The pH is above 9.0 with carbonate salts in great predominance. For reclamation these soils require different treatments. The mixed saline soil improves by simple leaching, whilst the saline soils after leaching get alkaline either under natural or artificial conditions and require chemical amendments for their improvement. Gypsum and sulphur in combination with farm yard manure have been found to be the best. Isbar has suggested burning the soil with field wastes, followed by the application of gypsum and green manures and then a crop of gram before sugarcane is taken.

The Report on Mysore of the Wastelands Survey and Reclamation

Committee⁹⁹ assigned higher priority to the reclamation of Khar lands (Category IV) 12 blocks of which in areas each of above 250 acres comprising a total area of 7,832 acres have been located in the districts of Chitaldrug and North Kanara. The reclamation of lands of this category seem to be the most profitable in terms of additional food production, which is about 12 maunds for an expenditure of about Rs. 120/- per acre on land improvement. Much useful work has been done by the Khar Lands Development Board which was set up by the erstwhile Bombay State and over 64,000 acres of coastal saline have so far been reclaimed including reclamation in North Kanara district. The expenditure on reclamation is initially met by the Government and 60 per cent of the reclamation cost, together with a nominal occupancy price, is recovered from the owners and the balance is treated as subsidy.

Work on Saline and Alkali Soils in Madhya Pradesh

At the suggestion of the Punjab irrigation Board, the work of pre-irrigation soil survey of Chambal commanded area in Madhya Pradesh which was carried out by the Agricultural Research Institute, Gwalior in 1953. The survey showed the occurrences of (i) soils with total soluble salts above 0.2 per cent. only in Gohad tehsil with high water table (3½ ft. to 17 ft.); (ii) alkaline soils having pH values above 8.5 in Sheopur tehsil and only a small area in Joura tehsil; and (iii) soils having high total soluble salts (above 0.2 per cent.) and high pH values (above 8.5) in the tehsils of Gohad and Mehgaon.

The approximate extent of total saline and alkaline areas in the Chambal commanded (gross) areas is about 3 lakh acres. The occurrences of saline and alkali lands in other parts of Madhya Pradesh is as under:—

(i) Gwalior Division excluding Chambal commanded area	1,000 acres
(ii) Bilaspur Division	256,600 acres
(iii) Indore Division	10,000 acres
(iv) Other Divisions	32,400 acres.

The total area of saline and alkali soils in the State will be about 6 lakh acres.

In the areas affected with salinity and alkalinity, leaching down of salts and creation of improved drainage conditions are essential.

Work on Saline and Alkali Soils in Rajasthan

The problem of saline and alkali soils is very acute in Rajasthan. Such soils occupy about one million acres in the State and are of varied nature affecting most parts of the State.

In the Luni basin or in alignment with it occurs most of the lakes and salt wells of Rajasthan, such as Didwana, Pochbhadra, Sambhar, Kuchman, Chanod and others, with several others along the periphery of the Barmar—Bikaner dune-free tract as at Pokaran, Phalodi, Bap and Lunkaransar. In addition, there is a group at Bharatpur. The theory of wind-borne salt is generally accepted to explain the saltiness of the inland lakes. The main difficulty against this theory is the decided difference between the chemical composition of the dissolved salts of the different lakes and normal sea brine as shown in the following table 14.

Table 14

Composition of Indian sea lake and well brines (on dry basis) in round figures

Particulars	Sea brine	Sambhar lake brine	Kuchman well brine	Kharsagha well brine	Didwana well brine	Pochbhadra well brine
Sodium chloride	77.76	87.3	84.2	70.8	77.2	85.7
Potassium chloride	2.5	0.13	..	2.0	..	..
Magnesium bromide	0.22	0.05	..	0.35	..	..
Sodium sulphate . . . .	..	8.6	10.5	..	20.6	..
Sodium carbonate . . . .	..	3.8	..	..	0.6	..
Calcium carbonate	0.35	..	0.5	0.06	..	..
Calcium sulphate	3.6	..	0.5	2.1	..	2.9
Sodium bicarbonate . . . .	..	..	..	..	1.6	..
Magnesium sulphate	4.7	..	2.6	2.3	..	9.4
Magnesium chloride	10.8	..	..	22.4	..	1.9

It will be seen from the above that the chief difference in the chemical composition of the brines of sea and Sambhar lake is the contents of the salts of magnesium sulphate and chloride. It has been suggested that by a process of base exchange the magnesium has gone into the formation of clay minerals possibly montmorillonite and the sulphate and chloride ions have combined with Na to form excess of Na_2CO_3 and $\text{Na}_2\text{C}_2\text{O}_4$.

In most of the areas affected with salts there is no other source of irrigation except the ground water which is saline and therefore improvement of saline waters and soils by chemical treatment or cultural methods will be useful in improving the soils as well as the crop yields. Three years' experiment on saline soils at Government Agricultural Farm, Bilara, irrigated by saline waters with ten treatments shows that treatment of 10 tons of F.Y.M. applied per acre in May-June, considerably improved the soluble salt content and physical make-up of the soils as well as led to better production.

Work on Saline Alkali Soils in Bihar

The north western and coastal parts of the alluvium north of the Ganges comprising the districts of Saran, Muzaffarpur and Darbhanga contain highly calcareous soils whose pH values are on the alkaline side and contents of available phosphoric acid and potash are generally low. At locations of impeded drainage and also low situations the soils are saline and also saline alkaline. South of the Ganges the soils of the district Sahabad consist of heavy clays with infertile patches of *usar* lands especially in the west and the central portions of the province. The total area of saline, saline alkali and alkali lands in Bihar will be about 10,000 acres.

The work on saline alkali soils carried out at the Central Sugarcane Research Station, Pusa, has shown that these soils may be handled in three ways, viz. (i) *eradication*—leaching with under-drainage, scraping and flushing. This is suitable for soils showing white efflorescence without much change in pH; (ii) *conversion*—application of gypsum with irrigation and cultivation in the surface but with ploughing under. This is suitable for lands showing extremely alkaline reaction; and (iii) *control*—retardation of evaporation by intensive use of soil mulch. This not only saves soil moisture but also prevents the translocation of soluble salts to the root zone.

Provision of Drainage for Reclamation of Saline and Alkali Lands

Saline soils can be reclaimed only by removing salt and preventing its return which requires leaching and drainage. Further, organic matter, amendments and fertilisers may improve crop growth on saline soils, but they cannot accomplish salt removal without drainage. Thus for any reclamation of soils with high water table, there must be the provision of drainage.

In developing a programme to improve drainage, it is necessary to determine the source of the accumulating water, the direction of

movement of the water and the quantity flowing. It is essential to try to intercept the water before it reaches the point where it is causing the damage. Drainage operations may involve;

- (i) Interceptor drains for removing overland surface water or sub-surface water;
- (ii) Relief drains may be either open ditches or tile drains;
- (iii) Relief wells.

Field observations and measurements, local experience and a full understanding of basic principles are required to design successful drainage systems. With more adequate data on hydraulic conductivities of soils, sources of incoming water, etc., predictions of drainage needs can be made and efficient systems installed. One of the main reasons for providing good drainage before undertaking reclamation operations is the substantial quantities of water required to leach out excess salts.

The quantity of water needed to leach soluble salts out of saline soils depends mainly on the amount of salts in the soil. According to R. M. Hagan, "as a general rule, one foot of water will reduce the salinity of the surface foot of soil by about 80 per cent., 2 feet of water will reduce salinity of the surface foot of soil about 90 per cent., while reducing the salinity in the second foot about 80 per cent. Consider a high saline soil with a saturation extract conductivity of 40 millimhos per centimeter in which a moderately salt-tolerant crop with a relatively shallow root is to be planted. For this purpose it is desired to reduce the average salinity to a value of not more than 8 millimhos to a depth of 3 feet. To do this approximately three feet of water will be required. After this leaching, the salinity in the third foot of soil would be reduced to a conductivity of about 8 millimhos per centimeter and in the upper two feet of soil to lower values. If, in this case, it was desired to lower the salinity in the third foot to 4 millimhos per centimeter, approximately 6 feet of water would be required.

At Walchandnagar in the Maharashtra State in the Deccan Canal area 10,000 to 15,000 acres of black soil in that farm were being served by deep drains maintaining the fertility of the land and producing sugarcane at the rate of 70 tons per acre.

The soil reclamation trials conducted by B. Ramamoorthy of Indian Agricultural Research Institute at the Botanical sub-station, Pusa (Bihar) have shown that it is necessary to determine the lateral movements of sub-soil water and the direction of

surface drainage in order to put the intercepting drains in a direction perpendicular to that of the above which will make them most effective. These intercepting drains, coupled with vertical organic mulches up to a depth of 3 to 4 ft. to pierce the thin sub-soil impervious calcic layers located about 36" below the soil surface, flooding with the addition of gypsum, and sannhemp-mung-sugarcane-mung rotation have made the reclamation of such soils both effective and quick as judged by crop yields and soil analysis. In the experiments conducted by Ramamoorthy at the National Dairy Research Institute, Karnal, where the saline alkali soil has impervious sub-soil layers, vertical organic mulches have been found to lower water table very considerably in a short period when combined with gypsum and flooding, as compared to gypsum and flooding alone. In the Indian Agricultural Research Institute farm, however, where there are no impervious sub-soil layers, tile drains installed in March, 1960, under a cooperative project with the Rockefeller Foundation, were found to be quite effective in lowering the water table; pH of the surface soil which was originally 8.1 decreased by about 0.2 unit and the soluble salt content of the surface soil which was originally about 0.2 per cent decreased quite significantly.

CHAPTER IV

Problems of Coastal Saline Soils

Nature and extent of the problem

The saline and alkaline soils are found in the inland and coastal areas. The factors associated with the salinity problem of inland soils are low rainfall, high evaporation rate and poor drainage. These are the natural factors. Besides there are human factors e.g. the poor irrigation practices and heavy fertilisation. The latter, however, may cause a localised problem. In the coastal areas and low lying soils along the sea coast, saline sea waters are the source of salinity and alkalinity.

Coastal saline soils are found along the long coastal line, which runs about 35,000 miles. The problem occurs in varying degree in the States of West Bengal, Orissa, Andhra, Madras, Kerala, Maharashtra and Gujarat. While no factual data are available as to the extent of the area affected, the problem area is roughly estimated to be about 20 to 30 thousand sq. miles and at least about half of that could be amenable for reclamation. The important areas needing attention from the reclamation point are the Sundarbans of West Bengal the delta areas of Krishna, Godavari and Cauvery, *Kari* soils in Kerala, *Khar* land of Maharashtra and Gujarat and Rann of Kutch. The nature of the problem is different in different parts and so the problems associated with these lands are varying too. The eastern and south western areas receive moderate to high rainfall. The rainfall is low with an arid type of climate in Gujarat.

The saline soils of Sundarbans in West Bengal are probably the result of inundation of backwaters from sea. In Kerala the *Kari* soils are peaty in nature, containing 10-40% organic matter. These are low lying and remain submerged under water during the monsoon. The soils are alluvial in nature. These low lying tracts are believed to be once parts of sea and were formed by gradual silting up by the sediment brought down by the rivers.

Khar and *Khajan* lands are formed in the coastal districts both in Maharashtra and Gujarat. These lands are subjected to periodic inundation of tidal waters. In Maharashtra the problem areas occur in the districts of Ratnagiri, Kolaba and Thana. The problem also occurs in North Kanara district now in Mysore State. In Gujarat the problem is widespread in the former State of Saurashtra and in

the districts of Ahmedabad, Amreli, Broach, Kaira and Surat. These soils are recovered from sea and are further formed by gradual silting by the sediment brought down by the rivers draining in these areas. Thus, for example, Kathiawar (in Saurashtra) was formerly an island which has risen slowly and become connected with the mainland. This is one of the reasons that in many places inland salty soils are found especially in low lying regions in basins and valleys, but sometimes in higher regions also. Many rivers flow into the seas surrounding the peninsula. They carry large quantities of water and inundate the lower regions during the monsoon but have only a very small discharge after the monsoon. The silt carried by the rivers, together with the continuing rise of the island has caused the peninsula to be surrounded in many places by more or less wide salt containing strips of land. These strips continue in wide saline tidal flats along the gulf of Cambay on the east and gulf of Kutch to the north-west side.

The work so far carried out and in progress for the reclamation of Little Rann of Kutch and of the Bhal tract in Gujarat has been described below.

Work on coastal Saline or Khar Lands in Gujarat

In Gujarat the area around the gulf of Cambay is affected by sea tides carrying salt laden silt deposits. Nearly 2 million acres comprising the estuaries of the Narbada, Tapti, Mahi and Sabarmati rivers in the districts Surat, Broach, Ahmedabad, Mehsana, Banas-kantha and Amreli have been damaged in this way. The chief source of salinity in the State is the underground sea salt deposits, although part of the salinity may be due to wind borne sands containing sand particles. Besides there are about 1 million acres saline areas formed in Kutch inundated by the tidal waves of the sea, especially in the monsoons. These soils are locally known as *khar* lands. Thus the total areas of saline soils in Gujarat is about 3 million acres.

Survey of some places in Surat, Broach and Ahmedabad by Talati has shown that soil under the tidal influence showed high content of exchangeable monovalent bases and of magnesium and a predominance of chlorides in the total soluble salts amounting to more than 50 per cent. In a series of articles on the saline and alkali soils of Gujarat, particularly of S.W. Gujarat, R.K. Shah and his co-workers 67,68,69,70,71,72,73 have examined the nature of such soils in typical places in Gujarat, e.g. the Dhandhuka-Patana Region, the Surendranagar-lake Nal Region, etc. Most of the soils under the class saline and alkali are generally sandy loam.

Basu¹⁸ has divided these saline soils into three categories:

- (a) Natural saline soils from salt-bearing parent materials or beds affected by sea water in the past caused by (i) arid climate, (ii) topographic situation which affects the surface soil due to salt washings from surrounding areas, (iii) nearness of saline sub-soil water; and (iv) impervious sub-soil conditions and or salt-bearing sub-soil strata.
- (b) Saline soils formed by irrigation; and salt incrustation generally of sodium sulphate and chloride and appearing only when the saline sub-soil exists within 4 ft. from the surface. Apart from surface incrustation of salts the horizons also showed considerable change due to sodiumisation.
- (c) The soils on the coast rendered saline by flooding by sea water, which are fairly extensive.

The soils in group (a) are amenable to reclamation and management by bunding and leaching of soluble salts and by suitable adjustment of cropping practices. Reclamation measures recommended by the Irrigation Research Division for the group (b) soils include, besides a system of drainage, scraping or flooding out of salt, application of gypsum, etc. Ordinarily the lands of group (c) are reclaimed by putting embankments with sluices to prevent the entry of sea water and to allow rain water to go out, if the soil be highly sodiumised and the drainage extremely poor, reclamation would be slow and difficult and thus too expensive. For irrigation of the above three classes of saline soils, classification for land use on the basis of the nature and amount of soluble salts in the profile and on the nature of compactness of the 'B' horizon is necessary.

Rann of Kutch

Two surveys carried out by the Indian Agricultural Research Institute in 1948 and 1955 (K. V. S. Satyanarayana⁶⁵) in the Great and Little Rann of Kutch, showed that surface deposits of salts of appreciable thickness are present in an area of 10 lakh acres in the Great and Little Rann. Gypsum is present in varying quantities. A good portion of the Little Rann is inundated by river waters. The resources of sweet water for washing out salts from the soils of the Great Rann area for reclamation purposes appear to be very meagre. The islands Pachham, Khadir and Bela in the Great Rann are no doubt populated and some type of cultivation is going on. However, due to lack of sweet water no increased demand can be made on the natural resources. The Little

49 PC—5.

Rann of Kutch has greater possibilities for reclamation, particularly in view of the fact that large and worst salt areas in Saurashtra namely the Bhal tract are effectively being reclaimed. The applicability of simple drainage principles for reclamation as adopted in the Bhal Reclamation Pilot Scheme and the availability of large quantities of sweet river water for reclamation purposes led to the conclusion that Little Rann area may be taken up for reclamation work by utilising the flood river waters with suitable arrangements for drainage. Nearly 5 lakh acres could normally be reclaimed from the Little Rann of Kutch. Also Soil Conservation Schemes for contour bunding, terracing and development of pasture land may be taken up in the Little Rann which has got greater scope for development. A scheme for the development of Little Rann of Kutch has been under the consideration of the Ministry of Food and Agriculture and the Central Water and Power Commission, involving both flood control and reclamation and coordinated approach from the engineering and soil point of view.

The Report on Gujarat of the Wastelands Survey and Reclamation Committee¹⁰³ shows that under the category—saline lands (category II), 31 blocks each of 250 acres or more having a total area of 58,115 acres have been offered for reclamation in the districts Banaskantha, Broach and Bhavnagar, as follows:—

District	Area (acres)
Banas-kantha	21,127
Broach	32,234
Bhavnagar	4,754

The above areas can be sub-divided into two groups, namely (i) khar lands, and (ii) bhal lands. A scheme is already under operation in Gujarat for the reclamation of khar lands, under which the expenditure on reclamation is initially met by the Government, and when the reclaimed lands are disposed of to the owners or tenants, 60 per cent. of the reclamation cost, together with a nominal occupancy price (when the land belongs to the Government), is recovered from the grantees and the balance is treated as subsidy. The cost of reclamation is estimated at Rs. 120 per acre. The Wastelands Survey and Reclamation Committee has recommended that in the reclamation of khar lands high priority should be assigned to areas receiving a rainfall of more than 35—40 inches and/or having irrigation facilities.

The *Bhal* tract is situated in the south-east corner of Saurashtra, with an area of 200 sq. miles. Only 20 per cent. of the land of this tract is cultivable, the rest being saline. The saline land can be reclaimed by leaching out salts with rain-water during the monsoon. The soil is mostly loamy but patches of black soil are also found. The average precipitation is 18 to 20 inches. The land is particularly suited for growing wheat, bajra, jowar, and mustard are also cultivated in certain areas if there are good rains in the month of June. The total reclaimable area in the tract is estimated at 60,000 acres.

The coastal areas of the former Saurashtra State are subject to inundation by tidal waters, which turn vast stretches of land into salt-marshes. The State Government initiated a scheme for the reclamation of these areas, which envisaged the construction of bunds, with waste-weirs, to prevent the ingress of sea-water, and to impound the rain-water to leach out salts from the soil. The impounded rain-water is drained off 3 to 4 times during the rainy season according to the frequency of floods, and to facilitate drainage hump-pipe drains are provided in the earthen bunds after every half a mile. This process of desalinisation was slow. At a later date some Dutch experts were invited to survey the coastal areas and to advise Government as to what measures should be adopted to hasten the process of desalinisation of land.

Bhal Reclamation Pilot Scheme at Vallabhpur

On the basis of the proposals submitted by the Netherlands Engineering Consultants, the Hague (N.E.D.E.C.O.) a pilot project ("polder") has been undertaken at Vallabhpur in Saurashtra, covering an area of 6,000 acres, of which 3,600 acres are to be reclaimed. For leaching out salts from the affected area, fresh water from the river Vegad is used. A dam has been built across the river, and this ensures a regular supply of water during the rainy season, but there is not much water in the river after the rains are over. The land in the project is divided into plots, which are bunded up and surrounded by ditches placed parallel to one another at a distance of 650 ft. The ditches are about 6 ft. deep, although the depth of ditches varies with the size of the plots. During the monsoon fresh water from the Vegad river is let into these bunded plots and kept constantly standing on the land. It is allowed to percolate through the saline layer of the soil into ditches from where it is carried to the main channel and finally to the sea. The leaching operations are continued during the rainy season. It is expected that this process will desalinise the land in 2 to 5 years, depending upon the salt content of the different patches. The salt contents of the surface and

sub-soil which are normally of the order of 3 to 5 per cent. have been quickly brought down to 1 to 2.5 per cent. Several methods are being tried to improve the permeability of the top layers of the soil so as to increase the rate of infiltration. At the same time, experiments are being conducted to find out as to which crops can be successfully grown after leaching has brought the salinity to a fairly low level, say, 0.2 per cent. or less. The success of the project will depend upon the extent to which it may be possible to prevent the re-appearance of salts in the soil by the introduction of suitable soil management practices, after the land has been desalinated. This is an important consideration in view of the fact that the river Vegad, which is the only source of fresh water in the area, has a limited supply during the monsoon, which is further curtailed during the years of failure of rains. Therefore, as suggested by the Wastelands Survey and Reclamation Committee, the results of the experiments in progress should be carefully studied before undertaking any large-scale projects of reclamation, since the cost of reclamation comes to about Rs. 350 per acre.¹⁰³

The Little Banni which is also partly saline area and proposed for reclamation, forms the southern portion of the Banni tract in the Kutch tract and comprises 10,000 acres each in villages Dhori, Samrasar and Nirona, in the Bhuj taluka of the Kutch district. It can be approached from Bhuj by road. The soil survey carried out by the State Agricultural Chemist and Soil Specialist indicates that the entire area of village Samrasar and about half the area in village Dhori are suitable for cultivation, whilst the remaining area in villages Dhori and Nirona are unfit for this purpose due to high soil salinity. The annual precipitation in this tract is 10-15 inches.

Work on Coastal Saline Soils in Madras

The saline soils in Madras occur as coastal saline in the districts of Kanya Kumari, Tirunelvali, Ramnad, Tanjore, South Arcot and Madras. There are also pockets of saline alkali lands developed in areas under irrigation, such as in the areas under command of the Toludur Project and the Kattalai High level channel. Saline and alkali soils also occur in pockets in low lying areas. The total area of saline and alkali soils in the State will be about one million acres.

Investigation in the Vriddachalam Taluq of South Arcot district commanded by the Willingdon reservoir in Toludur Project was undertaken to find out the causes responsible for the deterioration of the soils in that area. The alkaline patches were observed in depressions into which seepage water from surrounding areas had drained and may be due to lack of proper drainage. Improvement.

of drainage, application of green manure with lime, sulphur or gypsum were the recommendations made for purposes of amelioration.

The depth of ditches has connection with the resalinization by capillary rise during the dry season. The depth has to be closely related to the deep and speedy leaching.

Various stages in the reclamation process of these lands thus are:—

- (i) Protection of area from sea water.
- (ii) Drainage of the area by means of a system of drain ditches.
- (iii) Provision for adequate inundation of the area to ensure removal of salts by leaching.

These measures have to be related to (i) nature of the problem, (ii) soil conditions and (iii) feasibility and practicability of reclamation.

Once the areas are reclaimed where they could be put under farming, adoption of proper cropping system and soil management practices has to be ensured to make reclamation permanent.

General Progress of Reclamation of Coastal Saline Soils during the Plan Periods

Reclamation of *Khar* and *Khajam* was taken up in erstwhile Bombay State through the Khar Land Development Board. A scheme for reclamation of these lands was included in the First Five Year Plan and was continued in the Second Five Year Plan. In the Second Plan the programme of the Board envisaged reclamation of about 50,000 acres at the total outlay of Rs. 28,05,700. The available data shows that about 64,078 acres were reclaimed till the third year of the Second Plan, as follows:—

District	Area reclaimed (acres)
Kolaba	35354
Thana	10187
Ratnagiri	2789
Surat	14848
Broach	900
Kaira (Cambay Taluka) . . . . .	..
Ahmedabad . . . . .	..
Amreli . . . . .	..
Total .	64078

Apart from the above, in the Second Plan under the Pilot Polder Scheme in the Bhal tract of Saurashtra in the Gujarat State, which has already been dealt with reclamation of 36000 acres was contemplated at a financial outlay of Rs. 46 lakhs.

Programme of Reclamation in the Third Plan

In the Third Five Year Plan, an outlay of Rs. 264.31 lakhs is made for reclamation of about 82,625 acres as follows:

	Plan Provision Rs. lakhs	Physical target in acres
Maharashtra		
Reclamation of Khar & Khajan lands.	65.00	37,625
Reclamation of Khar & Khajan Coastal lands		
Gujarat		
Development of Khar land	49.31	45,000
Reclamation of Bhal tract	70.00	
Development of Khed area	60.00	
Reclamation of Little Rann of Kutch	20.00	

Organisational Needs

It is obvious that application of methods for reclamation of coastal and inland saline lands which present diversity of problems has to be related to proper diagnosis of the nature of the problem and soil conditions. For permanent reclamation, the reclaimed areas have to be used and managed properly. If reclamation is to be made a good technical job, there has to be a proper organisation for the purpose. Organisation is needed for (i) survey and study of soils to assess the nature of the problem and even to evaluate the stage of reclamation; (ii) application of reclamation measures and (iii) for developing proper technical know-how for use and management of the reclaimed areas.

CHAPTER V

Review of the work done in the survey of ground water and the demarcation of areas of sweet and saline ground water

The development of minor irrigation in India, which includes exploitation of ground water resources is apparent from the following tables.

Table 15

Area irrigated (millions of acres)

	1950-51	1955-56	1960-61	1965-66
Major and medium irrigation	22.0	24.9	31.0	4.5
Minor Irrigation	29.5	31.3	39.0	47.5
<i>Total:</i>	<i>51.5</i>	<i>56.2</i>	<i>70.0</i>	<i>90.0</i>

(Third Five Year Plan report)

Table 16*

Net irrigated as per centage of total irrigated area 1956-57

Percentage

Sl. No.	Place	Govt. Canal	Private Canal	Tanks	Wells	Other sources
1	2	3	4	5	6	7
1.	Assam	11.6	4.7	..	..	41.4
2.	Andhra	44.0	0.5	41.3	11.2	3.0
3.	Bihar	21.6	12.9	13.6	12.0	39.0
4.	Madhya Pradesh	46.8	0.3	13.2	35.5	4.2
5.	Bombay	17.3	1.8	14.4	63.6	2.9
6.	Jammu & Kashmir	18.8	76.6	0.5	0.7	3.2
7.	Kerala	41.3	8.6	9.3	3.5	37.3
8.	Madras	36.1	..	39.9	22.4	1.6
9.	Mysore	21.7	0.7	44.2	17.5	15.9
10.	Orissa	20.2	2.8	50.7	3.9	22.4
11.	Punjab	64.5	1.9	0.2	33.0	0.4
12.	Rajasthan	19.8	..	13.4	64.1	2.7
13.	Uttar Pradesh	37.2	0.2	9.1	47.4	6.1
14.	West Bengal	19.7	30.6	32.0	1.3	16.4

1	2	3	4	5	6	7
15.	Himachal Pradesh	..	..	..	..	..
16.	Manipur	..	100	..	..	..
17.	Tripura	..	75.0	25.0	..	..
18.	Delhi	45.0	7.6	..	47.4	..

SOURCE.—*Economic & Statistical Advisers' Report (1956-57). Ministry of Food & Agriculture, Government of India.*

From table 10, it is evident, that in the States of Bombay (undivided), Rajasthan, Uttar Pradesh and Delhi, the ground water is being used in about 50 per cent or more of the irrigated areas. In Punjab and Madhya Pradesh, well irrigation covers more than 33 per cent of the irrigated areas and it is next to canal irrigation. Thus it follows, that in Northern India, where the soils are mostly of alluvial nature, ground water is a most potent source of irrigation. The ground water resources in the Northern India have not been fully exploited in some areas due to the highly saline nature of water, great depth, and non-availability of cheap power.

In the following pages, the position of ground water and its quality in the different States is discussed.

Punjab

In Punjab, 33 per cent of the irrigation is being done with percolation and tube wells. This acreage is perhaps next to Uttar Pradesh alone, and shows that ground water forms a good source of irrigation. The distribution of the well irrigated area district-wise is shown in the table 17.

Table 17

Irrigated area in thousands of acres in different districts of the Punjab—1958-59

Sl. No.	District	Govt. canal	Private canal	Tanks	Wells	Other source	Total	Area percentage of irrigated to total area sown
1	2	3	4	5	6	7	8	9
1	Hissar	1233	..	..	7	5	1245	42.2
2	Rohtak	398	..	..	112	..	510	43.1

1	2	3	4	5	6	7	8	9
3	Gurgaon . . .	25	..	4	82	..	111	9.8
4	Karnal . . .	299	..	2	220	..	521	39.
5	Ambala . . .	7	..	11	53	1	72	9.5
6	Kangra . . .	3	105	..	..	..	108	22.5
7	Hoshiarpur . . .	31	..	..	60	4	95	13.5
8	Jullundur . . .	17	..	..	426	..	443	67.9
9	Ludhiana . . .	49	..	..	269	..	318	48.8
10	Ferozepur . . .	1015	..	..	123	..	1138	54.3
11	Amritsar . . .	500	..	..	228	5	733	85.7
12	Gurdaspur . . .	110	18	..	53	..	181	30.6
13	Patiala . . .	61	..	..	281	23	365	34.1
14	Sangrur . . .	454	..	..	246	..	700	42.7
15	Bhatinda . . .	647	..	..	10	..	657	44.9
16	Kapurthala . . .	2	..	..	129	3	134	51.7
17	Mohindergarh . . .	7	..	..	23	..	30	4.4
18	Total Punjab . . .	4858	123	17	2322	41	7351	39.8

(Source: Statistical Abstract of Punjab, 1960, issued by Directorate of Economics and Statistics, Punjab.)

From these statistics it will be evident, that ground water is a major source of irrigation in the districts of Jullundur, Ludhiana, Hoshiarpur, Kapurthala, Patiala, Ambala, Gurgaon and Mahindergarh. Even in the districts of Gurdaspur, Amritsar, Ferozepur, Sangrur, Karnal and Rohtak, where canal irrigation is quite extensive, the ground water is being used on a very high percentage of the area. The necessity of pumping and using the ground water for irrigation purposes has been felt in the canal irrigated areas of many districts such as Amritsar, Gurdaspur, Sangrur, Patiala, Karnal and Ambala, even as an anti-water-logging measure.

Uppal states that survey of the water table in the Punjab revealed, that deep waters are brackish while water from high water tables are sweet. The North-West part of the Punjab State has sweet water, while the south-east part has highly brackish water. In certain tracts such as Rewari, Bhawani, Hansi, Sirsa and Hissar, the salt content of ground water is very high. Even reasonable dilution with canal water will not make it fit for irrigation. In sweet water areas also there are pockets of highly brackish water.

The Punjab irrigation department has seven pilot schemes comprising of 12 miles radius of Amritsar, Zira, Hansi, Fazilka, Sangrur, Sunam, Suffaidon and Munik. Detailed studies of these areas are being made for the depth of soil crust, underground strata upto

100 feet depth, soil survey and water quality survey. In Amritsar within a radius of 12 miles, it has been observed that in 186 out of 240 bores, the depth of soil crust varies from 0 to 20 feet. For another 36 bores, it varies from 20 to 30 feet and in 18 bores only it is more than 30 feet. Except in 46 sites, the quality of ground-water in the rest, i.e., 81 per cent of the sites is good. These studies indicate, that in districts like Amritsar, Gurdaspur, Jullundur, Karnal etc. where canal irrigation has resulted in serious water logging, the ground water is generally of good quality and can be exploited through shallow tubes wells or percolation wells and the canal water thus saved can be used elsewhere. Actually there seems to be no necessity of using canal water in these areas. Well irrigation in these areas will not only mitigate the trouble of water logging, but also help in extending irrigation to drier parts of the country, where for want of means of irrigation, agriculture is restricted.

Ferozepur.—The position of underground water supply in this district is not easy in most of the parts particularly for the sinking of deep tubewells of sufficient yield. Although the depth of sub-soil water level in most of the North-Western parts is quite shallow i.e., from 5 to 25 feet below ground surface, but the quality of water beyond the first water bearing strata in most of the cases is unfit for irrigation purposes.

In some parts of this region, i.e. from Talwandi Bhai towards Faridkot, even the water of first strata is not fit for irrigation purposes. In the South-Eastern parts of this district, the depth of water level from ground surface varies from 60 to 120 feet and saline water is tapped from the sub-soil and other deep horizons. Well or tubewell irrigation in limited quantity is, practicable in the north western parts of this district.

Karnal.—For the purpose of underground water supply position this district can be divided into three regions:—

- (i) Area to the East of Delhi tributary of Western Jumna Canal. In this region the depth of water level is shallow viz. 0 to 15 feet below ground surface. The underground water supply is satisfactory and successful wells and tube wells can be sunk to the depths of 35 feet to 300 feet below ground surface respectively.
- (ii) Central Western Region:—The depth of sub-soil water level has risen considerably due to excessive percolation from the canals, and is about 5 feet to 25 feet below ground surface. Due to shallow water level and

fitness of sub-soil water of the first strata, well irrigation has become practicable but the water of deeper horizons is brackish and unfit for irrigation purposes. Therefore, this area is not suitable for the sinking of tube-wells.

- (iii) Western region:—The depth of water level is from 25 feet to 80 feet below ground surface. The quality of water tapped from the deeper horizons is either brackish or saltish, so its utilization for irrigation purpose is very much restricted to the areas where good water is tapped due to some local factors.

Underground water supply in this district is somewhat satisfactory in the bet area of river Sabi in the South Western parts of Rewari Tehsil and some success is available in the Khaddar area along the river Jumna. The depth of sub-soil water level in these areas varies from 0 to 40 feet below ground surface and successful wells and tube-wells can be sunk to the depths of 60 to 400 feet respectively. On the either sides of Aravali hills, well irrigation is successful in limited quantity as percolation from the sub-soil is very poor. The depth of sub-soil water level varies from 20 to 120 feet below ground surface. In most of the cases, brackish or saltish water is tapped. As a whole, the underground water supply position is hopeless.

Hissar.—Leaving aside the Ghaggar bet area, where the depth of sub-soil water level varies from 10 to 40 feet and successful wells and tube-wells can be installed to the depth of 60 to 400 feet respectively, in rest of the areas either well or tube-well irrigation is not practicable, because brackish water is tapped from the sub-soil and other deep strata. Even in the Hansi-Jind area, where the sub-soil water level is high, well irrigation is not possible because the water of sub-soil is not fit for irrigation purposes.

For assessing the underground water supply, this district can be divided into three parts:—

- (a) *Area lying on the left side of the river Ghaggar*.—This area can further be divided into two parts (i) Ghaggar bet area: This area is suitable for sinking of wells as well as tube-wells. The depth of success is 60 to 400 feet respectively and the depth of sub-soil water level varies from 5 to 40 feet. (ii) Area beyond and above on the left side of the river Ghaggar is neither suitable for sinking wells nor tube-wells, because the quality

of sub-soil water obtained in most of the cases is not good for irrigation purposes.

- (i) *The area lying on the South-Western side of Barnala and Sunam.*—This area is not very suitable for sinking of tubewells because the water of deep strata is not fit for irrigation purposes. The depth of sub-soil water level is moderate and varies from 10 to 40 feet below ground surface. The well irrigation is not very common as in some parts sub-soil water is unfit for irrigation purposes.
- (ii) The underground water resources in rest of the district are quite rich and both well and tube-well irrigation is very successful. The depth of sub-soil water level varies from 5 to 20 feet below ground surface and successful depths of wells and tube-wells varies from 25 to 40 feet and 150 to 300 feet respectively.

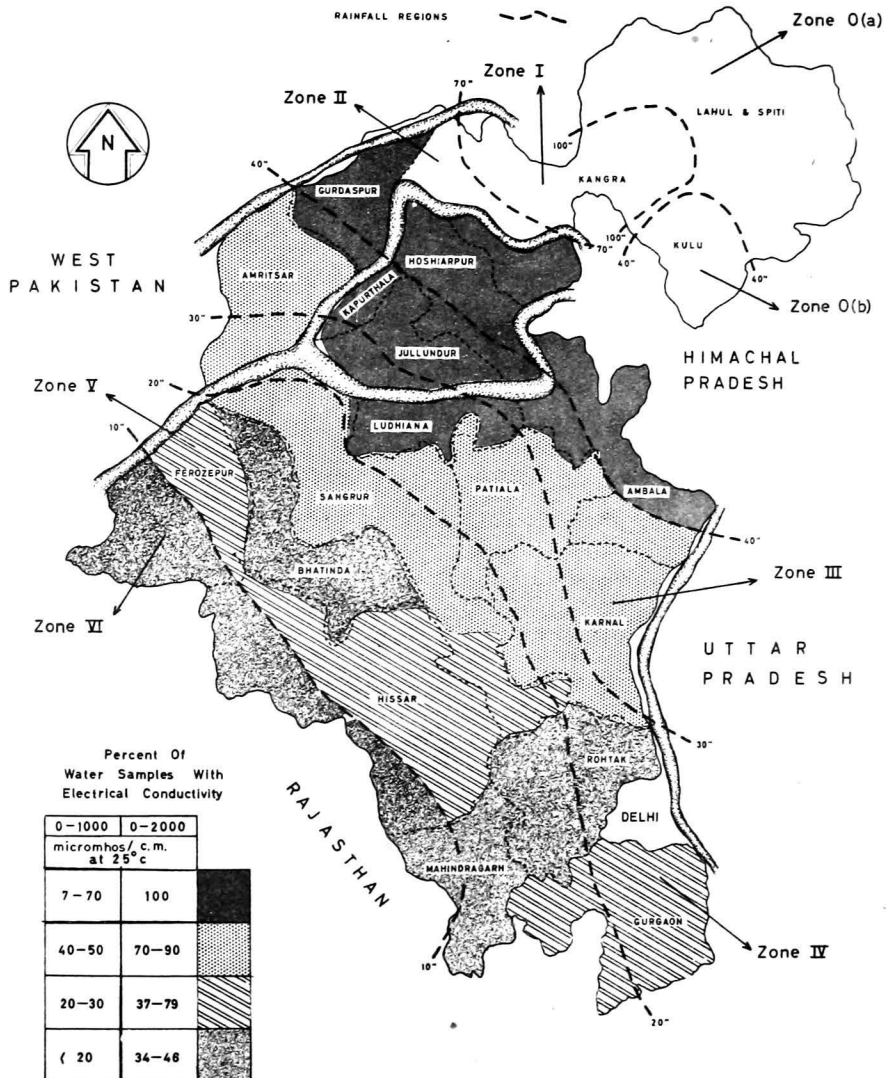
Bhatinda.—Leaving aside the areas lying between Dhuri-Bhatinda and Bhatinda-Ferozepur railway lines on the north-eastern sides of the district, the underground water supply position is unsatisfactory and saline or brackish water is tapped from the sub-soil. But in the remaining areas very little underground water supply is available and that too only near the first water bearing strata. The water of subsequent strata is unfit for irrigation purposes. The depth of water level in the successful area varies from 5 to 45 feet below ground surface, and in the unsuccessful areas from 45 to 150 feet below ground surface.

Quality of ground waters of the Punjab.—Although no regular survey of the quality of ground water has been made, however, from numerous analyses done by soil testing laboratories in respect of percolation and tube-well water samples collected from cultivators, and some special short projects for the determination of quality of irrigation water undertaken by the Agricultural Chemist, Punjab, in the districts of Gurgaon, Mohindergarh, Hoshiarpur, Amritsar and Rohtak, and irrigation department in the Bhakra Canal project areas, it is possible to form an idea about the quality of irrigation water in different districts of the State. Since no uniform pattern for reporting results has been followed therefore, only salient features of these studies are discussed below:—

In a survey of Bhakra Canal project areas Dhawan et al 26 concluded, that the percentage of good waters in Hissar, Karnal, Ludhiana, Ferozepur, Jullundur and Hoshiarpur districts is 30, 38, 100, 17, 90 and 100 per cent respectively.

MAP-13

GROUND WATER ZONES OF THE PUNJAB BASED ON ITS QUALITY FOR IRRIGATION
Electrical Conductivity



In table 18, the distribution of water samples in different districts in various categories according to electrical conductivity of water, which is a measure of salt load is shown (Ref. Map 13). The average chemical analysis of water is also given in the above table. The division of good waters of various districts can be made as shown in table 19.

Table 18

Showing distribution of water samples of different qualities in different districts

District	Percentage of water samples in each category according to electrical conductivity—EC X10 ⁶					Average chemical analysis m.e. per litre					Analyst	
	A	B	C	D	E	ECx10 ⁶	CO ₂	HCO ₃	Ce+SO ₄	Ca+Mg		
	0—1000	1000—2000	2000—3000	3000—5000	5000							
Gurdaspur . . .	90	10
Hoshiarpur . . .	100,82	18
Jullundur . . .	*90,83	17	..	..	..	900	nil	6.50	1.59	4.90	Agri. Chemist Pb.
Kapurthala . . .	80	20	..	..	..	728	nil	6.40	1.07	4.31	"
Ambala	72	22	..	..	..	872	nil	6.17	1.76	4.63	"
Ludhiana	*100,54	46	..	..	..	966	0.63	6.92	1.40	4.91	"
Amritsar	50	30	8	..	2	1181	0.61	10.20	1.70	4.20	"	
Sangrur	50	16	16	18	..	1742	..	12.15	3.60	6.60	"	
Patiala	45	47	5	3	..	1047	..	7.73	2.3	6.60	"	
Karnal	42	48	6	4	..	..	..	..	..	..	..
Rohtak	8	26	7	19	40	..	..	..	..	..	..
Gurgaon	23	27	14	18	18	3505	..	8.23	22.12	16.49	"	
Hissar	*30,25	12	38	..	25	..	..	..	..	..	..
Ferozepur	32	47	11	5	4	1904	6.51	9.74	5.40	5.33	"	
Mohindergarh	14	32	9	23	22	..	..	..	..	..	..
Bhatinda	16	30	15	24	15	2996	1.0	9.52	10.5	8.90	"	

*Analysed by Director, Irrigation and Power Research Institute, Amritsar.

Table 19

Division of good waters of various districts

Sl. No.	District	Percentage of water samples in various categories	
		A	A+B
1	Hoshiarpur, Gurdaspur, Kapurthala, Jullundur, Ludhiana, Ambala	>70	100
2	Patiala, Sangrur, Amritsar, Karaal	40—50	70—90
3	Gurgaon, Hissar, Ferozepur	20—30	37—79
4	Mohindergarh, Bhatinda, Rohtak	20	34—46
4	Mohindergarh, Bhatinda, Rohtak	<20	34—46

A=EC. 10⁶(0—1000) B=EC. 10⁶(1000—2000)

From these results, it would appear, that in the districts of Hoshiarpur, Kapurthala, Jullundur, Ludhiana, Ambala and Gurdaspur, generally the ground water is of excellent quality and it should be used as extensively as possible. It also follows, that in these districts, there is no necessity of using canal water. In fact canal irrigation is simply adding to water logging trouble, which is increasing at an alarming rate. Canal irrigation in these areas can be restricted only if cheap motive power is supplied to the farmers, so that they are encouraged to sink more of percolation wells and install pumping sets and tubewells. Since in this way, the canal water can be liberated for use in other drier areas, where ground water is of brackish nature, therefore, the part of the cost of energy to be supplied to this region for minor irrigation should be borne by the people of the dry area, who will be benefited by this policy.

It also seems desirable, that intensive survey of the quality of water in these areas should be done so that the marginal and bad quality waters, if any, should be located and suitable measures for improving their quality taken.

It also necessitates detailed soil survey of this area so that the soils which are not suitable for a particular type of water may be demarcated and steps taken to improve them or suitable crops introduced so that successful farming may be possible.

It may be mentioned, that this classification of ground water is only tentative and actually the satisfactory classification is possible only if quality of water both with regard to conductivity, residual sodium carbonate, S.A.R., boron content and plant nutrient content of water particularly nitrate and potash is considered along with

the soil, crop and climatic factors. Kanwar has proposed a triangular diagram for the classification of water (Fig 3). In this diagram the suitability of water is determined by its chemical composition (salinity and sodium hazard), crop and soil texture. Instead of 16 classes of quality as proposed by U.S.S.L.⁹⁴ (p. 54), 20 classes are proposed. The categories of sodium hazard are the same as of U.S.S.L., but instead of four categories of conductivity five, as given below, are proposed.

Low	C1=0	—250 micro mhos/cm	} at 25°C
Moderate	C2=250	—750 micro mhos/cm	
Medium to High	C3=750	—2250 micro mhos/cm	
High	C4=2250	—5000 micro mhos/cm	
Very high	C5=5000	—10,000 micro mhos/cm	

Soils:—Soils are divided into four major textural groups.

1. Sand
2. Sandy Loam (Loamy sand and sandy loam)
3. Loam (Silt loam, clay loam, sandy clay loam and loam)
4. Clay (Silty clay, sandy clay and clay)

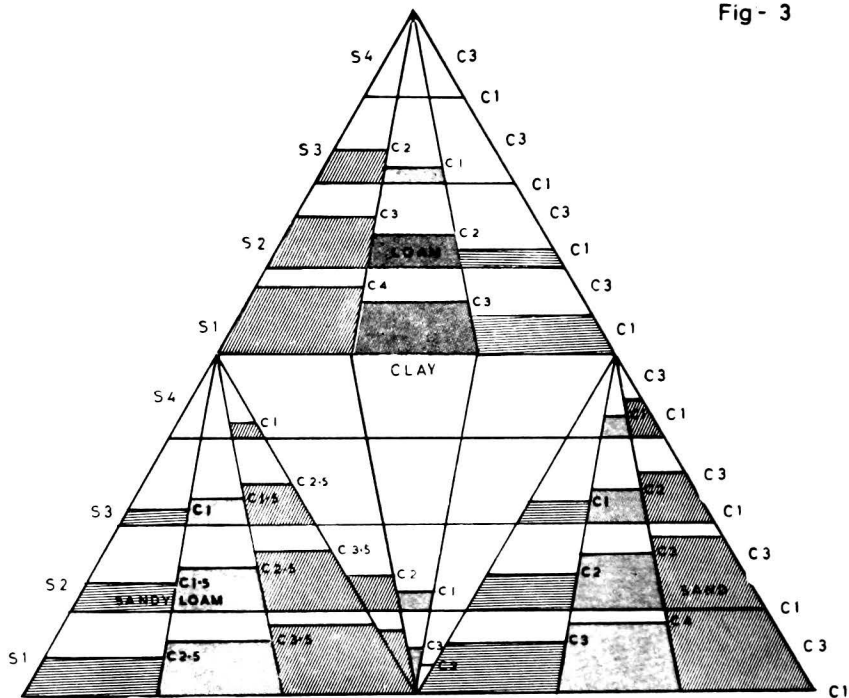
Crop Groups.—The crops are divided into three categories according to salt tolerance and sensitivity to sodium. The main classes are sensitive, semitolerant and tolerant to salts. The common crops in the Punjab are arranged in descending order of tolerance in table 19(A).

Table 19(A)

Type	Sensitive crops	Semi tolerant crops	Tolerant crops
Field crops	Field Beans	Wheat	Barley
		Oats	Dhaincha
		Rice	Sugarbeet
		Jowar	Tobacco
		Maize	Turnips
		Arhar	
		Flax	
		Safflower	Cotton
		Castor	Wheat (Local variet
		Beans	Sugarcane
			Taramira
		Fodders	Guara	Turnips . . . . .	Salt bush
Senji	Bermuda		
	Grass or		
Sudan Grass	Dub Grass		
Lucern	Rhodes Grass		
Metha			
Jowar			
Maize			
Berseem			
Cowpea			

TRIANGULAR DIAGRAM FOR DETERMINING THE SUITABILITY OF IRRIGATION WATER

Fig- 3



Salinity Hazard Classes of Irrigation Water

LOW	C ₁	0-750	}	micromhos/cm at 25°C
MODERATE	C ₂	750-2250		
MEDIUM to HIGH	C ₃	2250-5000		
HIGH	C ₄	5000-20000		
VERY HIGH	C ₅			

Sodium Hazard Classes of Irrigation Water

LOW	S ₁
MODERATE	S ₂
HIGH	S ₃
VERY HIGH	S ₄

- WATER UNSUITABLE FOR IRRIGATION PURPOSES
- WATER SUITABLE FOR IRRIGATION PURPOSES EVEN FOR SENSITIVE CROPS
- WATER SUITABLE FOR IRRIGATION PURPOSES FOR TOLERANT CROPS
- WATER SUITABLE FOR IRRIGATION PURPOSES FOR SEMI-TOLERANT CROPS

Types	Sensitive crops	Semi tolerant crops	Tolerant crops	
Vegetables	Celery	Tomato	Turnip	
		Cabbage	Beet-root	
	Radish	Cauliflower	Kale	
	(English variety)	Lettuce	Asparagus	
		Potato	Spinach	
		Carrot	Radish	
		Onion		
		Pea		
		Cucumber		
		Pumpkin		
		Karela		
	Fruits		Pomegranate	Date-Palm
			Olive	Falsa
			Fig	
			Grape	
		Guava		
		Mango		
		Banana		
		Pear		
		Apple		
		Orange		
		Grape fruit		
		Prune		
		Plum		
		Almond		
		Apricot		
	Peach			
	Strawberry			
	Lemon			

Sodium hazard Classes of Irrigation Water:

Low	S ₁
Moderate	S ₂
High	S ₃
Very high	S ₄

The suitability of irrigation water for different types of soils and crops is given in table 20 (Fig. 3).

Table 20

Upper limit of the suitability of different classes of water of soil of various textures and crops of different degrees of salt tolerance.

Soil Texture	Upper limit of suitable classes of water		
	Sensitive crops	Semi-to-lerant crops	Tolerant crops
I	2	3	4
Clay	S ₁ C ₂	S ₁ C ₃	S ₁ C ₄
	x	S ₂ C ₁	S ₂ C ₂
	x	x	x
	x	x	x

1	2	3	4
Loam	S ₁ C ₂ S ₂ C ₁ x x	S ₁ C ₃ S ₂ C ₂ S ₃ C ₁ x	S ₁ C ₄ S ₂ C ₃ S ₃ C ₂ x
Sandy Loam	S ₁ C _{2.5} S ₂ C _{1.5} S ₃ C ₁ x	S ₁ C _{3.5} S ₂ C _{2.5} S ₃ C _{1.5} x	S ₁ C _{4.5} S ₂ C _{3.5} S ₃ C _{2.5} x
Sand	S ₁ C ₃ S ₂ C ₂ S ₃ C ₁ x	S ₁ C ₄ S ₂ C ₃ S ₃ C ₂ S ₄ C ₁	S ₁ C ₅ S ₂ C ₄ S ₃ C ₃ S ₄ C ₂

It must be admitted that the data are very meagre and more detailed investigations are needed to determine the compatibility and quality of irrigation water and crops. The tolerance of crops for total salts, sodium, boron and other toxic constituents would vary not only with the nature of the crops, but also with its variety. For instance, there is a certain local variety of wheat called 'Kharchi' which has been selected by the farmers of Gurgaon and adjoining districts of Rajasthan after centuries of experience, which can be grown with very saline waters more successfully than the improved varieties.

Secondly it has also been noticed, that these irrigation waters, which contain nitrates can be used quite successfully even though they are high in salt content. The main relieving factor in this case is the nitrate content of these waters. It indicates that if the fertility status of the soil is improved, saline waters also can be used by crops advantageously.

Adding of fertilizers and manures and improvements in the fertility status of the soil make the crops more tolerant to salts. Thus the use of fertilizers should also help in the use of more saline waters. With suitable agronomic practices, selecting the proper type of seed beds, and choosing the right time for the application of irrigation water, it is possible to use comparatively more saline waters.

Thus it may be concluded, that in the present state of our knowledge, the interpretation of quality of water without the consideration of soil, crop, climate and agronomic practices is not very useful.

Boron content of waters.—The boron which can become toxic to plants is quite widely distributed in the ground waters of the

Punjab. The amount, however, varies with the nature of soil strata. Kanwar and S. S. Shah Singh ^{85A} determined the boron content of irrigation waters of Punjab and their results are given in table 21.

Table 21

Showing boron content of water samples of different districts

District	Water samples tested	Boron ppm.
Hoshiarpur	3	0.19
Gurdaspur	3	0.20
Kapurthala	3	0.18
Jullundur	3	0.16
Ludhiana	3	0.21
Karnal	3	0.13
Patiala	3	0.22
Rohtak	2	0.25
Sangrur	5	0.31
Ferozepur	3	1.52
Hissar	4	0.16
<i>Gurgaon Distt.</i> Gurgaon Tehsil	6	0.31
Balabgarh	2	1.29
Palwal	2	0.41
Ferozepur Jhirka	1	0.67
Nuh	1	0.10
Rewari	3	0.65
Bawal	2	1.58

From the above table it may be concluded, that generally boron content of these waters except in Ferozepur and parts of Gurgaon is not high, but its effect on the soil will depend on the permeability of the soil and its other physical and chemical characteristics. The studies conducted by these authors have also revealed, that even though boron was present in safe limits in the waters of Patti Tehsil of Amritsar district, but its accumulative effect because of low permeability of the soil and rise of water table has led to the accumulation of toxic amounts of boron. Thus it follows, that in these areas where ground water is generally of good quality, the boron status of water and soil should be determined so as to predict the probable effect of water on the soil.

The quality ratings of ground waters of different areas have been super-imposed on the soil zones of the Punjab and water suitability map prepared which is shown in Fig 1.

From this map it is evident that in soils of zones IV and V, which have high pH and salinity, the ground waters are also of poor quality and even their boron content is high, thus the bad effect of such waters on soils becomes soon apparent. In these areas, therefore, more and more of canal water should be used. The extension of canal irrigation should proceed along with the installation of good drainage system so that the possibilities of water-logging are minimised.

From these results, it would appear that most of the waters in this district have high salinity as well as high sodium hazard. They generally fall in C_3 to C_4 and S_3 to S_4 class according to U.S.S.L. classification system, but in spite of such high salinity and sodium hazard, they did not produce any bad effect on the soils of the area. It is probably attributed to any of the following reasons:—

- (i) Light texture of the soil
- (ii) Good drainage conditions
- (iii) Growing of salt tolerant crops of barley and wheat
- (iv) High nitrate and potash contents of waters which stimulates crop growth and makes it more tolerant of salinity.
- (v) Occasional heavy showers of rains, which leach down the accumulated residual salt.

Thus as pointed out by Kanwar³⁵ the quality rating of water without the knowledge of soil, crop, and climatic conditions is misleading. It also stands to reason, that for exploring the ground water potentials of an area, the soil, water, crop, and climate inter-relation must be taken into consideration. This calls for detailed soil and water survey and adoption of suitable cropping and irrigation patterns. The effect of fertilizers and manures in mitigating the bad effect of comparatively more saline and alkaline waters should also be considered.

Delhi State

In Delhi State, 41 per cent of the irrigation in 1956-57 was done from wells and tube wells. The average depth of sub-soil water in this State is generally 8-10 feet. The soils are sandy loam on the

surface and alkaline in reaction. An analysis of 168 water samples from this area revealed the following results:—

Table 22

pH	7.2 to 9.1
Conductivity ECx10 ⁶	220 to 14000
Carbonates	0 to 4.8 m.e./litre
Bicarbonate	0.5 to 27.8 m.e./litre
Chloride	0.2 to 114.9 m.e./litre
Sulphate	0.01 to 71.8 m.e./litre
S.A.R.	0.62 to 48.0

Classification of waters

Conductivity	percentage of water samples
0—1000 mmho/cm	16
1000—2000 „	21
2000—3000 „	12
3000—5000 „	13
5000 and above	38

From the above results, it would appear that only 16 per cent water samples are of very good quality and majority of waters in this region have high salinity. The analysis of these waters for boron is not available, nor any critical study seems to have been conducted to determine the effect of these waters on the soils. Since most of the crops grown in this area are generally wheat, barley, gram and jowar which are not very sensitive to salinity, therefore, the farmers are using these waters.

Although canal irrigation is also being extended in this State, but well irrigation would continue to be the most important source of irrigation. In view of the fact, that the sub-soil water is also on the increase in this state, it becomes all the more desirable to make use of ground water for irrigation purposes. Thus there is an urgent need for a systematic detailed survey of the quality of ground waters in this State and interpreting the results of such analysis in the light of soil surveys of the area. This project should be taken up on a priority basis, as any extension of canal irrigation is likely to lead to more serious trouble of water-logging.

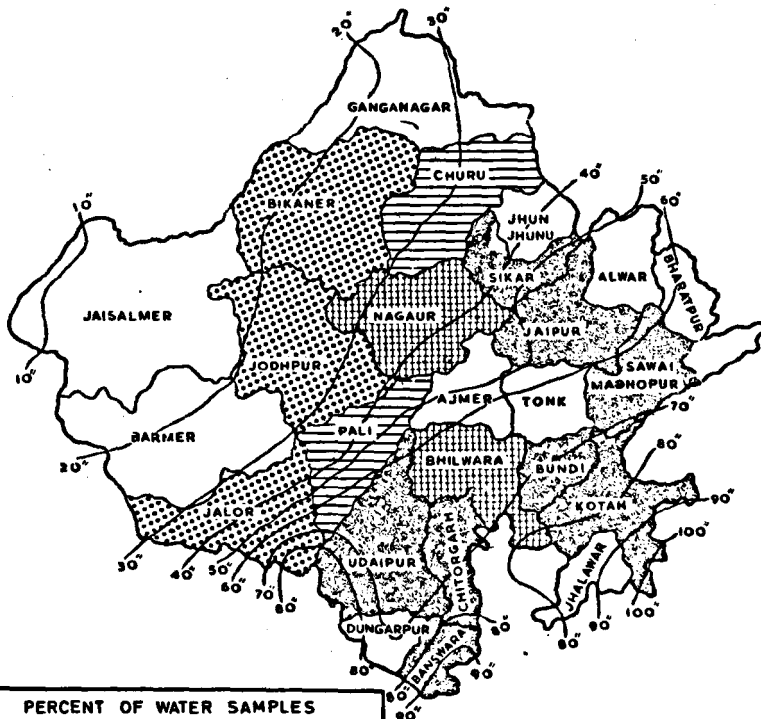
Rajasthan

In Rajasthan the underground water is still a major source of irrigation which covers about 33 lac acres of irrigated land. According to Directorate of Economics & Statistics (1958-59 report), 50 per cent of the net area cultivated under irrigation was receiving water by wells. The water used for irrigation are generally saline and in some cases they are alkaline also. The distribution of good and bad water does not have any particular pattern though generally in the zones of alluvial and medium black soils, good quality waters are of more common occurrence. According to the Agricultural Chemist, Rajasthan, in the districts of Jaisalmer, Barmer, Jalore, Jodhpur, Bikaner, Churu, Sriganganagar, Nagar, Sikar, Jhunjhunu and parts of Jaipur, Pali, Ajmer, Bhilwara, Alwar and Bharatpur, at least more than 50 per cent waters are highly saline and the salinity varies from 3 mmhos to 20 mmhos. The saline waters of Rajasthan contain mostly sodium sulphate and sodium chloride and in some cases sodium bioarbonates also. In most cases the Ca/Na ratio is very low and sodium forms 90 per cent of the total cations. According to general standards for quality ratings of water, they are extremely saline. Based on the conductivity of the irrigation water, the well waters of every district of Rajasthan are divided into various categories (table 23) and along with the percentage of well waters falling in each category, the analysis of typical waters of each category is also shown in this table. From these data it would appear that according to quality, the well waters in the different districts of Rajasthan can be grouped into 4 zones as shown below in table 4 (Map 14).

GROUND WATER ZONES OF RAJASTHAN

BASED ON ITS QUALITY FOR IRRIGATION
(ELECTRICAL CONDUCTIVITY)

MAP 14



PERCENT OF WATER SAMPLES FALLING INTO DIFFERENT CATEGORIES .
MICRO-MHOS/CM

CATAGORY-A	CATAGORY-A+B	CATAGORY-C+D+E
60-100	75-100	NIL
20-30	25-50	50-75
10-20	14-25	75-85
< 10	25-40	60-75
NO INFORMATION IS AVAILABLE .		

Table 23

Showing distribution of irrigation waters of different districts in various categories and their chemical composition.

Serial No.	Division and District	No. of water samples	Percentage of water samples in each category according to electrical conductivity					Average chemical analysis of some typical waters							
								milliequivalent per litre							
			A	B	C	D	E	Ca	Mg	Na	CO ₃	HCO ₃	SO ₄	Cl	
			0-1000	1000-2000	2000-3000	3000-5000	5000 and above								
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
1	Jodhpur	50	26	Nil	12	20	42	A 9.6	4.0	Nil	..	6.8	2.0	5.0	
								B 6.0	4.94	14.24	..	2.5	5.62	17.5	
								C 2.5	6.36	68.0	..	2.2	4.0	50.0	
								D 7.8	4.29	42.0	..	5.5	18.48	30.0	
								E 19.6	16.26	164.0	..	4.0	24.2	175.0	
2	Nagaur	45	6.6	31.1	17.7	31.2	13.3	A 2.3	2.0	8.5	1.60	3.1	2.77	5.36	
								B 4.5	1.0	16.34	1.60	7.1	8.3	5.1	
								C 5.5	2.91	29.93	0.68	6.4	25.66	5.5	
								D 5.11	3.16	37.25	0.60	14.2	24.9	5.74	
								E 9.8	5.04	61.93	1.20	14.1	40.75	25.0	
3	Jalga	51	24	24	24	25.5	2.5	A 2.4	3.16	8.68	..	5.39	2.16	6.86	
								B 3.2	1.60	8.14	..	4.59	2.02	6.47	
								C 4.8	0.48	31.25	..	6.8	4.6	25.71	
								D 5.2	14.00	36.43	..	6.0	7.35	42.5	
								E 8.4	7.28	122.43	..	41.59	2.0	95.16	
4	Pali	39	15.6	10.2	28.2	18.0	28.2	A 5.2	2.66	4.3	0.5	5.64	3.10	3.10	
								B 11.2	4.0	11.9	0.416	5.8	10.30	11.60	
								C 17.6	4.0	17.5	0.266	1.93	0.51	37.17	
								D 16.6	5.0	2.4	0.3	5.14	11.16	3.30	
								E	..	..	..	..	..	..

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
5	Bikaner . . .	4	25	25	50	..	..	..	..	..	..	(Samples not analysed so far)		
6	Churu . . .	7	14	..	..	..	85.7	A 0.85 B 2.35	0.2 8.75	9.2 12.78	.. 1.54	7.3 2.0	1.40 1.36	0.9 9.0
7	Udaipur . . .	34	61.8	17.6	3.0	11.8	5.8	A 5.75 B 1.70 C 16.30 D 11.60 E 2.35	1.4 5.2 .. 16.6 8.95	2.9 21.17 25.7 34.64 127.79	1.0 0.4 6.0 1.2 15.46	3.7 5.2 8.0 6.2 20.0	1.54 15.2 9.89 7.5 13.63	2.28 7.0 29.0 47.4 90.0
8	Bhilwara . . .	34	9.7	16.1	48.4	19.35	6.45	A 1.25 B C D E	1.05	1.75 .. .. .. ..	..	2.97	0.216	0.65
9	Chittorgarh . . .	2	100	..	..	..	..	A 8.05	..	..	..	4.8	1.9	1.3
10	Banswara . . .	5	100	..	..	..	..	A 8.0	0.4	2.9	..	6.6	1.73	2.8
11	Kotah and Bundi	317	72.4]	23.3	1.8	2.0	0.3	A 2.0 B 0.2 C 10.0 D 46.58 E 11.6	.. 5.4 8.83 6.3 15.3	6.5 15.0 11.6 6.6 13.3	.. 0.8 .. 2.4 ..	7.0 1.4 4.6 32.6 13.6	0.75 6.6 23.6 15.0 40.8	0.8 4.6 7.5 22.8 3.9
12	Jaipur . . .	21	66.6	9.52	23.8	0.4	..	A 1.5 B 1.6 C 4.67 D 5.15	0.2 1.0 1.4 1.0	6.37 22.0 32.2 57.5	.. .. .. ..	7.19 8.4 5.4 4.4	0.05 5.4 5.4 4.1	1.2 10.5 26.56 49.0
13	Sawaimadhopur . . .	6	100	..	..	..	..	A 0.35	1.25	2.78	0.31	2.26	0.33	1.48

14	Sikar	.	.	1	100	..	..	..	..	A 3.2	..	4.52	0.3	5.0	1.5	2.3
15	Jhunjhunu	.	.	1	..	100	..	..	..	B 3.0	0.80	23.3	0.2	15.59	3.48	8.0
16	Alwar	.	.	2	..	50	..	..	50	B 2.67	1.0	14.54	1.6	23.6	1.5	1.4
										E 11.78	6.4	53.8	0.4	1.6	22.47	47.3

Source : Personal communication from Shri K.M. Mehta Agricultural Chemist, Rajasthan.

Table—24

Percent of water samples falling into different categories

*Group	Name of the district	Category	Category	Category
		A 0—1000	(A+B) 0—2000	(C+D+E) 2000—5000
1.	Udaipur, Chittorgarh Banswara, Kotah, Bundi, Sawai madhopur, Sikar, Jaipur	60—100	75—100	Nil
2.	Bikaner, Jodhpur, Jalore	20—30	25—50	50—75
3.	Churu, Pali	10—20	15—25	75—85
4.	Nagaur, Bhilwara	10	25—40	60—75

It must be mentioned, that this classification is based on very meagre data, therefore, no generalisation is possible. However, it is evident, that in the districts of group 1, there is a possibility of the extension of well irrigation by tapping the ground water which is generally of good quality. Concerted efforts should be made to make detailed survey of ground water, depth of ground water and types of soils in this area so as to clearly demarcate the zones in which percolation well or tubewell irrigation should be intensified.

In the districts of Bikaner, Jodhpur, Jalore, Churu, Pali, Nagaur and Bhilwara, where high percentage of well water are saline, the use of ground water for irrigation is fraught with danger.

Ground water survey.—Systematic survey of ground water in the different districts of the State has not been done and much less detailed information on the water table depth, water bearing strata, quality of water etc. is available. However, in the districts of Jodhpur, Pali and Bhilwara, some detailed soil survey and irrigation water surveys have been done and the results are discussed below.

Jodhpur district.—Jodhpur district is in western Rajasthan and is situated between 25°-45° and 27°-30° N latitude and 71°-31° to 73°-50 longitude. The district as such does not have any mountains but there are scattered rocky ridges of hills in the eastern part of the district in Bhilwara and Jodhpur tehsils which are stony, naked and devoid of vegetation. In the western part of the district is the vast undulating plain of shifting sand dunes which form a part of Thar desert.

There is no perennial river, except Luni river, which is also seasonal and receives the drainage water from the Aravallies. The water of this river is saline beyond Balotra in Barmer district.

Quality of water.—The pH of the water varies from 7·1 to 8·5 and the general range is 7·7 to 7·9. Electrical conductivity varies from 7·5 to 32 mmhos/cm. The detailed results of analysis of water is given in table 25.

From these results it will appear, that sodium is the predominant cation, which generally forms more than 80 to 90 percent of the total cations. Carbonates are negligible and bicarbonates vary from 2·18 to 12·04 m.e./litre. The chlorides predominate varying from 5·1 to 146 m.e./litres. SAR. varies from 3·7 to 125·07 and the general value is more than 15·0. Thus the main problems of irrigation waters are high conductivity, high sodium and high SAR, which are unfavourable to general crops.

A very detailed soil and ground water surveys was carried out in villages Kaparda, Palasni and Goliya, which are irrigated with well water. The analysis of water samples in these villages reveals the following facts:—

Table 25

Analysis of typical water samples of Jodhpur district, Rajasthan

Village	pH	Ec mhos cm at 25° C	Cations me/litre				Anion me/litre				
			Ca ⁺	Mg ⁺	Na ⁺	K ⁺	CO ₃	HCO ₃	SO ₄	Cl	SAR
Stalana . . .	7.7	18.0	8.61	14.58	156.00	0.68	0.00	3.56	53.47	123.00	45.74
Surpura . . .	7.4	13.50	13.51	24.75	96.00	10.21	0.33	5.76	7.74	121.00	21.72
Manklao . . .	8.5	7.80	2.55	6.36	68.00	1.04	0.00	2.18	4.00	50.00	32.2
urpura . . .	7.8	14.0	2.80	2.64	133.00	0.38	0.00	5.32	39.50	94.00	80.30
Manklao . . .	8.1	8.50	4.08	5.82	77.00	2.10	0.00	6.18	27.82	54.00	30.11
Manklao . . .	8.6	18.00	2.55	9.41	173.00	2.04	0.80	12.04	28.95	140.00	125.01
Lordi . . .	8.6	18.0	2.04	1.92	176.00	1.04	0.92	9.80	24.20	145.00	125.07
Manklao . . .	8.5	7.80	2.55	6.36	68.00	1.04	0.00	2.18	4.00	50.00	32.2
Bilaspur . . .	8.1	1.8	3.31	2.13	14.80	0.96	0.10	6.20	6.14	8.06	8.48
Dhawa . . .	7.9	10.0	6.12	13.68	81.00	0.30	0.00	6.50	26.60	68.00	25.74
Bilaspur . . .	7.7	12.0	7.31	4.60	110.00	0.41	0.00	6.10	37.23	76.00	52.13
Baori . . .	8.9	8.0	2.5	2.80	4.87	0.19	0.20	0.00	4.20	7.67	12.00
Baori . . .	7.9	14.0	6.63	23.07	110.00	0.10	0.00	7.50	52.30	80.00	28.57
Netrada . . .	8.4	9.0	3.06	0.65	86.00	0.98	0.00	9.20	25.49	56.00	63.14
Lawera . . .	7.5	3.7	4.59	0.05	25.00	0.62	0.00	4.50	13.75	18.00	10.84
Khurd . . .	8.1	2.4	2.80	5.36	16.00	1.02	0.00	6.10	7.18	12.00	7.92
Lawera . . .	8.0	3.5	3.31	7.33	22.00	0.24	0.00	7.20	9.41	14.20	9.54
Kalan . . .	8.0	2.0	2.79	1.67	16.00	1.10	0.00	5.13	7.56	8.20	11.37
Bilara . . .	7.3	10.00	7.65	0.76	19.00	2.00	0.00	6.24	36.17	58.00	33.9
Bilara . . .	8.1	9.0	5.65	7.62	76.00	1.00	0.10	8.20	26.07	55.00	29.5
Bilara . . .	7.5	8.0	8.40	18.81	58.00	0.00	0.00	4.84	16.37	54.00	15.71
Jodhpur . . .	7.3	0.90	2.65	1.00	5.00	2.26	0.00	3.84	9.09	5.10	3.7

Table 26

	Kaparda	Palasni & Goliya
pH	7.2 to 8.6	7.3 to 7.9
E.C.	3.5 to 24.0	2.00 to 55.60
SAR	6 to 101	6 to 114
<i>cations and anions m.e./litre</i>		
Ca	4.26 to 21.26	4.30 to 27.70
Mg	4.24 to 23.00	0.98 to 51.24
Na	18.20 to 190.00	14.24 to 516.00
K	0.32 to 2.00	0.24 to 2.00
CO ₃	0.0 to 0.80	Nil
HCO ₃	1.90 to 12.50	2.5 to 10.0
SO ₄	7.84 to 55.0	2.78 to 183.1
Cl	10.0 to 210.0	11.0 to 420.0

From the above figures, it is apparent that the ground waters are extremely saline, but still they are being used for irrigation purposes. It has also been observed that as a result of irrigation with these waters, the soils have become highly saline-alkali, whereas the adjoining soils which are not irrigated are not so saline. It has happened inspite of the fact that the soils contain about 80 per cent of sand, and the silt and clay seldom exceeds 20 percent. Thus it follows that the continuous use of such waters without suitable amendments is fraught with danger. In the area where soils are already saline alkali, it is all the more undesirable to use such saline waters for irrigation.

Survey of the Quality of Water by the Geological Survey Organisation.—According to Taylor and associates⁶⁰ the Pali region lies in a single and relatively thin zone of saturation which extends through contiguous bodies of the alluvium and of igneous and metamorphic and consolidated sedimentary rocks. No locally perched water tables exist, and the regional geology precludes the existence of deep artesian aquifers.

A study of water table depth in 374 uncased wells shows, that 90 percent of the wells lie between 10 to 60 feet below the land surface

in this region. The average chemical composition of well waters derived from various rock systems in this region is as follows:—

Table 27

Rock system	No. of samples	Average salt content			Percentage of waters of different types			
		HCO ₃	Cl	SO ₄	HCO ₃	Cl	SO ₄	Mixed
Alluvial (Younger)	(15)	492	2,574	912	20.0	80.0	..	..
Alluvial (Older)	(151)	642	2,252	678	29.1	58.3	0.7	11.9
Vindhyan limestone	(14)	442	1,077	234	5.9	87.3	0.0	11.8
Malani Volcanic	(8)	1,071	1,106	775	37.5	0.0	12.5	50.0
Jalore Granite	(88)	628	1,666	721	34.1	45.4	4.6	15.9
Aravalli Slate	(82)	641	1,364	350	30.5	54.9	0.0	14.6

There is an indication of high concentration of dissolved salts in normal ground waters of most of the Pali region. Chlorides (NaCl) are the most abundant. Carbonates are generally absent or present as traces. Bicarbonates, however, are quite abundant. Sulphates are generally slightly less than bicarbonates. In the above table, the percentage of well waters with more than 50% of the anions of HCO₃, Cl, SO₄ or mixed type is also shown. Thus it would appear that in Malani volcanic, Jalore granite and Aravalli slate systems, the percentage of waters is of bicarbonate type and in other of chloride type.

Survey of Quality of Water by Agricultural Chemist, Rajasthan.— From the analysis of water samples done by the Agricultural Chemist, Rajasthan, it is apparent that the pH and electrical conductivity of the underground waters varies from 7.4 to 8.5 and 1.0 to 22.0 mmhos/cm. In case of Pali and Sojat tehsils, the pH of well waters is generally below 8.0 and the electrical conductivity more than 8.0, while in case of Kharchi, Bali, Desuri and Jaitran tehsils, the pH is more than 8.0 and conductivity less than 5.0. The pH and electrical conductivity of soils follow the pH and electrical conductivity of well waters. The soil irrigated with waters of pH more than 8.0 and electrical conductivity less than 5 mmhos/cm. shows:

pH more than 8.8. In the case of soils irrigated by waters with a pH less than 8.0, the soil pH, too remains below 8.8, but the electrical conductivity of the soil extracts shows high values. The areas irrigated by the tanks also show, rise in pH and electrical conductivity at certain places.

Bhilwara district.—The district consists of elevated plateau with gradual slopes to the north-east. The important rivers of the district are the Banas, Mansi, Khari, Kothari and the Berach. The drainage of the area is good. There are 340 small storage tanks each irrigating about 250 acres and covering 46,032 acres in all. Besides, there are major tanks which contribute for an estimated irrigation of 78,000 acres. The underground water table is about 20 feet and there are 72,000 wells out of which 70 percent are in use, irrigating about 2,49,000 acres.

Quality of waters.—The underground waters of the area vary in pH from 7.5 to 9.0 and generally is more than 8.3 indicating the presence of CO_3 and HCO_3 . The electrical conductivity ranges from 0.2 to 15.0 mmhos/cm at 25°C , but is generally below 5.0. The problem of bad waters is prevalent in the tehsils of Banera, Gulabpura, Mandal, Bhilwara and Asind.

General observations.—From the foregoing it is evident, that in Rajasthan, even the well waters are highly saline, but still they are being used extensively. The use of such waters, no doubt, make difference between the failure and success of a crop, but the continuous use of such waters has resulted in salinity and alkalinity problem in the soil. To ward off the effect of such waters, the common practice with the farmers is to leave the fields fallow for 1 to 4 years depending upon the intensity. The idea is to allow the rain water during monsoon to leach the salts, which takes 2-4 seasons, when the irrigation water contains high salts. The rabi crops are mostly confined to wheat and barley, which are resistant to saline waters. Among the varieties of wheat, Kharchi (red) wheat is commonly grown as it has acclimatised itself to highly saline waters. The yields in most cases are low and have been so during the last several years, but the same practice is continuing, because there is no other source of irrigation and no solution to improve these waters. The farmers have learnt by experinece, that if farmyard manure is used, the bad effect of saline waters can be mitigated. No doubt, these irrigation waters produce salinity and alkalinity, but the farmers are obliged to use them because of scarcity of rain. Generally, most of the wheat and barley produced in Rajasthan is due to irrigation by these well waters. The Agricultural Chemist, Rajasthan, has observed that 10 tons of farmyard manure on an

average resulted in an increase of 352 lb. wheat per acre when saline water of electrical conductivity 6:0 mmhos/cm. was used. The pH of the soil was 8.1 and conductivity 1.15 mmhos/cm. as against a pH of 8.3 and electrical conductivity of 2.2 in the control. It shows, that besides providing nutrients, farmyard manure treatment also mitigated the salinising effect of water.

These results confirm the observations of Kanwar³⁸ that addition of nutrients and presence of organic manures makes the plants more tolerant of even saline waters. It may also be mentioned that wherever saline alkali soils occur, the ground waters generally are also of high salinity though reverse may be the case in the normal soils of the region.

The aforementioned studies indicate, that in Rajasthan the ground water is generally highly saline and according to prevalent standards of the quality of water, it may be considered unsuitable for irrigation purposes. However, it is being used extensively for irrigation purposes particularly for growing crops like wheat, barley etc. In case canal water were made available in these areas, the ground water could be used more successfully after dilution or the residual effect of saline water could be removed by leaching with good quality water, but this is not possible on a large scale, therefore, there is a necessity of evolving suitable techniques for reducing the salinity of waters and for introducing such crops or varieties of crops which may not be susceptible to high salinity. Determination of leaching requirements and gypsum requirements for saline waters so as to remove most of the salts from the root zone of the plant and cultivation of salt tolerant crops are some of the other important methods of using saline waters. Date palm, falsa, guava, sugarbeet, barley, wheat are some of the important economic crops, which can be grown under such conditions. There is a need for breeding or selecting more salt tolerant varieties of important economic plants so as to make the best use of available ground waters.

Gujarat

In North Gujarat tubewells were drilled in the non-saline areas after thorough geochemical investigations. The water of this tube wells was found suitable for irrigation purposes according to current standards. Later on the exploratory tube well organisation of the Government of India undertook to drill trial bores in the areas which were demarcated as saline. All these yielded waters, which contained high amounts of sodium chloride. There was a popular demand from the villagers where these trial wells were drilled to retain them for irrigation purposes, even though the water may be of marginal quality or unfit for irrigation. This problem is

inherent in the arid region of North Gujarat, where the ground water is likely to be saline and where there is no alternative source of sweet water. Shaligram⁷⁸ has reported analysis data in respect of 373 irrigation wells along with the crop and soil conditions from Viramgam Lakhtar area in North Gujarat.

Some typical analyses are given below:—

Table 28

Chemical analysis of underground water of North Gujarat
(Parts per 100 litres)

Village	Zone (Depth in feet)	Diss- olved salts	CaCO ₃	MgCO ₃	Na ₂ CO	NaHCO ₃	NaSO ₄	NaCl	pH
Ua-lam	161-207	184	15.0	17.7	..	17.7	..	116	8.0
	253-322	171	14.0	23.6	7.6	16.0	22.7	87	8.4
	667-920	148	11.0	9.3	7.6	24.8	13.4	80	8.2
Asjol	56-89	681	19.0	15.4	12.1	29.8	16.4	520	8.3
	122-146	742	26.0	19.4	14.8	..	60.1	530	8.4
	226-289	759	24.0	20.2	12.7	Nil	50.1	520	8.2
	318-360	180	15.0	10.1	3.2	Nil	13.5	118	8.3
	452-514 541-596	234	17.0	..	3.2	..	..	143	8.1
Rode	102-137	279	18.0	10.1	19.1	..	37.4	175	8.2
	430-450	216	24.0	13.5	8.5	..	14.3	119	8.3
	856-882	179	20.0	2.5	4.3	..	4.3	112	7.8

The classification of these waters has been made by the same author as follows:—

Table 29

Class	Electrical conductivity (B C x 10 ⁶)	Percentage of well waters falling in each category	Effect on crops (% cases)		
			average crops	poor crops	bad to failure
I	less than 1000	4.8	61.1	38.9	Nil
II	1000—2000	21.2	23.45	59.25	17.28
III	2000—3000	18.1	22.05	54.41	23.52
IV	3000—5000	21.3	17.07	37.8	45.70
V	5000 and above	33.4	2.0	20.0	78.0

The ground waters are thus of a moderate to highly saline nature. Sodium chloride forms the bulk of the constituent. Its content varies from 50 to 90 per cent. of the total soluble salts. Their pH value does not exceed 8.4 and most of them have pH between 7.4 and 7.8. The good quality water in 61 per cent cases produced good crop, but bad quality water (Class V) produced good crops only in 2 per cent. cases. The samples of soil from the irrigated and non-irrigated fields were collected to find out the changes in soil due to irrigation. The results proved that use of irrigation water with electrical conductivity more than 2000 micromhos/cm at 25°C increased the salt content in the soil to a considerable extent. The soil in most cases had a light texture varying from sandy to sandy loam. The salts get leached with the monsoon rains. Where the soil is not so light textured the use of saline waters of class higher than III would spell a disaster, unless cultural treatments and restricted intensity of irrigation are adopted.

V. K. Shaligram⁷³ has proposed the following criteria for water and soils of Gujarat:—

Table 30

Water Class	(in parts per 100,000 parts)					
	I	II	III	IV	V	VI
Total salts	100	150	200	250	300	More than those in class V in each case.
NaCl	40	60	100	125	150	
Na ₂ CO ₃	8	10	12	20	20	
Ca./Na	1.4	1.4	1.4	1.6	1.6	

The interpretation of the water classes and the suitability charts for irrigational use are given below:—

Table 31

Suitability Chart

Permeability of soils inch/hour	2.0 to 0.8	0.8 to 0.4	0.4 to 0.2	0.2 to 0.15	0.15 to 0.1
Water class					
Class I	Perennial	Perennial	Light perennial and seasonal	Seasonal	Seasonal with correctives.
Class II	Light perennial and seasonal	Seasonal	Seasonal with corrective	Unsuitable	Unsuitable

Permeability of soils 2.0 to 0.8 0.8 to 0.4 0.4 to 0.2 0.2 to 0.15 0.15 to 0.1
inch hour

water class

Class III	Seasonal only	Seasonal with correctives may have to be followed by leaching.	Unsuitable	Unsuitable	Unsuitable
Class IV	Seasonal only with correctives followed by leaching.	Unsuitable	"	"	"
Class V	Light seasonal on high lying lands. Use of salt resistant varieties, use of fertilizers and leaching	"	"	"	"
Class VI	Unsuitable	"	"	"	"

The system seems to be very sound but along with the salinity hazard, the sodium hazard of water, its boron content should also be considered.

The problem of salinity in the tubewell waters is linked up with their location. In the first two plans the tubewells were sunk in non-saline zones, which were demarcated on the basis of geochemical studies of the Gujarat alluvial basin. As a result the chemical failure of tube wells due to bad quality water was hardly 2.5 per cent. Any further development of the tubewell programme must, therefore, precede a thorough geo-chemical investigation so as to be sure about the possible quality and quantity of the underground waters. As a general rule, tubewells should be drilled in regions where ground water having total salts not higher than 200 parts per 100 litres or upto class III should be available. Aquifers yielding water with salts more than 250 parts per 100 litres, are the subaquiferous formation and should not be normally tapped, and no tubewell should be located in the area. If the well or tubewells are already located there, restricted use should be made for irrigation and generally class VI waters should not be used.

Kaira district.—The Kaira district of Gujrat State with rainfall of 25 inches and sandy loam alluvial soil has 86,100 acres under irrigation. Out of this area, 60,800 acres are irrigated by wells and tubewells. The important crops of the tract are tobacco and bajra.

According to Dr. B. V. Mehta (personal communication) 85 per cent of the water are suitable for irrigation purposes, 10 per cent are marginal and 5 per cent unfit. The distribution of waters of different quality is shown in map 15. In areas where drainage is very good even the marginal waters can be used.

Mehsana district.—Mehsana district has an average rainfall of 20-25 inches. The soils are sandy to sandy loam in the major parts of the district. The total irrigated area is 3,42,249 acres. The area irrigated by wells and tubewells is 2,98,712 acres. About 80 per cent. of the well waters are fit for irrigation purposes. Bajra, jowar wheat, cotton, tobacco, oilseeds and vegetables are the important crops of the area.

The unfit or marginal waters are in the pockets of saline sub-soil pockets of Harychanasma, Mehšana, Patan and Sidhpur talukas. There is possibility of using these waters upto 10-15 percent. in scarcity years only. At present there is no canal irrigation in this district. If the river Sabarmati and Saraswati projects materialise, upto 15 percent of the unirrigated area, i.e. about 50,000 acres can be brought under irrigation.

Quality of Well Waters of Bidi Tobacco zone in Gujarat.—The Bidi tobacco growing areas in Gujarat are scattered in Baroda and Kaira districts. The analysis of typical well waters of this area is given in table 32.

Table 32.

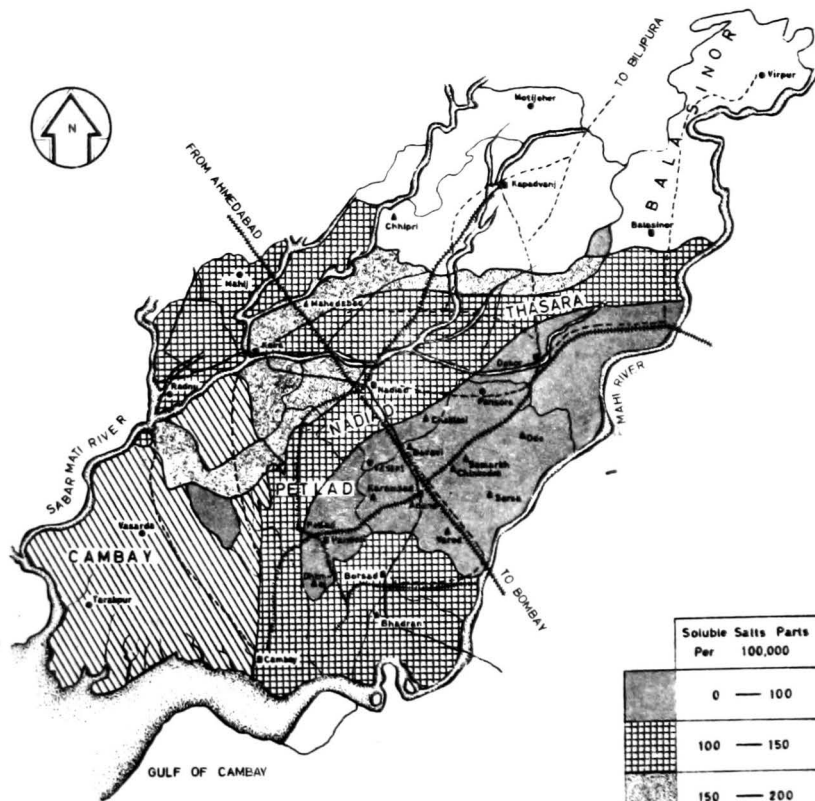
Composition of well water of Bidi Tobacco Zone of Gujarat*

	Baroda (Baroda Distt.)	Dehram (Kaira Distt.)	Padra (Baroda Distt.)	Mehkoda- bzyd (Kaira Distt.)	Sojitra (Kaira Distt.)	Anand (Kaira Distt.)
1. Total soluble salts	98.0	131.0	225.0	205.0	185.0	95.0
2. CaCO ₃	..	7.7	..	..	..	..
3. Ca(HCO ₃) ₂	9.6	..	14.4	3.6	10.6	15.6
4. Mg(HCO ₃) ₂	..	..	6.6	6.6	19.6	26.4
5. NaHCO ₃	72.6	99.0	99.4	122.2	68.6	19.6
6. MgCl ₂	..	..	..	..	..	..
7. NaCl	7.6	16.0	87.1	68.8	70.2	21.2
8. Na ₂ SO ₄	11.8	10.3	14.8	14.0	15.2	13.3
KNO ₃	6.4	..	..	.8	2.4	2.0
10. Quality of water	Good	Good	Moderate	Moderate	Moderate	Good

MAP 15

SALT CONTENTS OF SUB - SOIL WATER KAIRA DISTRICT (GUJERAT)

- Railways ————
- National High Way ———
- State High Way - - - - -
- Towns (2000-5000 Population) ●
- Towns (5000-10000 Population) ▲
- Towns (More Than 10000 Popu.) ■



Soluble Salts Parts Per 100,000	
0 — 100	
100 — 150	
150 — 200	
Above 200	

From these results it would appear that most of the well water used for cultivation of bidi tobacco contain nitrates and have moderate salinity.

General conclusions.—From the above discussion, it can be concluded, that there is an urgent need of survey of ground waters in different districts of the State. The depth at which good quality water is present should be determined by exploratory tubewell borings, so that the right quality of water may be tapped for irrigation purposes. It is also suggested, that in order to save the cultivators from disappointments, and spoiling their land with bad quality water such experimental bores must precede before any tube-well venture is undertaken. In the districts of Kaira and Mehsana, where good quality water is available, more and more wells and tube-wells should be sunk so as to make the best use of this natural resource.

Uttar Pradesh

In U.P., cultivated area is 38 million acres, nearly 30 percent. of which is irrigated. The maximum irrigated area is under well and tube-well irrigation. U.P. also has the largest area under well irrigation in India. Thus it is evident, that ground water forms the most important source of irrigation in this State.

U.P. is bounded by Himalayan ranges on the North and Vindiyachal mountains on the South. According to geochemical conditions, this tract is in a syncline and is thus very rich in underground water storage. It is crossed by a number of perennial rivers such as Jumna, Ganga and Ghaggar etc. The Jumna and the Ganga rivers have been tapped to their maximum capacity, and in addition to 7,000 State tube-wells and large number of private ones have been constructed for irrigation. The demand for more tube-wells necessitates the investigation and determination of (a) the maximum abstraction from individual tube-wells, (b) the most efficient spacing for tube-wells.

The area of the Ganga, Jumna Doab in U.P. encompasses nearly 24,700 square miles and covers the following districts:—

- (i) Dehra Dun
- (ii) Saharanpur
- (iii) Muzaffarnagar
- (iv) Meerut
- (v) Bulandshahr
- (vi) Etah
- (vii) Mainpuri
- (viii) Etawah

- (ix) Farukabad
- (xi) Kanpur
- (xii) Fatehpur
- (xiii) Some parts of Agra, Mathura and Allahabad.

This tract is roughly 520 miles in length and extends in width to 65 miles in the upper parts. It is characterised by a gently rolling topography except in Dehra Dun and parts of Saharanpur district where the gradient varies from 20 to 5 feet/mile. The gradient generally flattens from 4 ft. to 2 feet per mile in the districts of Muzaffarnagar, Meerut, Bulandshahr, Aligarh, Agra, Mathura, Etawah and Mainpuri and is reduced to 1.5 to 1 foot per mile in the districts of Farrukhabad, Kanpur and Allahabad. The annual rainfall varies from 30-50 inches. The distribution of rain being unfavourable, the higher yield from a crop is dependent on irrigation. The Doab is mainly served by the following three canal systems along with the State and private tube-wells:—

- (i) Eastern Jumna Canal System
- (ii) Upper Ganga Canal System
- (iii) Lower Ganga Canal System.

Ground Water Potentials.—In addition to these canal systems, the following districts are also irrigated by about 3064 tube-wells:—

- (i) Saharanpur
- (ii) Muzaffarnagar
- (iii) Bulandshahr
- (iv) Aligarh
- (v) Etah
- (vi) Mainpuri
- (vii) Farukhabad.

In this, Doab, there are 50 observation lines having nearly 700 observation wells scattered all over the area where record of fluctuations in water table in May and October is kept. During the last 40 years no appreciable change in ground water has taken place in the tube-well pumped areas of the Ganga Jumna Doab except in tube-well divisions, Bulandshahr and Meerut where the water table is depleted by 2-3 feet.

The Ganga and the Jumna rivers are both effluent throughout their lengths in this Doab, during the month of May. However, in some of the districts e.g., Fatehpur, Kanpur, Etawah, these rivers

recharge the ground water table during and after the flood stage. According to Dwidi and Gupta²⁷, the ground water potentials of the Doabs of Hindan, Jumna, Kali Ganga, Hindan Kali, Isan Pandu, Arin Pandu, Sengar Jumna, Arin Sengar, Isankali and Karan Jumna available for use after pumping is given in table 33.

Table 33

Additional ground water potential that can be pumped

Doab	Area	Average rise of water table	No. of the tube wells suggested acre feet.
Hindan Jumna	3,22,000	1.5	64
Kali Ganga	5,53,400	1.5	1,106
Isan Pandu	88,200	1.0	175
Hindan Kali	49,000	1.0	Nil
Arin Pandu	2,73,500	1.0	546
Sengar Jumna	1,13,200	1.5	230
Arin Sengar	2,80,300	2.0	560
Isan Kali	1,19,000	1.0	238
Karan Jumna	1,23,500	1.0	254

The Doabs of Sengar Jumna, Isan Pandu and Karan Jumna are getting water-logged with increasing drainage problem. The water-logging seems to have been created by excessive irrigation, heavy seepage of water through bed and sides of canal system and inadequate surface drainage. If part of the commanded area of the canal systems in these water logged areas could be transferred from canal irrigation to tube-well irrigation, it would have double advantage of reducing the water-logging conditions in the Doab as well as releasing the canal water for irrigation in the lower reaches, where there is acute shortage of water. It is advisable to explore possibilities of constructing tube-wells in these areas if suitable strata is available.

In the tract of about 80 miles in the districts of Fatehpur, Kanpur and Etawah, the rivers Ganga and Jamuna recharge the ground water during the flood season.

Quality of water.—Agarwal and associates⁵ examined the well waters of Etah, Farrukhabad and Kanpur districts of U.P. Analysis of water samples shows, that the composition of well waters in all the three districts is in general of medium salt content. The highest

content of dissolved salts are generally met with in recently deposited soil areas, while the lowest area is in mature high lying soil regions. The dissolved salts are divalent in mature soils. The anions are bicarbonates in immature soil though in Kanpur area, carbonates form 11 per cent of the total anions. Toxic concentrations of chlorides are present in all area where salinity is high. In new alluvium areas, sulphate is predominant.

According to Agarwal and Mehrotra ³⁴, the average analysis of typical waters of Aligarh district is as follows:—

	pH	Total salts	E cx109
Well (Uplands)	8.1	501	715
Well water (Low lands)	8.4	1140	1629
Tubewell]	7.7	642	917
Drainage	8.8	1821	2602

The well waters of low lands in areas are worse than those of uplands. The drainage waters are most saline, particularly in saline areas, where the percolation waters have taken up vast amounts of salts in the course of their flow. At time the drainage waters are so alkaline, that they acquire caustic properties and become brown in colour.

It can be generally concluded, that there are very vast potentialities for utilising ground water in this State and detailed survey of the quality of ground water needs to be made and interpreted in relation to soil types.

CHAPTER VI

Suitable Trees, Grasses and Crops for Saline and Alkali Soils

The degradation of the fertile neutral soils into saline, saline-alkali or alkali soils occurs much more rapidly under arid conditions. The species of plants which flourish in different environments are well adapted to the habitat. In the arid and semi-arid environment the species of plants which flourish are not only hardy in respect of drought resistance, but are also well adapted to the alkalinity of the soil. As the soils tend to become sodic, the calciferous plants are replaced by sodium tolerant ones. It is the exchangeable sodium which regulates the osmotic concentration of soil solution and ultimately the growth of plants. The important factors which modify the effect of exchangeable sodium in soils are the clay and silt contents, specific surface area, and type of clay minerals e.g. potassium, calcium, soluble silicate, and organic matter status of the soil. Besides, exchangeable sodium also affects the physical properties of the soil. Higher the exchangeable sodium and clay content worse will be the physical condition of the soil. In conjunction with exchangeable sodium the type of anion Cl, SO₄ or CO₃ differentially influences the reaction of the plants growing there. In the Punjab Puri (1934) McKenzie-Taylor, Puri and Asghar (1934) showed that yields of wheat were negatively correlated with the proportion of exchangeable sodium in the clay and that there is correspondingly but less close correlation with its pH. They suggested that degree of alkalisation is a good measure of the capability class of any salty soil from the aspect of crop production.

Relative Tolerance of plant species to Salinity

The comparative tolerance of plant species to salt in the soil is appraised according to three criteria: (i) the ability of the plant to survive on saline soil; (ii) the outturn of the plant on saline soil; and (iii) the relative yield of the plant on a saline soil as compared to its yield on non-saline soil under similar growing conditions⁹⁴. Depending upon the performance of the plant species these could be further classified into (i) high salt tolerant; (ii) medium salt tolerant; and (iii) low salt tolerant plants. Some plant species can germinate at high level of salinity but give very small yield. Others may have low germination but once having

germinated the yield per plant may be high. Several grades of performance are noticed in between. But there is no doubt that germination is the most critical phase from the aspect of total stand of the crop. The plant species which can germinate at high concentration of salt in the soil do generally make very satisfactory growth. The other critical phase is the seed development. The stress at this phase depends upon the cationic ratio as well as on the anions associated with exchangeable sodium in the soil. When the anion is carbonate the seed development is highly deficient, less so with chloride and least with sulphate.

The salt tolerance is also conditioned by the pH of the soil, i.e., whether the soil is (i) high in exchangeable sodium, but has moderate pH; (ii) high in exchangeable sodium, but with a pH of 8.5 or above, and (iii) high in exchangeable sodium but with a considerable accumulation of titratable carbonate. But now it is recognised that electrical conductivity of soil-water extract is a better measure of the salinity tolerance of plant species. The U.S.D.A. Salinity Laboratory now recognises the following degrees of salt tolerance.

TABLE 34

Influence on Plant Growth]	Electrical conductivity Millimhos per cm at 25°C.
1. Salinity effects most negligible	0—2
2. Growth of very sensitive plant species restricted	2—4
3. Growth of many plant species restricted	4—8
4. Only tolerant plant species grow satisfactorily	8—16
5. Few very tolerant plant species grow satisfactorily	above 16

Electrical conductivity of the soil solution is a measure of the osmotic concentration of the solutes in the soil. It has direct relationship to plants' (i) capacity to increase the osmotic pressures of the tissue fluids to compensate for the increase in osmotic pressures of the substrates; (ii) the capacity to regulate the intake of ions so as to bring about the increase in osmotic pressure and yet avoid an excess accumulation of ions; and (iii) the inherent ability of the protoplasm to resist the deleterious effects of the accumulated ions in the cell sap. These characteristics are very much in evidence in halophytes.

Indicator Plants

As the alkalinisation of the soil occurs simultaneously there occurs a succession of species. This succession indicates that slightly tolerant grasses are succeeded by more coarse ones and unpalatable species, and finally by salt accumulating plants. In one of the studies *Bouteloua* and *Stipa* community was replaced by *Hordeum jubatum*; *Hordeum distichon* *Suaeda*—*Chenopodium*; and *Salicornia* in the increasing order of salinity in the soil. The last named species is a true halophyte (Keith, 1958). This group has been further classified into euhalophytes, crino-halophytes and glauc-halophytes. The euhalophytes have low rates of respiration and low activities of the oxidative enzymes, peroxidase, polyphenol-oxidase and catalase, which remain stable in the presence of added salt. The well known species of this group are *Salicornia herbacea*, *Suaeda*, *corniculata*, *Petrosimonia litwinowi*, *P. triandra*, *Salsola soda* and *Echinopsilon hyssopifolium*. This group has been further sub-divided into halo-succulent which show low daily and residual moisture deficit, and haloxeritic which have high moisture deficit and lower water contents. To the former sub-group belong *Suaeda prostrata* and *Salicornia herbacea* and to the latter sub-group *Petrosimonia triandra*, *P. litwinowi*, *Echinopsilon hyssopifolium* and *Salsola soda*. The crinohalophytes are salt secreting plants. The best example of this group is *Statice gmelini*. The glyco-halophytes restrict the accumulation of salt in the body of the plant and have higher respiratory rates than other halophytes. To this group belong the species of *Atriplex salina* and *Atriplex tatarica* (Henckel, 1954; Henckel & Antipov, 1956 and Pokrouskaja, 1957).

These studies have largely carried out for the purpose of characterising soils from the aspect of the levels of salinity. The studies in the Punjab on the subject (Hoon and Mehta, 1937) are summarised as under.

(i) *Prosopis specigera* (Jand or Khejari).—It occurs in areas where rainfall is below 50 cms. The soils are usually compact, calcareous and have low pH value and low salt content.

(ii) *Salvadora oleoides* (Wan, Jal).—The pH value of the soils on which it flourishes is about 8.5. The content of calcium in the base exchange complex is high. Such soils need leaching to bring them back to fertility.

(iii) *Tamarix articulata* (Okan, Farash).—It has high tolerance for salt, well distributed throughout the profile. Usually exchangeable potassium in the top horizon of the profile in the base exchange complex is high. Its leaves accumulate high content of potassium.

(iv) *Capparis aphylla* or *C. decidua* (Kareer). It grows vigorously where top soil is loose and the sub-soil is compact. The predominant salts are sodium chloride and sodium sulphate. The surface soil has usually high pH value. The salt content in the lower horizon may also be high.

(v) *Suaeda fruticosa* (Lani).—It usually indicates high pH and high salinity of the soil. It often occurs on degraded sodic soils. It colonises in salty flooded lands. It is a succulent halophyte.

(vi) *Butea monosperma* (Dhak).—Like *Sueda* it is indicative of an advanced stage of deterioration of salty land. These soils usually are compact and of heavy clay texture. Salt content and pH are high throughout the profile.

(vii) *Sporobolus* spp.—This is the pioneer grass on heavy alkali soils which have reached the final stage of deterioration. These are short duration species of stunted growth.

(viii) *Salicornia* spp.—This plant flourishes on lands where the salt has accumulated throughout the profile and forms a salt crust on the surface but is close to a water source. Colonies of this are formed around the edge of the water ponds or streams. It is a true halophyte.

Salt tolerance in economic plant species Crops.—According to experience of crop culture in alluvial soils the field crops with high salt tolerance are rice, sugarcane, *dhaincha* (*Sesbania bispinosa*), barley, sugarbeet, *senji* (*Trigonella* spp), *methi* (*Fenugreek*), berseem, rape and cotton. The medium salt tolerant species are wheat, *jowar*, *bajra* and castor. And the low salt tolerant species are gram, field beans, peas, pigeon pea, linseed and sesamum. In *gorau* soil which has coarse sandy texture the crops that have high salt tolerance are tobacco, *bajri*, cotton and *guar*; moderately tolerant is tomato and least tolerant are beans, peas and cabbage. In the irrigated black cotton soil, rice, sugarcane and shevri have shown high salt tolerance.

Rice is usually the first crop grown on salty lands to reclaim them. Coarser varieties have higher tolerance than finer varieties of rice. Jhona 349 and N.P. 130 varieties have shown higher tolerance than Basmati varieties. For the purpose of reclamation after the leaching process transplant paddy is grown as the usual crop in the monsoon season. It is followed by berseem which also has high water requirements. The growing of this crop further aids in the

leaching process of the soil. This is usually followed by *Dhaincha* (*Sesbania bispinosa*) as green manure crop which opens up and adds nitrogen and organic matter to the soil. This is then successively followed by sugarcane, jowar, cowpeas for fodder, berseem, cotton, maize, peas, wheat and gram. When a reclaimed soil can successfully produce gram crop, it is considered fit to grow any other crops.

The integrated work started in 1950 on saline alkali soils in the Uttar Pradesh has shown the relative resistance of various crops on the basis of production pattern. The results of past 10 years are summarised below.

In the initial stages the kharif crops, particularly paddy constituted 75 per cent. of the total production. As reclamation operations progressed the production from rabi crops progressively increased. Now the rabi crops contribute 75 per cent. of the production and the contribution of rice in the total production is small. The observations on salinity resistance of crops have shown the following relative tolerance in descending order:

1. Transplanted Paddy:

- (i) Late Paddy
- (ii) Medium Paddy
- (iii) Early Paddy

2. Paddy broadcast or sown in lines at the break of rains:

- (i) Late Paddy
- (ii) Medium Paddy
- (iii) Early Paddy

Dhaincha (*Sesbania bispinosa*)

- 4. Mustard
- 5. Oats
- 6. Barley
- 7. Wheat
- 8. Sanai (*Crotalaria juncea*).
- 9. Gram & Peas

Since the phase germination is the most critical for the crop development in its production, germination studies on a number of *bajra* and *jowar* varieties were conducted. The data are summarised as under:

Table 35

Salt tolerance at germination of bajra varieties

Particulars	RSK	T5	Bika- ner	Sar- dar sha- har	T55	Jet sar	Gadra Road	Agra	Mani- hari	Ka ta
Conductance of extract (Millimhos per cm at 25°C	8.0	8.0	12.0	12.0	12.0	12.0	12.0	12.0	16.0	16.0

Low salt tolerance was shown by recommended varieties R.S.K. and T5; medium by T55 and Agra and several collections from dry areas of Rajasthan and high by three new collections from arid zone. The general level of salinity tolerance in *jowar* varieties was lower than in *bajra* and degree of variation was also high (Table 36).

Table 36

Salt tolerance at germination of jowar varieties

Particulars	Varieties										
	Texas Hybrid 610	M 47-3	Gadra Road	Texas Milo of 25245	Pok- ran	Sweet Sudan 1.5 704	Neb- raska JW5809	J 118	T I	PJ 4R	M 35-1
Conductance of saturation extract (Milli- mhos per cm at 25°C	8.0	12.0	12.0	8.0	12.0	0.7	4.0	4.0	0.2	4.0	0.7

The highest salt tolerance is shown by the strains M47-3, Gadra Road and Pokaran; medium tolerance by Texas hybrid 610 and, Texas milo of 25245; and low tolerance by Nebraska J. 5809, Delhi I. S541, J.118 and PJ. 4R. The strains highly susceptible to even a small amount of salinity were sweet Sudan I.S. 7011, T.I. and M. 35-1. Similar studies on other crops at different stages of growth will give their relative tolerance and hence adaptability to the various degrees of degradation of soils.

Observations on salt tolerance of sugarcane have been recorded at various stations in the country. The general conclusion drawn is that high fibred varieties have high tolerance than varieties which have high sucrose and low fibre values. The varieties may be broadly classified as under:

High tolerance	Co 205 ; Co 285 ;
Medium tolerance	Co 210 ; Co 331 ; Co 312 ; Co 321 ; Co 513 ; Co 290 ; Co 453 ; Co L. 9 ; Co 421 ; Co. S. 109 ; Co. 3 ; Bo 10 ; Bo 24 ; Bo 3 ; Co 413
Low tolerance	Co 213 ; Co 214 ; Co 313 ; Co 419 ; Co 449 ; Co 527 ; Co 622 ; Co S. 245 ; Co 617 ; Co. 251.

This tentative classification is based upon the observations recorded at various Sugarcane Research Stations in the country.

In cotton varieties the short staples ones are more hardy than the medium and large staple ones. The former are, therefore, preferred for growing on the salty soils than the latter. Of the mustard crops *tara mira* is the most tolerant, and *rai* the least. *Sarson* and *toria* have medium salinity tolerance.

Grasses:

Few regular investigations on salt tolerance of grasses have been conducted in India. But pertinent observations have been recorded on the performance of various grass species. Based upon these observations a tentative classification is given below:

(i) High tolerance. *Sporobolus arabicus* or *Khari doro*; *Sporobolus pallidus* or *Palinia*; *Chloris gayana* or *Rhodes grass*; *Cynodon dactylon* or *Bermuda grass*; *Paspalum notatum* or *baikas*.

(ii) Medium tolerance. *Brachiaria mutica* or *Para grass*; *Cynodon plectostachyumi* or *giant star grass*; *Elyonurus indicus* or *sewan*; *Aristida hystrix* *Echinochloa colona*.

(iii) Low tolerance. *Panicum antidotale* or *blue panic*; *Cenchrus ciliaris* and *Cenchrus setigerus*; *Dichanthium annulatum*; *Eragrostis tremula*; *cymbopogon spp*; *Aristida funiculata*; *Dactyloctenium indicum*; *Eleusine flagellifera*.

Of the cultivated grasses the most tolerant to salt is *Rhodes grass*. Next to it is *para grass* and *giant star grass*. Other cultivated grasses do not stand high salinity. *Dub* or *Cynodon dactylon* has been successfully grown to reclaim soils under irrigation. Under natural environment the succession of species from highly saline to

least saline condition consists of *Sporobolus* spp; *Cynodon dactylon*, *Echinochloa* spp, *Aristida* spp, *Eleusine flagellifera*, *Dactyloctenium indicum*, *Eragrostis tremula* and *Dichanthium annulatum*. The cultivated species can be introduced at different stages of reclamation of the salty lands.

Fruit trees:

A large amount of work on salt tolerance of fruit trees has been carried out in the U.S.A. "With the exception of date palm, most of the fruit crop plants are relatively sensitive to salinity and even when moderately tolerant, like the grape, are prone to specific leaf injury symptoms when critical quantities of chloride or sodium are accumulated in the leaves" (Bernstein, 1962). Stone fruit trees, avocado and citrus accumulate both chloride and sodium in their leaves with consequent leaf-injury symptoms. Strawberry is also sensitive; even when toxic chloride levels do not occur, 50 per cent reduction in yield is recorded at 2.3 to 2.5 mmhos/cm for the shasta and lassen varieties. Grape varieties are differentially sensitive to salt in the soil. They show wide variation in chloride accumulation. Orange, plum, apricot and almond absorb toxic amounts of salts with high concentration and defoliation occurs. In India malta oranges flourish in irrigated soils recently reclaimed from salinity but cannot withstand high cationic ratio. The leached soils must have sufficient of active lime and exchangeable potassium to offset the effect of sodium in the profiles. Other citrus fruits in descending order of salinity tolerance are lemon, sweetlime, Nagpur orange; mosambi. In this respect *guava*, mango, jackfruit etc., are less sensitive to salinity. The grafted varieties of mango and lichi are more sensitive than ungrafted mango varieties. Extremely sensitive plants to salinity are papaya, coffee and cocoa. Grapes are difficult to establish on moderately saline soils. After establishment they can withstand moderate quantities of salt. Seedless varieties are more sensitive to salinity than others.

Forest trees and shrubs: Salty lands are more suitable for raising fuel plantations rather than for timber. One of the best in this respect is *Dalbergia Sissoo*. Once the seedlings have established they make a good growth and can withstand moderate to high degree of salinity. In fact Bari soils which have high content of carbonates and bicarbonates have been reclaimed by planting *D. Sissoo* under irrigation after preliminary reclamation by lister ploughing and leaching. The other species which can stand moderate amount of salinity are *Prosopis juliflora*, and *Acacia arabica*. In a recent assessment it has been observed that the former species has very high fuel and timber value. The *Acacia* wood is

more commonly used for agricultural implements and house construction than for manufacture of furniture or for use in other timber industries. Recently *Acacia spirocarpa* introduced from Israel has shown high tolerance to salt. In its natural habitat it is extremely resistant to salinity.

Of the fuel species the high salt tolerance is shown by *Tamarix articulata*. It has high rate of growth and seedlings established well in such habitats. It prefers sandy soil rather than heavier ones. *Dhak* (*Butea monosperma*) is another species that flourishes on compact saline soils, in medium to high rainfall tracts. It also grows fast and possesses good regeneration character from the dispersed seeds. *Neem* (*Azadirachta indica*) has medium to low salt tolerance. The seedlings readily spring up from the dispersed seeds but are not so readily established on salty soils. Once established they make good growth. Comparatively *Salvadora persica* is more resistant to salinity than *Salvadora oleoides*. In Pachpadhra area of western Rajasthan close to salt work *S. Persica* and *Prosopis Juliflora* are the two species that are flourishing. In this area the profile upto a depth of 35 ft. is fully saturated with salt. *Capparis aphylla* is less tolerant than *Capparis decidua*. Both prefer habitat where 'A' horizon is compact and free of salt. This shrub grows slowly. Once established it has high persistence. *Zizyphus nummularia* and *Z. jujuba* have medium salt tolerance. The former prefers more compact habitat than the latter. It is a hardy species and stands upto heavy lopping and, therefore, has high persistence. It is more valued for top feed than for timber or fuel. The bole formation is slow and tardy. *Calotropis procera* has medium salt tolerance under very arid conditions where it grows into a small tree. Its leaves are used as fodder and wood as fuel. *Gymnosporium montana* is a medium salt tolerant species. It grows upto 10-12 ft. height. It is good fuel species and locally its leaves are used as fodder.

Other species of the arid zone which have low salt tolerance are *Tecomella undulata* (Marwar teak); *Prosopis spicigera*; *Acacia senegal*; *Acacia leucophloea*; *Albizia lebbek*; *Butea monosperma*; *Tamarindus indica*; *Acacia jacquimontii*. The first species has two strains. The yellow flower one, grows to a bigger height and develops fast. The pink flower strain develops slowly and prefers sandy habitat. Usually both co-exist side by side. *P. spicigera* has wide distribution. It flourishes on sandy soils almost free of salinity. Its leaves are used as fodder. Its fuel value is high and to a small extent it is used as a small timber. *Acacia senegal* is best suited to rocky and semi-rocky habitats. It is the source of gum arabica. It is very hardy and slow growing species and has good fuel value. *Acacia*

leucophloea and *A jacquemontii* do not grow into a tall tree. Their salt tolerance is low. Their wood finds use as fuel and for basket making. *Albizzia lebbek* (*siris*) is good avenue tree. It grows into good height in salt free soils. Its wood is good for small timber and fuel and leaves are fed to cattle in scarcity years. *Butea monosperma* and *Tamarindus indica* grow into tall trees and supply fuel. *Calligonum polygonoides* is a small shrub which vegetates on sandy soils and sand dune areas. It has little salt tolerance. Its underground shoot and roots are a good source of fuel in very arid tracts. *Balanites aegyptica* is a shrub which prefers sandy habitat but cannot stand high salinity. Its wood is used as fuel and fruits are good washing material. The kernel of the fruit is a medicine for intestinal troubles. *Cummiphora mukul* is a thorny shrub suited to rocky sites. Its gum is commercially exploited which is good as an incense and medicine. *Grewia tanex* is a plant of semi-rocky habitat. Its leaves are readily eaten by cattle and timber is good fuel.

In the semi-arid region the common species met with are *Pongamia pinnata*; *Acacia* Spp; *Melia azaheerach*; *Thespesia populnea*; *Morus alba*; *Tamarindus Indica*; *Casuarina equisetifolia*; *Prosopis spicigera*; *P. juliflora*; *Acacia arabica*; *Delonix regia*; *Cassia fistula*; *Moringa pterygosperma*; *Azadirachta indica*; *Albizzia procera*; *Albizzia amara*; *A lebbek*; *Cassia auriculata*; and so on. Of these *Prosopis juliflora*; *morus alba*; *Pongamia pinnata*; *Acacia spp*; *Moringa pterogosperra* and *Cassia auriculata* are highly salt tolerant species. The medium salt tolerance is possessed by *Tamarindus indica*; *Albizzia lebbek*; *Delonix regia* and *Cassia fistula*. The rest of the species have low salt tolerance.

In coastal area where salty vapour and salt in the sandy beaches are experienced by the vegetation, the species found suitable for plantation are *Eucalyptus saligna*; *E. robusta* and *F. rostrata*; *Thespesia populnea*; *Casuarina equisetifolia*; *Tamarix articulata* and *Prosopis juliflora*. Most of them are meant for fuel.

CHAPTER VII

Water-logged Lands

The spread of irrigation since Independence has been on a very large scale. In 1950-51, nearly 51.5 million acres were being irrigated from various sources of which more than 50 per cent from sources other than canals. The first Five Year Plan (1951-56) laid the foundation for rapid development of irrigation in the country with assured water supply from reservoirs. The tempo of work initiated in the First Plan was continued in the Second Plan. With the completion of the Third Plan, it is expected that about 90 million acres will be under irrigation.

Irrigation, however, is not an unmixed blessing. Consequent on large areas being brought under canal irrigation some areas in the country are getting water-logged. In the wake of irrigation, sub-soil water level has steadily risen specially in areas where there are flat slopes as in the Indo-Gangetic plains. As a consequence, large areas are getting water-logged, and are going out of cultivation. If attention is not paid to remedy this situation, the results could be catastrophic.

Land is said to be water-logged when the soil pores within the root zone of crops get saturated with water. The cutting off of the normal circulation of air which is very necessary to the growth of the plants reduces the yield of the crops appreciably.

Water-logging usually occurs due to rise of sub-soil water, and this happens in almost all the irrigated tracts unless there are specially fortunate circumstances.

It can safely be surmised that in the pre-canal period the water-table was in a state of equilibrium. The inflow into the soil from outer sources was equal to the outflow due to seepage. It should not be concluded from this that the sub-soil water level remained static. It did fluctuate with the amount of rainfall from year to year but there was no continuous rising trend. There would be a sudden rise in a year of heavy rainfall which would be adjusted in a subsequent dry year.

However, with the introduction of canal irrigation a rising trend in the sub-soil water level has been established due to the addition

of seepage water from the canals and other causes. The causes that lead to such a condition need to be analysed in detail. For extending cultivation most of the cultivable land has been levelled, and as a consequence flow of surface run-off is not so quick and free. Also with the encroachments on the flood zones the flooding is of a relatively longer duration. These result in increased addition to the sub-soil water-table. Also water seeps through the banks of unlined canals. Further, cultivation under the misconception that higher doses of irrigation water would be helpful in getting higher yields resulted in heavier irrigation. As a consequence more water seeps through and adds to the sub-soil water table. As the outflow does not increase correspondingly, the water-table shows a rising trend.

This is the type of condition prevalent in the flat alluvial plains of northern India. In south India drainage conditions are much better. Due to steeper gradients there is better outflow from the sub-soil water-table with the result that though there has been increased addition to the ground water due to the various causes enumerated above, there has not been a corresponding rise in the water-table.

Extent of water-logging

Unfortunately no accurate statistics regarding the extent of the problem of water-logging and the rate at which it has been increasing have been maintained in the States, with the exception of Punjab. Hence no idea of the rate of increase of water-logging of land can be formed in many States.

According to the latest figures available, the Punjab is the most affected State, followed by Maharashtra, Jammu & Kashmir and Delhi. Table 37 gives the approximate figures of water-logged area in these States. Area affected by water-logging in other States, is given in Table 38. Figures are not available for a number of States. Of these States, water-logging is a problem in Mysore and Orissa.

The rate of increase of water-logging in the Punjab can be seen from Table 39 (Reference Map 16). There has been a continuous rising trend of water-table and the need for tackling the problem on an emergent footing cannot be over-emphasised. It is also noteworthy that there has been a significant fall in the area affected by water-logging in recent years, mainly due to the implementation of surface drainage measures.

MAP - 15

MAP OF THE PUNJAB SHOWING WATER-TABLE OCTOBER-1958

SCALE
MILES 0 8 16 24 32 MILES



RIVERS
CANALS
NALAS OR NATURAL
DRAINS
IRRIGATION BOUNDARY

WATER DEPTHS 0' TO 5' (Blue)
DO DO 5' TO 10' (Grey)
DO DO 10' TO 15' (Red)
DO DO 15' TO 20' (Orange)
DO DO 20' TO 25' (Yellow)
DO DO 25' TO 30' (Green)
DO DO ABOVE 30' (White)

INDO PAKISTAN BOUNDARY

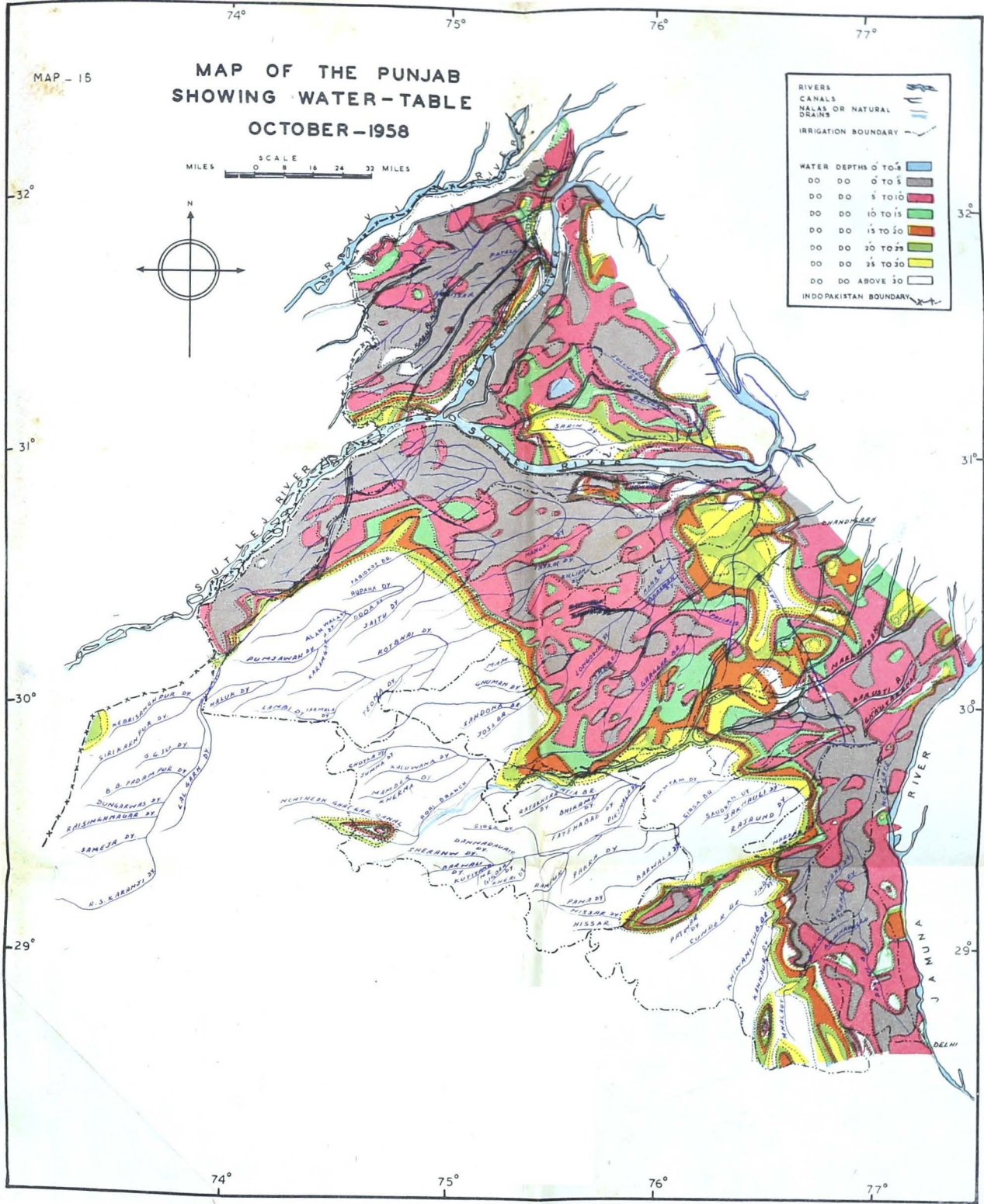


Table 37

(in acres)

	Water table 0 to 5 ft. deep. Category 'A'		Water table 5 to 10 ft. deep. Category 'B'		Water table 10 to 15 ft. deep. Category 'C'	Salt affected area in deep water table Category 'D'
	Water-logged	Salt affected	Water-logged	Salt affected		
Punjab*	2,513,838	1,300,000	2,187,334	4,50,000	1,488,905	1,250,000
Maharashtra	10,821	17,900	Nil.	53,744	Not known	Nil.
Jammu & Kashmir	4,500	Nil.	25,000	Nil.	24,000	Nil.
Delhi	3,200	Nil.	6,000	Nil.	600	Nil.
U.P.	Nil.	Nil.	Nil.	Nil.	Nil.	2,300,000

* Figures based on 1956 data.

Table 38

Area waterlogged in various States (in acres)
(Based on latest data as received from States)

Assam	Nil
Andhra Pradesh	Being collected
Bihar	N.A.
Gujarat	Nil
Jammu & Kashmir	4,500
Kerala	Nil
Madhya Pradesh	300
Maharashtra	55,230
Mysore	Being collected
Madras	Being collected
Orissa	N.A.
Punjab	25,00,000
Rajasthan	Nil
Uttar Pradesh	Being collected
West Bengal	Being collected
Delhi	3,200

Table 39

Year-wise data of area affected by water-logging in the Punjab

Year	Acres water-logged
1. October 1951-June '52	15,31,372
2. October 1952-June '53	16,75,422
3. October 1953-June '54	12,73,054
4. October 1954-June '55	14,33,822
5. October 1955-June '56	12,15,957
6. October 1956-June '57	16,44,542
7. October 1957-June '58	28,08,554
8. October 1958-June '59	20,04,994
9. October 1959-June '60	20,04,992

CHAPTER VIII

Surface Drainage

In the Third Five Year Plan "Surface Drainage" has been rightly grouped under "flood-control" since these are closely allied subjects, both aiming at the reduction of damage due to flooding. Similarly, surface drainage and sub-surface drainage (anti-water-logging) are also closely inter-related. Surface drainage deals with the disposal of water on the surface of the land, and sub-surface drainage caters for drainage of that part of precipitation which infiltrates into the ground and drains out eventually as ground water to vegetation, soil, streams or to the ocean. As soon as ground water saturates the soil, on account of faulty sub-surface drainage, the land is said to be water-logged and this in turn vitiates surface drainage. Alternately, if surface drainage is not efficient it tends to saturate the soil and creates conditions of water-logging. These two problems have generally to be tackled jointly in order to attain maximum results, because land drainage has been one of the principal factors in retaining the fertility of the soil.

The problem of surface drainage

The problem of flooding in general was the subject of enquiry by a number of committees set up in the States since 1925. Improvement of drainage channels and reduction of drainage congestion by extending water-way of existing bridges has figured in the recommendations of almost every committee. At the Inter-Provincial Flood Conference, held at Lucknow in 1939, the Technical Sub-Committee came to the conclusion that the increase in flood levels "were also partially attributable, particularly in Bengal, to the blockage of natural spill-ways" by marginal bunds or road and railway embankments, which have openings with inadequate water-ways. More recently, the High Level Committee on Floods (1957) pointed out the necessity of improving drainage as part of the programme for flood control.

In spite of the awareness that the problem of surface drainage congestion exists, very little work in this direction has been done. It was only in 1954 that surface drainage received recognition as part of the national flood control programme initiated after the

devastating floods of that year. Even during the last seven years, not much work has been done, because there does not exist any distinct authority charged with the responsibility of improving drainage.

Generally speaking, the problem of surface drainage exists in varying degrees in most parts of the country, but it is particularly inadequate in the Indo-Gangetic plains, which have flat land and poor out-falls. In the Deccan, the drainage conditions are generally better, except in some intensely irrigated tracts, where the problem is more one of sub-surface drainage. The problem is specially urgent in Assam, Punjab, U.P., North Bihar, West Bengal and in the lower deltaic part of Orissa. Accurate figures of areas affected on account of the surface drainage congestion are not available for the entire country, but the following rough figures for some States will give an idea of the magnitude of the problem:—

Table 40

State	Approx. area affected (lakhs of acres)	Rough estimate of the cost of necessary drainage works (Rs. in lakh)
Punjab	15	2,142
Uttar Pradesh	19	1,469
Bihar	N.A.	567
West Bengal	N.A.	180
Orissa	N.A.	..
Assam	N.A.	109
Andhra Pradesh	N.A.	90

In the Punjab and Uttar Pradesh, the problem arises mostly on account of inadequate water-ways under roads, railways and canals and an inadequate drainage system—both natural and artificial. The inadequacy of the drainage system has resulted from deterioration of drainage channels by silting. In some parts of the Punjab, as in the district of Gurgaon, even the rudiments of a drainage system do not exist. This was high-lighted during the floods of 1958 when parts of the district, including long stretches of national highways Nos. 2 and 8, were inundated for months after the close of the monsoon. The solution of the problem in this district is linked up with

that in Bharatpur district of Rajasthan, where the problem stems from the deterioration of natural drainage channels in the southern part of the district, and the absence of any significant drainage lines in the northern part. In the northern part of Bihar, the problem is essentially one of drainage of numerous low lying areas called "chaurs". In coastal Orissa drainage has been obstructed mainly by the construction of coastal embankments without making provision for drainage facilities. In West Bengal, in addition to the provision of sluices in embankments, it is necessary to re-excavate a large number of maribund rivers and to drain low lying areas. In Assam, due to long neglect, drainage channels in many of the areas have deteriorated. Some low lying areas between tributaries have also to be drained out. The problem has been further aggravated by obstruction of natural drainage by haphazard construction of long lines of embankments.

Further, in most of the States, inadequate waterway under bridges is responsible for considerable drainage congestion.

The statement below gives an idea of the magnitude of work to be done in respect of extension/remodelling/construction of road bridges alone, with a view to provide such water-way as will not cause undue afflux.—

Table 41

State	No. of bridges due for extension/remodelling/construction	Amount required (Rs. in lakhs)
Andhra Pradesh	4	17.31
Assam	N.A.	51.03
Bihar	68	163.94
Bombay	N.A.	17.59
Madras	7	22.59
Madhya Pradesh	132	138.29
Orissa	N.A.	N.A.
Punjab	117	95.00
Uttar Pradesh	364	40.00
West Bengal	N.A.	19.95
TOTAL	622	535.06

NOTE.—The above table does not include Railway Bridges.

The problem, therefore, before us today is essentially one of improving existing drainage channels, excavation of new ones and the provision of sufficient water-way under embankments, roads and railways etc.

The importance of surface drainage

Unlike river spill which tends to subside comparatively quickly, inundation due to drainage congestion is prolonged, because of the absence of a suitable outlet. Therefore, in addition to the usual damage caused by flooding, there are some specially undesirable features of inadequate drainage, both in urban and rural areas. Prolonged accumulation of water around habitation tends to promote insanitary living conditions, while in the country-side it hampers agricultural operations in many ways. It damages standing crop and causes deterioration of land due to soil saturation. It may render the land unfit for subsequent sowings, and also lowers crop yields. Lack of control of hill-side drainage tends to aggravate soil erosion.

Insufficient water-way under bridges causes undue afflux which in turn affects the safety of important lines of communication. Several accidents have, in recent times, taken place due to failure of a bridge or its bank connections. Even aviation requires drainage to ensure safety in landing and taking off of air-craft.

Irrigated tracts in many of the States require surface facilities in order to keep up productivity of irrigated lands. Unfortunately, statistics in this respect are not yet available.

The Agricultural Production Team of the Ford Foundation in their report on "India's food crisis" have emphasised the importance of improvement of surface drainage for increasing food production and village employment. They have further stated that "millions of acres could be reclaimed and made productive by drainage improvement".

It is significant that the acreage rendered unfit for agriculture by drainage congestion can only be replaced by developing corresponding irrigation projects at much greater cost and time, because the easier and more economical project sites have already been, more or less, exploited. Taking the requirements of the States of Punjab and U.P., as an index, which the area affected is about 34 lakh acres, the capital investment required for placing an equivalent new area under irrigation would be of the order of about Rs. 119 crores (Rs. 350 x 34 lakhs), as the cost of new irrigation schemes.

On the other hand, based on the tentative plans drawn up by these States, improvement of drainage is expected to cost less than Rs. 36 crores. Drainage schemes have in addition the specially desirable advantage of easier and quicker planning and execution, yielding earlier results, without being encumbered by complex technical know-how and foreign exchange requirements. A modest investment can play a significant part in helping to close the estimated gap of 28 million tons in our foodgrain requirements by 1965-66.

It is, therefore, clear that our attitude towards that sector of the Plan which aims at holding what-we-have needs to be drastically reoriented. Surface drainage, which aims at the removal of excess water in a manner, so as to safeguard and promote many interests should occupy an important place in the Plan for water resources development.

Review of the work done on surface drainage

As has been stated above, flood control received recognition only after the disastrous floods in 1954. But, it took another year to realise the importance of surface drainage as an essential aspect of this programme. The statement on the flood situation laid on the Table of the Lok Sabha, by the Union Minister for Planning, Irrigation and Power, on the 27th July, 1956, revealed that "it was the lesson of 1955 floods that pointed out the necessity of planning efficient drainage systems, including channel improvements, in order to reduce flooding resulting from local rain and inadequate natural drainage, particularly in the flat areas of the Indo-Gangetic basin".

Consequently, organisational nuclei were set up in the States of Punjab and U.P., where some Public Works Divisions were specially charged with the responsibility of planning and executing surface drainage schemes. Smaller units have been set up in some other States. At its third meeting, held in the latter part of 1955, the Ganga River Commission recommended the setting up of Road Bridges Committees in the States, in order to make a detailed study of such bridges as were causing drainage congestion and suggest remedial measures. The Committees have also been set up in the States of U. P., Bihar, West Bengal, and Orissa. In some of the States, the State Technical Advisory Committee is looking after this work. The Committees of U. P. and Bihar have finalised their reports while the reports from the other States are still awaited. A Committee has been appointed by the Railway Board to conduct similar investigation in respect of railway bridges. This Committee

has submitted the report which is under consideration of the Government.

The table below indicates the number of surface drainage schemes, together with cost etc., that have been taken up since 1955 up to the end of the Second Five Year Plan:

Table 42

State	No. of schemes taken up	Estimated cost (Rs. in lakhs).	Approximate area benefited (in lakhs acres)
Andhra Pradesh	2	17.46	0.10
Assam	14	39.28	0.27
Bihar	2	10.8	0.14
Gujarat	9	17.28	0.14
Delhi	8	2.28	N.A.
Kerala	4	12.54	0.07
Orissa	24	21.55	0.06
Punjab	61	430.44	16.00
Uttar Pradesh	50	72.71	1.30
West Bengal	9	25.41	0.25

It will be observed that although beginning has been made, appreciable work has been done only in the Punjab. This is probably due to lack of sufficient field data, inadequate organisation and inadequate funds.

Since then, organisations have been built up, which are now looking after the interests of the surface drainage in most parts of the country. The problem of flooding in the western districts of U.P., Gurgaon district in Punjab and Bharatpur district in Rajasthan has been the subject of special study by a group of Engineers from the States concerned and the Centre, with a view to finalise an integrated plan for the drainage of this area. One scheme in this connection is under execution and others are expected to be completed by 1964. Plans for drainage improvement in other parts of Punjab have been also drawn up by the State Government. In Rajasthan, in addition to the schemes linked with the Punjab and U.P., a few schemes have recently been approved for channel improvements in the southern part of Bharatpur district. A joint plan for improvement of the flow conditions of the river Ghaggar has also been evolved. The U.P. Government finalised a number of drainage schemes both for the western and eastern districts of the State. A few schemes for

extension of waterways of bridges have been completed. Work on the first phase of improvement of the Najafgarh Nallah in Delhi has almost been completed, while the long term scheme is under execution. Schemes for improving drainage in the urban Delhi are also under preparation. In Bihar, plans have been drawn up for drainage of *chaurs*. In West Bengal a number of schemes have been prepared to improve moribund rivers (Khals) and to drain 'Bils'. Work on the construction of about 60 sluices in embankments of Assam has been taken up.

Thus, work has so far been mainly concentrated on the execution of emergent schemes, together with surveys and investigations for drawing up a programme of further work. Hardly any work has been done on improving water-ways of bridges. A clear picture of the requirements for extension of water-ways of bridges has emerged only recently and the States are now in a position to carry out the works. With the data now available, a large scale programme of surface drainage improvement can be launched.

Coordinated projects for flood control, drainage and irrigation.

The programme for water resources development must insist on properly coordinated projects, integrating flood control, irrigation and drainage, as there are inevitable partners in any water conservation programme. The practice in East Germany, where no irrigation project is taken up, without a corresponding drainage project, is well worth emulating. The menace of water-logging may not have assumed its present proportions had proper attention been paid to drainage in the working of the different irrigation systems.

It would, therefore, be appropriate if action on the following lines is initiated immediately:—

(i) *Start work on schemes that are ready.*—Work on the execution of drainage schemes which are technically and economically sound should be taken up right away, as the immediate phase of a long-term Plan.

(ii) *Draw up a Master Plan.*—Intensive surveys should be initiated throughout the country jointly by flood control and transport engineers, agriculturists, and soil scientists, to locate all areas which are subjected to drainage congestion. These investigations should preferably be carried out in self-contained "doabs" so that the Master Plan will have clearly demarcated regions. These plans should contain a clearly spelled out programme of construction priorities to be implemented on completion of the necessary investigations. It

should include studies setting forth the economic implications of draining out a particular tract. Such a scientifically conceived plan will indicate the best use for which each piece of land is best suited, *viz.* whether it can advantageously be utilised for agriculture, pasture or forestry.

(iii) *Provide interim relief.*—While surveys and investigations are in progress and before actual implementation of the Master Plan is taken up, information should be widely disseminated on the cultivation of crops that can stand prolonged inundation, which is a distinct characteristic of drainage congestion. The "Bao" strain of deep water paddy has been developed for this purpose in Surma Valley of Assam. Cultivation of deep water paddy could be extended to other parts of the country as well.

(iv) *Check up working of existing irrigation schemes.*—As has already been indicated by the Planning Commission and the Ministry of Irrigation & Power, surveys and water table observations should immediately be organised in existing irrigated tracts, to see if there has been any rise in water table due to seepage from canals. This should be tackled as a sub-surface drainage problem, before it assumes serious proportions. A strict watch should also be kept against the extravagant use of irrigation water.

(v) *Drainage by inter-linking borrow pits along railway lines, canals and roads.*—The inter-linking of borrow pits along roads, railway lines and canal embankments so as to form sufficient new side channels is a measure which is deemed essential in addition to the natural surface drains, for removing waterlogging in a tract. During the rainy season, flood-waters collect in these pits and depressions and in the absence of any outlet, seep into the sub-soil thus adding to the ground reservoir. So far no attention has been given to this problem.

Generally, the earth needed for road building and laying of railway lines has been taken from pits irregularly spread along the roads and railways. In the pits water collects, and from these points water-logging trouble starts since no drain-off is provided, thus favouring the fatal effect of roads and railways obstructing natural surface drainage. As a general rule, it has been suggested and approved by the Technical Committee of the Punjab State Flood Control Board that where a drainage exists nearby, the borrow pits should be dug so as to lead the drainage from the road towards the natural drainage. These measures will greatly benefit road maintenance. At present all the roads in water-logged areas are suffering from lack of drainage resulting in un-even settlement of road surface. This will be checked to a large extent.

(vi) *Research and studies.*—While the Master Plan is being investigated, studies should be undertaken (preferably by a centralised agency in each State) on drainage materials and methods in different situations and hydrological conditions for different regions in the country. This is particularly important, because no blanket methods can be prescribed on account of the diversity of the problem from region to region.

(vii) *Provide sufficient finance.*—The existing statistical data, as reproduced in earlier paragraphs, by no means reflects the actual requirements of the country for improvement of surface drainage. The financial implications and the resulting benefits have, therefore, not been adequately brought out. Third Plan provision of Rs. 25 crores is not likely to be sufficient. But this has to be confirmed by field surveys that should be undertaken to determine the exact size and nature of the problem. The solution to the problem and the resulting benefits are economically and technically so attractive that it should, as far as possible, be completed within the Fourth Plan itself, after completing the surveys, etc. The provision for surface drainage should, therefore, be increased liberally particularly because the success of our Plans depends, to such a large extent, on adequate agricultural production.

(viii) *Conduct campaign for public education and cooperation.*—No programme can possibly succeed without public cooperation. Demonstration units (through the Community Development Organisation) should be spread throughout the country, to educate the public in general and the farmer in particular, on the importance of drainage and the dangers of extravagant use of irrigation water. It has to be impressed upon the farmer that good drainage is an important factor in ensuring the fertility of his arable soil.

Some suggestions on organisation

The magnitude of the problem clearly justifies a single agency, which should be given the responsibility for coordination and improvement of all natural and artificial drainage works, together with other allied flood-control activities, including water-logging. The Plan once having been approved, its implementation should be decentralised into manageable units with well and inescapable responsibility with the necessary authority.

Surface drainage, which has immense potentialities, should not be relegated to the "business-as-usual" part of our development activity. It should form part of our drive for better living, safer communications and above all, self-sufficiency in foodgrains.

CHAPTER IX

Problems of Sub-surface Drainage

The effect of faulty sub-surface drainage.—Due to inadequate sub-surface drainage, the sub-soil water table tends to rise in many of the irrigated tracts of the country. There exist vast areas where the sub-soil water table has risen to within 5' of the surface. As a consequence, soil pores within the root zone of crops, get saturated with water thus cutting off the normal circulation of air which is very necessary for the growth of crops, thereby reducing the yield considerably. If such a rise continues unchecked vast areas would go out of cultivation. A high water table also tends to reduce the stability of the foundation of engineering structures which were originally not designed for such conditions.

Sub-surface drainage could be improved by means of deep drains, tile drains, shallow tube-wells or by reducing seepage into the underground reservoir by lining canals etc. Benefits that will accrue through proper sub-surface drainage are:

- (i) It gives the root zone greater depth, which increases the available supply of plant food and moisture.
- (ii) It results in warmer soil and aeration of soil which is conducive to the better growth of plants.
- (iii) It provides physical improvement of the soil resulting in granular structure producing good tilth.
- (iv) It helps in removal of surplus water enabling crops to withstand wet weather conditions.

Tile drains.—Sub-surface drainage by means of tiles is the most efficient method. These drains consist of a system of cylindrical pipes from 1" to 6" to diameter in convenient lengths. These pipes are placed end to end with gaps or alternately there are slots in the body of the pipes for admitting seepage water. The material for these pipes may either be clay or porous concrete. Usually a tile drain system consists of one or more independent units each having a separate outlet into an open channel either natural or artificial. The tile drain system is composed of mains, sub-mains, and laterals. The area drained by each unit should be as large as the surface conditions will permit making the number of units for a given area as few as possible. The first step in the design of a tile drain system

is to locate the outlet. The outlet should be so situated that it is not liable to be submerged.

The arrangement of tile drains is determined largely by the topography of the land the source of the water to be removed. There are six types of alignments. It has been seen from experience that these alignments either singly or in combination result in satisfactory drainage under all natural conditions.

Since tile drains are laid in order that the full productivity of the land is ensured, the depth of the drains should be such as to hold the ground water at a level which would not be harmful to standing crops. This, however, depends on the type of land, texture of sub-soil and the crops to be raised. Experts on agriculture are of the confirmed view that the water table should be at least 3 feet below the surface. To achieve this, the drains are to be placed at least 4 ft. below the surface. In arid regions, however, the tile drains are to be provided at a greater depth ranging from 5' to 7' as the soils being less dense there is possibility of the roots of crops going deep.

In the Punjab certain types of indigenous tiles locally called "kolabas" are found to be fairly effective. There is, however, urgent need to have them standardized with regard to length, size of gap, diameter, number of perforations etc. before they can be adopted on a large scale. For this field trials are essentials. In this connection it would be necessary for the Punjab, which is the most affected state due to surface drainage congestion and where emergent remedial measures are necessary, to initiate early action in this regard.

Prof. Janert, the East German Drainage expert, who was invited by the Punjab Government to advise them on the problem of water-logging emphasised the need for providing adequate sub-surface drainage as also to adopt indigenous type of sub-surface drains for lowering the cost and also resort to mechanisation if need be.

In India very little has been done regarding the use of tile drains for improving sub-surface drainage. Prof. Janert during his stay in the country initiated certain experiments at the Irrigation Research Laboratory at Amritsar. His experiment using kolaba were fairly successful. There is need for further research for standardising the kolabas, also in reducing their cost. Further work in this regard should be earnestly taken up and a system of sub-surface drainage by means of pipes be perfected to suit our conditions.

In Delhi porous concrete drains have been laid along the Central Vista for improving the sub-surface drainage of the area which used

49 PC—9.

to get water logged during the monsoon period. The result of this attempt would also be helpful in deciding the possibility of large scale adoption of this method of sub-surface drainage.

Tubewells.—Use of tubewells for pumping out water from the sub-soil is another effective way of improving sub-surface drainage and checking rise of the sub-soil water table. This method has the added advantage that if the tubewells yield sweet water it could be profitably utilised for either extending irrigation or to supplement canal irrigation thereby reducing flow in the channels, and consequent seepage. Brackish water within certain limits can also be utilised for the purpose of irrigation after diluting the same with canal water. However, if the water pumped out is totally unfit for use, then it has to be properly disposed off. Where the subsoil water-table has risen to within five feet of the surface it would be beneficial if canal irrigation were to be replaced by tubewell irrigation.

Running costs of tubewells are high as pumping has to be done more or less throughout the year. Further tubewells have a purely local effect and as a consequence to be effective, they have to be used in batteries and should be continuous. This is especially true in areas where a suitable natural outfall for a sub-surface drainage system is not possible, without pumping.

Tube wells were first used in Amritsar area where between 1911 and 1917, 15 tubewells were sunk. Their gross discharge when first opened was 28.5 cft./sec. However, this rapidly reduced and by about 1936 it was only 660 cft./sec. The cost of operation rose steeply and the experiments taken up at Ferozepur and Gujarawala also failed. All these three experiments were not successful because the tubewells were too few in number and their discharge utterly inadequate. Later a large scale experiment was tried at Rasul on U.C.C., L.C.C., J.J.C. and L.J.C. tracts, involving the installation of about 1860 tubewells of 2 cft./sec. each at a total estimated cost of about Rs. 8.00 lakhs. The results obtained by this large scale experiment are not known.

In recent times, however, large scale adaptation of tubewells for lowering the sub-soil water-table has been undertaken in Delhi where 303 tubewells each with a capacity of 1400 gallons/hour have been installed. The working of this scheme is expected to yield reliable results as to how effective tubewells can be in improving sub-surface drainage and lowering the watertable and the relative economics of the method when compared to other methods. In Punjab four pilot projects involving the use of tubewells were started in the Amritsar,

Sangrur, Sunam and Fazilka areas. Results from both these projects are expected to give valuable data with regard to the technical and economic aspects of the use of this method of lowering the water table.

Lining of Canals.—Lining of canals is an efficient although an expensive way of preventing infiltration from irrigation channels. Lining as a preventive measure is finding favour with many engineers and is yielding favourable results. Experimental work and research to evolve a suitable and cheap method of lining is being studied. The lining of canals not only helps in preventing water-logging but also prevents waste of irrigation water which is stored at very high cost. The water so saved can be utilised to bring more areas under irrigation.

While this method could be introduced with advantage in the new canal system, its adoption on an existing system in a tract where the subsoil water level is already high involves various practical difficulties as the lining work can only be carried out during canal closures. If the working period for lining is to be extended, costly canal diversion will have to be undertaken. Since the lined canal would be considerably smaller it may sometimes be more economical to have a new lined channel and abandon the old one. In seriously affected areas, where lining is most needed the bed of the canal can never be dry due to its being below subsoil water level and without a dry bed, the usual methods of lining cannot be adopted. This is in fact one of the biggest obstacles in the way of lining existing canals.

A novel and economical method of lining of canals has been evolved in some of the western countries requiring no closure of canals. As a matter of fact this method requires that the canal should be flowing when it is applied. The basic principle consists of introducing properly graded and treated colloidal particles of 'bentonite' (hydrated aluminium silicate) in the water flowing in the canals. The fine particles of this substance are drawn into the soil pores by the escaping water. These particles have the remarkable property of attracting fine sand and clay particles in suspension, which seal the seepage passages forming a highly impervious clay lining. If seepage were to develop again due to breach or for any other reason, it can easily be stopped by a second application.

Another method of making porous soil in the canal bed impervious is by injecting into the soil suitable mixtures of bentonite and jelly chemicals or a mixture of cement and clay under pressure. This

type of treatment is stated to be more or less permanent. This method of treatment also has the advantage of being done when the canal is flowing and does not require any closure of the canal. It is being extensively employed in France, Italy and Switzerland for opening foundations for hydro-electric plants in waterlogged areas.

✓ By proper compaction of the earth, canals can be made impermeable. This method has been extensively used in U.S.S.R. In the U.S.A., 4.2 million sq. yards of such lining has been executed with fairly successful results.

In India, these methods are still to be tried. It is very necessary that the latest and advanced techniques in this regard are learnt and their application in Indian conditions tried. ✓ As bentonite is locally available in India this method of canal lining could be tried with advantage. The Hungarian team which visited India recently in connection with the use of 'bentonite' in canal lining was very enthusiastic about its possible large scale use for canal lining. As a matter of fact they were of the opinion that the Indian bentonite when properly activated was superior even to the best American Wyoming bentonite and as such would be very effective.

Lining of channels was first tried in 1911 in the Punjab when a number of materials were tried. So far the only materials that have proved reasonably successful are:—

- (i) Kankar Lining on Gang canal.
- (ii) Brick lining on Haveli canal.
- (iii) Cement concrete lining on Thal canal.

More recently the Bhakra canals have been lined using concrete for the Hydel Channel, and bricks for the rest. The Rajasthan canal is being lined with bricks. In South India stone slab lining has been adopted on an extensive scale.

Studies made in this regard reveal that 44 per cent of water diverted into a canal system gets lost in transit. Of this, main canal and branches accounts for 15 per cent, distributaries 7 per cent and water courses 22 per cent. Thus major contribution is from the main canal and branches. Lining of main canals and branches at the time of original construction is by far the cheapest. The possibility of lining major distributaries also should be considered at the construction stage itself as the increased cost may in some cases balance the reduced cost in land, earth work and masonry works. Considerable economy could be effected by lining the water courses in perennial channels. The relative advantages and merits have to be studied in detail for each canal system.

The Economics of Subsurface Drainage vis-a-vis The Problem of Waterlogging

In respect of waterlogging and drainage, the difficulty is not in diagnosing the disease, nor are there any highly complex technical problems. It is not very difficult to evolve statewide plans and prepare comprehensive schemes with indications of costs. This has already been done to a certain extent by the Punjab, and can be done by the other States where the problem is not yet acute. But the real difficulty is that such projects are very costly.

The ultimate success of various anti-water-logging measures depend on the fertility of the land. Where the fertility of the soil has remained unimpaired or is not beyond repair, the possibility of taking proper remedial measures merits serious consideration. The economics of various remedial measures must be based on the cost benefit studies. Its effects on the country's economy are heavy specially when viewed in the context of the critical shortage in food. The economics of these measures must be viewed here in this light than in the conventional method of calculating the expenditure to be incurred and the revenue to be expected from the reclaimed lands.

Further steps necessary to remedy the present situation

(i) *Public Cooperation and Demonstration Farms.*—For reducing the subsoil water level, there have to be a large number of drainage channels which can, with advantage, be dug and maintained by private individuals. An effort may be made to confine the role of the Government to providing the technical know-how to the peasant and to coordinate the work to be undertaken by individuals and voluntary organisations. There is an analogy in the field of irrigation. It is well known that on an irrigation project all canals and distributaries are dug and maintained by the Government whereas field channels are dug and maintained by the individual owners of land. A similar procedure may be extended to the field of drainage schemes, whether surface or sub-surface. It is no doubt true that in some instances where the construction of field channels for irrigation is beyond the capacity of individual owner of land, this work is being done by the Government and the cost recovered from the beneficiaries. If necessary a somewhat similar procedure can be followed for the construction of small drainage channels also.

To ensure public cooperation and education, it is also suggested that an extensive network of demonstration farms should be set up in the affected areas, to propagate ideas concerning drainage and anti-waterlogging.

(ii) *Disseminate information on the lining of canals and its economics.*—A lot of research work has been done in India on the problem of lining of canals in order to minimise seepage losses. Various materials have been tried in laboratories and their relative economics studied. But, a broad review of the work so far done appears to suggest that the entire work was confined to the laboratories and not much has been done by way of actual field experimentation. All the available knowledge in respect of canal lining including the experience of the Nangal Power Channel, Rajasthan Canal etc. should be coordinated and consolidated to be of use in future works.

(iii) *Investigate and collect necessary data.*—The importance of investigations and collection of technical data could hardly be over-emphasised. A lot of scientific data is necessary on the physics and chemistry of soils, the chemical and physical modifications that will be affected as a result of drainage schemes, and the agronomical potentialities together with a study of economic implications. Similarly study of economic implications and preparation of sub-soil water contour maps is essential. Though India has been a pioneer in the field of irrigation not much data exists on which effective anti-water logging measures could be based. The collection of such data would be helpful in preparing effective counter-measures.

CHAPTER X

A review of the work done in some States to tackle the problem of water-logging along with suggestions for future work.

PUNJAB

Water-logging and the attendant evil, *thur*, made their first appearance in the Punjab in the tract irrigated by the Western Jamuna Canal round about 1850.

The effects were a considerable fall in crop yields and deterioration in the general health of the people caused by malaria and other diseases. Investigations showed that as a result of the logging of natural drainages and defective alignment of the canal, the water-table in this area had risen appreciably. Between 1870 and 1880, the canal was realigned and the natural drainage improved by the provision of adequate water-ways, which brought about a marked lowering of the water-table.

By 1907, these evils had appeared in other canal systems also and the resulting conditions had worsened to such an extent that in 1915, Government took serious notice of the problem, and by 1918 set up a Drainage Board.

After the abnormal rains of 1925, a Water-logging Enquiry Commission was constituted to carry out statistical investigation and experimental work in connection with both water-logging and *thur*. This led to the creation of the Irrigation Research Laboratory, which was entrusted with investigations regarding chemical and physical examination of soils and movement of moisture and drainage water in the soil columns.

In 1928, the Water-logging Enquiry Committee was expanded and converted into the Water-logging Board, and a new circle named the Water-logging Investigations Circle, was formed in the Irrigation Branch. Extensive work was then done in order to evolve methods of reclamation of water-logged and salt affected areas. As reclamation of salt affected areas progressed, a separate Reclamation Board was formed to look after the work.

In 1944, another Drainage Circle, called the Northern Drainage Circle was opened in addition to the already existing Water-logging Investigation Circle which was re-named the Southern Drainage

Circle. Both the Circles did extensive work on the construction of new drains and reconditioning of the old drains.

This programme of drainage and reclamation was confined practically to that part of the Punjab which is now in Pakistan with the result that little or no notice was taken of the problem as it existed in Punjab (India) till some time after partition. The gravity of the problem was aggravated by the abnormal floods of 1947, 1950 and 1952. In June, 1953, a Water-logging Board for this State was set up.

The unprecedented floods of 1955, followed by the floods of 1956 further aggravated the water-logging and *thur* menace. It was, therefore, decided by the Punjab Cabinet at a special meeting held on 15th April 1957, to set up an Action Committee, in order to tackle this problem effectively on a top priority basis. The Action Committee recommended the following remedial measures:

- (i) Minimisation, if not total prevention of flooding of the affected area from river, big streams and creeks.
- (ii) Improvement of land surface drainage.
- (iii) Installation of an adequate number of tube-wells and revival of percolation wells fallen into disuse to stabilise the sub-soil water at the proper level.
- (iv) Lining of water courses, main canals and distributaries, if economically possible.
- (v) Increase in the water allowance in *thur* affected areas so as to attain an intensity of 200 per cent.
- (vi) An appropriate crop rotation including the use of green manure.
- (vii) Construction of seepage drainages parallel to the existing channels.

The above recommendations were examined in great detail during discussions between the representatives of Planning Commission, Central Water and Power Commission and the Punjab Chief Engineers, as a result of which the following suggestions were made to the State Government.

- (i) Work should be concentrated on improving surface drainage in the State.
- (ii) A correct appraisal should be made of the extent of water-logged area by careful observation of ground water

table, both in the pre-monsoon and the post-monsoon period. A map should be prepared to depict the depth of the ground water-table in the various regions.

- (iii) The *thur* affected area should be carefully assessed and demarcated on maps before any large scale remedial measures are considered.
- (iv) The treatment of *thur* land should be taken up in stages beginning with a pilot scheme to demonstrate results.
- (v) Anti-water-logging measures should be concentrated in selected areas to produce significant results instead of spreading work over large areas.
- (vi) Lining of distributaries and minor and of the main stems of water courses should be taken up in selected regions where the trouble is most acute.
- (vii) The use of percolation wells should be encouraged where ground water table is high. Electricity at concessional rates might be made available for pumping from such wells.
- (viii) A pilot scheme for making underground lined rains in a selected area should be prepared and executed to demonstrate their effectiveness before a large scale programme is launched upon.

The State Government is formulating their schemes keeping the above points in view. Field experiments on a pilot scale have been conducted by the Punjab Government. For instance, there is Nissang Reclamation Farm in the Karnal District, which covers an area of 200 acres and which as a result of chemical treatment of erstwhile barren land, is yielding bumper sugar-cane crop.

The State Government also obtained the services of Prof. Janert of the Greifswald University of East Germany who has done pioneering work on problems of this type in that country. His recommendations are summarised below:

(i) *Installation of tube-wells and percolation wells.*—The use of shallow tube-wells for lowering the water table is highly commended by Prof. Janert, specially in areas where natural outfall cannot be provided.

(ii) *The construction of sub-surface drainage at a suitable depth.*—This method has not been practised in India on a large scale due to

high cost. However, mechanisation of the whole process of sub-surface drainage has greatly reduced the cost wherever it has been adopted. As there is no other equally effective measure, this method ought to be given a reasonable trial.

(iii) *Improvement of surface drainage.*—In water-logged areas in the Punjab, surface drainage has been neglected and is one of the main causes which has aggravated the situation. Due to siltation and uncontrolled growth of weeds, the natural drains have been choked up. In addition, the construction of culverts and siphons with insufficient waterway has worsened the situation. The reconstruction of the surface drains should, therefore, receive top priority.

(iv) *Planting of trees with high rate of transpiration.*—Surface drainage with or without subsurface drainage will have to be accompanied by several supplementary measures. One such measure suggested by Prof. Janert is the plantation in areas where the problem of water-logging is not very acute of trees which have high water consumption. These will not only serve as a shelter belt against wind, but would pump much water from the sub-soil, keeping the water table at a sufficient depth, and preventing it from interfering with cropping of the land.

Pilot Projects for Drainage and anti-water-logging.—Based on the recommendations of the Action Committee and Prof. Janert, the State Government have undertaken the following six pilot projects. Depending on the success of these pilot schemes, future large scale schemes are to be formulated.

(i) *Hansi Pilot Scheme.*—This scheme which is estimated to cost Rs. 13.95 lakhs involves the installation of 6 pumping stations and the excavation of 75 miles of long deep drains. The scheme is estimated to protect an area of 8,000 acres.

(ii) *Sangrur Pilot Scheme.*—The scheme is estimated to cost Rs. 36.35 lakhs and envisages the construction of a large number of drains with a cunette excavated at the bottom to act as seepage drains in addition to the installation of 40 shallow tube-wells. An area of about 1,600,000 acres is expected to be reclaimed.

(iii) *Sunam Pilot Scheme.*—The scheme similar to the Sangrur Pilot Scheme as regards most of the details, is estimated to cost Rs. 17.26 lakhs benefitting an area of about 223 sq. miles, i.e., 1,42,720 acres.

(iv) *Zira Pilot Scheme.*—The scheme provides for the deepening of existing drains in addition to the execution of a large number of

link drains to form a net work of seepage drains. The total cost of the proposed measures is estimated to be about Rs. 32·85 lakhs.

(v) *Fazilka Pilot Scheme*.—The scheme involves the construction of new field drains and the installation of a number of shallow tube-wells in addition to the deepening of existing drains. The estimated cost of these measures is about Rs. 21·23 lakhs.

(vi) *Amritsar Pilot Scheme*.—(a) The scheme estimated to cost Rs. 17·97 lakhs covers an area of 79,900 acres. It provides for the installation of 5 shallow tube-wells in addition to the construction of a number of seepage drains and provisions of pumps for dewatering depressions in the area.

(b) The scheme covers an area of about 16,000 acres involving the construction of shallow tube-wells and drains in addition to the lining of the canal.

Suggestions by Shri M. S. Sivaraman

Shri M. S. Sivaraman in his tour report (April, 1962) has given some suggestions in respect of the above pilot schemes which are quoted below:

“In dealing with these pilot projects a scientific approach is called for, untrammelled by pre-conceived notions, as the problem of water-logging is bound to increasingly dominate the economy of the State and it is necessary to evolve inexpensive practicable measures. Here and there where the soils are light the rise in the water table has been checked by provision of surface drains; but there is a tendency to generalise this as equally applicable to the more heavy soils which predominate. In order to evaluate the success of the pilot measures it is necessary to have the basic bench mark data at the inception, even on a random sample basis. Thereafter observations on the incidence and extent of water-logging in the project area, the effect of the measures adopted on the yield of crops and pattern of cropping in the major soil types should be made periodically”.

Shri Sivaraman has also suggested a method for reclamation of water-logged areas in the Punjab which is quoted below:

“The observations recorded by the Irrigation Research Institute, Amritsar, have been exhibited in a map and this map shows broadly the existence of a continuous sub-soil obstruction approximately running from Fazilka to Faridkot and thereafter in a south-easterly direction down to Rohtak. Within one to eight miles of this ridge the water table falls considerably but surface topography does not show

any marked variation. An analysis of over 250 borings has shown that the soil crust generally varies from 10 to 12 ft. in depth with 15% to 20% of clay, 40% to 50% of sand and the rest silt. The total salt content varies from 0.1% to 0.8%. The top crust in a large part of the tract is seen to consist essentially of heavy soils with an excess of soluble sodium salts and such soils will not easily part with water. Observations have shown that the lateral effect of the drains on the occluded water in the clay does not extend beyond a few feet. No doubt the drains help to relieve storm water accumulations and this is necessary but something more than the surface drains suggested by the "Action Committee" will be required to alleviate water-logging in the heavy soils.

It is possible that a large number of criss-cross drains will help to dewater the clayey soils and the pattern of such drains for the different types of soils requires to be studied in the pilot schemes; but it is likely that many cultivators would not agree to have their land crossed by too many drains. Observations in the Research Institute have shown that horizontal drains laid 10 to 12 ft. below the surface would help to reduce water from the clayey soils but this will be an expensive undertaking costing from Rs. 500 to Rs. 1000 per acre.

A cheaper alternative may lie in the direction of the experience in some parts of South India where channels are dug 20 to 25 ft. deep to the bottom of wells in order to lead the water from the aquifers below, to the surface about a mile or more away, taking advantage of difference in surface levels. The difference in the level of water table to the north and south of Fazilka-Faridkot-Rohtak ridge offers a tempting possibility of similar construction. For instance, the water table at Hansi is less than 5 ft. below surface, while five miles to the south it is 80 feet from the ground level, and if a drain piercing the clay crust of 10 to 12 ft. is dug down to the sandy aquifer in the north water could continuously flow to the unsaturated areas to the south. Surface topography would allow emergence of such drains to surface levels within a short distance.

In the course of discussions, it was mentioned, that there is a scheme of soakage pit on the 'Lissara nals' which may throw light on this. But the essential problem to be studied is the possibility of dewatering the top clay crust by tapping the water from the top-most aquifer below at different parts of the Fazilka-Rohtak ridge. Even pits going down to this aquifer dug in the 5 ft. drain may help to dewater if there is sufficient hydraulic pressure on the top crust which allows the water level to rise to less than 5 ft. in the pit. A more detailed investigation of sub-soil conditions on either side of the ridge and

evolving of simple drainage systems for lowering the water-table appear to be necessary and these should be taken up as a pilot scheme either separately or as a part of the other schemes in operation."

UTTAR PRADESH

This State has been experiencing troubles due to water logging and *reh* affected lands for several years. The State Government has established the following practices for the last several years:—

- (i) Construct and maintain an extensive system of surface drainage *pari passu* with the canal system.
- (ii) Restrict the intensity of irrigation to 35% or 45%.
- (iii) Refuse irrigation to areas where the spring level is already high.
- (iv) Encourage the use of wells.

As a result of the application of these measures particularly drainage, large swampy areas have been reclaimed, and in many other places the spring level has been lowered.

In spite of the measures which have been adopted so far, the problem has been getting from bad to worse. In April, 1958 when some information regarding the areas water-logged in different States was asked for, U.P. had intimated that in that State the area water-logged in April, 1952 was of the order of 6,71,870 acres which had increased in April 1957 to 18,88,705 acres. These figures, however, include areas water-logged due to drainage congestion as well as due to rise of sub-soil water-level. Latest figures pertaining to the area affected by the rise of the sub-soil water level are being collected. In addition to this, there are about 23 lakh acres which are affected by appearance of salt on surface.

MAHARASHTRA

Bombay P.W.D. Irrigation Development Division Paper No. 17 on Water-logged Land on Bombay Deccan Canals and their Drainage and Improvement by Shri I. M. Magdum, Executive Engineer, dated the 20th June, 1951, gives the following information on the problem:

"Major irrigation works in Bombay Deccan are mainly confined to the Central Plateau flanked by the Western Ghats on the west, with precarious rainfall belts and famine stricken tracts on the east. The three major irrigation valleys are (i) the valley of the Nira river, feeding the Nira Right Bank Canal and Nira Left Bank Canal commanding 5.96 lakhs of acres of cultivable area; (ii) the Pravara Valley containing the Pravara Left Bank Canal and Pravara Right Bank

Canal with a gross cultivable command of 1.82 lakhs of acres; (iii) the Godavari canals commanding 2.19 lakhs of cultivable acreage under the Godavari Left Bank and Right Bank Canals. Before the construction of the storage reservoirs and development of irrigation in the valleys concerned, the main and the tributary river valleys had ground water table and low lying black cotton soil tracts were known for their fertility”.

“In the early phase of irrigation development, the demand for canal water fell short of supply conditions and the irrigation authorities had to make special efforts to induce the cultivators to adapt themselves to canal irrigation in preference to their orthodox methods and in some cases canal water was even allowed free to them. The charges for canal water were also kept low. All this tended to make the cultivators less conscious of the need to economise canal water. In the early stage of development, therefore, there was lack of controlled and planned irrigation, and this coupled with improper sub-soil drainage led to water-logging.

Water-logging and salt damage to lands under irrigation was noticed a few years after the opening of first Deccan Canal in 1884. “This set the engineers thinking of measures to overcome the problem and for a few decades that followed, the technique of land drainage was being evolved though not quite seriously. In the early stages, the damage was most restricted to low lying portions and beds of natural surface drainage line over a narrow width, and the nallahs and valleys were subjected to an inappreciable rise in their bed levels though the ground water-table was showing a rapid increase in the rate of rise. The harmful effects of this rise were, however, noticeable when the water level came within 10ft. from the ground surface, at this stage and thereafter, the problem of drainage assumed serious proportion calling for remedial measures”.

However, no precautions were taken in time so much so that by 1948, “Lands measuring about 77,000 acres in the areas commanded by the Deccan canals were thus thrown out of commission as they were no longer suitable for cultivation unless artificially drained and reclaimed. Out of these 77,000 acres, about 57,000 acres were salt affected lands in varying degrees and the remaining 20,000 acres were water-logged with water level almost at G. L. to water level 3-4 feet below the surface.” The rapidity of deterioration can be gauged from the fact that “during the period of 25 years (from 1924 to 1948) the damage almost trebled from 29,000 acres to 77,000 acres”. As per the data supplied by the State, the lands further deteriorated till they amounted to 86,000 acres in 1952. Several reclamation operations were therefore, carried out on the few drained lands on the canals in ques-

ton with varying degrees of success. Following anti-water-logging and reclamation measures were generally tried:—

- (i) Lining of canals or distributaries to prevent percolation;
- (ii) Devising the cropping according to soil suitability, and avoiding over irrigation;
- (iii) Extracting the accumulated water in the low lying damaged lands and keeping the water level 4-10 feet below the surface by means of open trenches, porous pipe lines or lift irrigation.
- (iv) Scraping the surface salt and leaching the lands by flooding during monsoon;
- (v) Growing test crops of fodder, millet and the like according to their salt resistant capacity, and the concentration of salt in the top soil; and
- (vi) Cultivation of cane crops after depletion in surface salts and with suitable green or farm yard manure.

After extensive trails and experiments on the above measures "the technique of land drainage has now been almost standardised. The principle underlying this is to provide open trenches and pipe lines (in costly lands) in the previous strata at depths varying from 8 feet to 10 feet to drain away the percolation water and keep the water level below 4 feet from the ground level".

"A drainage project in the Bombay State usually depression serving as a carrier drain connecting a number of branches consists of a main drain along the natural drains, draining the subsidiary valleys. Open trenches are generally used as carrier drains. Where the land is very costly, pipe drains are constructed as branch drains which ultimately join the main open trench".

The Government of Bombay have now in hand several drainage schemes to reclaim the water-logged and salt affected areas in the State.

DELHI

It has been observed that there has been a steady rise of water table in New Delhi area since 1912. The rise varies from 2½ to 15½ feet in different parts of New Delhi. An *ad hoc* Committee was, therefore, appointed in September, 1953 by the Government of India to examine the question whether the sub-soil water was rising and if so to suggest necessary protection measures.

The Committee investigated the problem thoroughly and found out that in October, 1958, there were 3200 acres in New Delhi which were badly affected (water table below 6 ft. deep) and about 6000 acres which were moderately affected (water table between 6 ft. to 10 ft. deep). The Committee has suggested the following measures to combat this menace in New Delhi:—

- (i) The present drainage system should be based on a rational method of design of storm water drains and should not be any *ad hoc* basis. On this basis, the drainage system of New Delhi will have to be remodelled for a run-off of $\frac{1}{2}$ inch., that is, doubling its present capacity.
- (ii) Regrading of saucer shaped lawns and gardens.
- (iii) Providing underground storm water drains in open areas like the Central Vista and other lawns where such drains do not exist.
- (iv) Ensuring effective drainage of bungalow compounds.
- (v) Whenever new areas are taken up for development, drainage of these areas should be worked out on the basis of rational method.
- (vi) Provision of tube-wells to lower the water table in the badly and moderately affected areas where the water table is near the ground surface or is approaching it.
- (vii) Laying of porous concrete drains in open areas and also in areas to be developed.
- (viii) Further collection of data concerning the sub-soil water table.

Estimated cost for the complete scheme incorporating the above recommendations is Rs. 2.68 crores capital outlay and Rs. 18.12 lakhs recurring expenditure on running tube-wells. Work on this scheme is in an advanced stage of progress.

CHAPTER XI

Suitable trees and grasses for water-logged areas

A vast expanse of the water-logged areas necessitates their well-planned economic utilization. The few isolated experiments conducted hitherto suggest that these areas can be taken up for the production of forest crops and fuel plantations with or without introduction of drainage. Experience has shown that better results are achieved by the introduction of drainage which raises the soil productivity by removing excess water and by creating a favourable environment for the root system. The most common injury in swamp plantations is due to the root rot resulting in heavy mortality. Though basically agricultural and forest crops are affected almost similarly by water-logging, certain difference with regard to the depth of roots, tolerance to water-logged conditions etc. lead to infer that water-logged areas are amenable to reclamation through tree planting. Following afforestation the water level sinks at a rapid rate on account of increased transpiration by the new vegetation that develops luxuriantly after the drainage. This also results in a perceptible diminution in the amount of soluble salts. Thus, tree plantations are cheaper and more efficient in dealing with the swamp lands. The various difficulties accompanying the afforestation of swamps should, however, be well appreciated before any measurable success is ensured.

Introduction of drainage brings about favourable changes in the soil properties such as structure, poresize distribution, permeability, moisture availability, air capacity and nutrient availability, all of which influence plant growth. The results of the investigations obtained so far point out that these effects of drainage become noticeable after a few years. Following successful completion of the drainage operations, many unproductive areas have now been covered by vigorously growing high quality stands of forest crops in countries such as Finland, Sweden, Holland, Germany and U.K. It is important that the drainage operations of water-logged areas should be as cheap as possible so that they could economically be adopted in practical forestry. For this purpose minimum amount of digging etc. necessary to achieve desired benefits should be resorted to. Draining of water-logged areas becomes most profitable where a forest already exists and which is expected to thrive better after drainage.

The following methods may be profitably employed to improve drainage:—

(i) Ridge and furrow method.

(ii) Open ditches or trenches.

Out of these, ridge and furrow method will give the best results, as the tree will thereby be put high enough on ridges to be unaffected by the stagnant water in the early stages and also the furrows will improve drainage of the area. The high transpiration rate of the planted trees coupled with improved surface drainage will go a long way in converting a swamp into a dry land after a lapse of few years.

Lowering of the permanent water table by drainage, tube-well pumping etc. seems to be an effective method of obviating the ill-effects of high ground water level. It is obvious that for achieving greater production, afforestation of water-logged areas must be preceded by properly planned drainage.

✓ Suitable trees for water-logged areas

The choice of suitable tree species for the afforestation of water-logged areas is of paramount importance. The value of a high transpiring tree species cannot be overemphasized in this connection. However, as the soil, climate and other factors vary considerably in different places, it is difficult to recommend a list of species for general adoption. The surface vegetation naturally occurring in the area is a good indicator of the biological value of the soil. The existing local demand for forest products should be taken into consideration while making a correct selection of the species. Fuel value of the planted species is also of great significance. In order to make the project profitable it will be preferable to undertake artificial afforestation only on extensive areas.

Poplar planting has become an important use of wet lands after drainage in forestry. Fast growing *Eucalyptus* species, especially *Eucalyptus robusta* is usually recommended for planting in water-logged areas. In Madras, *Lagerstroemia flos-reginae* and *Dalbergia latifolia* were grown successfully in badly drained swampy areas. *Salix babylonica* was planted successfully in swampy areas after making suitable drains. *Eucalyptus rudis* has also been raised successfully. *Eucalyptus robusta* was tried in three swampy localities in Coorg in 1926-27. In Assam, *Barringtonia acutangula* has been found to grow well in the midst of swamps. In West Bengal, *Bischofia javanica* has been grown successfully in wet areas. In Orissa, Andhra Pradesh, Mysore, and Madras, *Casuarina equisetifolia* has grown well on water-logged sandy soils. *Syzygium cumini* was planted on mounds in a swampy area at Dhekulia in Orissa.

Experiments were conducted in Punjab to find out some suitable species for water-logged soils. The species tried were *Tamarix articulata*, *Eucalyptus rostrata*, *Salix babylonica*, *Salix tetrasperma*, *Dalbergia sissoo* and mulberry. Out of these species *Eucalyptus rostrata* showed good promise. *Salix* species were also fairly successful. *Sissoo* and mulberry gave worst results. In Pakhawal Jhil area, *Eucalyptus rostrata*, *E. tereticornis*, *E. hemiphloia*, *E. rudis* and *E. saligna* were tried. Out of these *E. rudis* and *E. rostrata* proved more successful and were finally selected for planting. Chinese Tallow tree *Sapium sebiferum* did well in swampy areas. The reed *Arundo donax* should also be of use for this purpose. *Cassia siamea* did well in drained plots in Balaghat.

Zizyphus jujuba, *Butea monosperma* and *Acacia arabica* grow freely in areas liable to inundation. *Tamarix articulata*, *Azadirachta indica* and *Populus euphratica* have been suggested in some cases.

Teak was raised successfully by planting on bunds (3', 1', 3") between the subsidiary drains (2-1|2 wide, 1 deep, 3-1|2 apart), but the cost of bunds alone amounted to Rs. 65 per acre and, therefore, the method was not considered practicable in Nilambur. It was also found that *Dalbergia latifolia*, *Lagerstroemia flos-reginae*, *Lagerstroemia lanceolata* and *Terminalia tomentosa* could grow on badly drained lands.

Tamarid, mango, *Cedrela toona*, *Balanites aegyptiaca* may be of use in certain localities. *Terminalia tomentosa* and *Syzygium cumini* sown on ridges parallel to the drainage are expected to succeed. A fair amount of success was obtained with *Lagerstroemia hypoleuca* and *Pterocarpus dalbergiodes*.

In addition to the above species *Randia uliginosa*, *Phyllanthus reticulatus*, *Trewia nudiflora*, *Jussiaea suffruticosa*, *Polygonum glabrum*, *Leea macrophylla* and *Mallotus philippensis* are also suggested for planting on low lying water-logged areas.

From the foregone account it will be evident that certain species are capable of thriving well on water-logged areas without any drainage, whereas in the case of other species it becomes necessary to introduce drainage to ensure success.

In the low-lying depressions, where water-logging is accompanied by the development of salinity and alkali, efforts should be made to plant exacting species on such areas. Two methods can be employed for afforesting the saline and alkali soils: (i) by growing salinity and alkali tolerant plants without any reclamation and (ii) by first improving the soil conditions before less resistant but economic plants can be grown. In the first method it is necessary to

select correct species and to adopt suitable planting techniques before any success is ensured. In the second method the measures for amelioration of the soil conditions will vary according to the nature and concentration of salinity and alkali. Washing away of salts by application of good quality water, provision of adequate drainage, lowering of water table and treatment with gypsum, calcium chloride or sulphur together with F.Y.M. or green manuring with *Sesbania aculeata* are some of the measures which will be required for improving the soil conditions. However, since the use of most of the reclamation measures is costly, attention should be focussed on growing salinity and alkali resistant species by using suitable planting techniques. Only those species which are inherently capable of producing a prolific root system, are able to resist salt content and can thrive well under conditions of low moisture supply should be selected for planting. Amongst the various species *Acacia arabica*, *Azadirachta indica*, *Albizia* spp., *Butea monosperma*, *Madhuca indica*, *Prosopis juliflora*, *P. spicigera*, *Tamarindus indica*, etc. appear to have shown good promise. A satisfactory soil working should aim at producing a suitable mass of loose soil amenable to rapid proliferation of root system and maintaining a salt-free condition of the soil mass through leaching. To achieve these objectives ridge method appears to be most suitable.

Planting of saline blanks-

The saline blanks are found in littoral regions in the tropics, in the estuaries of the rivers, in creeks and lagoons and on low and flats on the sea coast, where the soil is characteristically silty loam or stiff clay depending on the vicinity to tidal influence. The water-logging with saline water is a common feature. Aeration is very defective and the saline nature of the soil moisture renders the sites physiologically dry. Xerophytic foliage is a common feature which helps the vegetation against the conditions of physiological drought. Due to defective aeration, the vegetation has developed devices like stilt roots, knee roots, pneumatophores, and large lenticels on the roots. Afforestation of saline blanks is of great economic importance. Artificial regeneration of *Prosopis juliflora* in the Rann of Kutch provided a clue to the afforestation of saline blanks. Species like *Salvadora cleoides*, *Pongamia pinnata*, *Acacia arabica*, *Azadirachta indica*, *Tamarix gallica*, *Acacia leucophloea*, *Butea monosperma* etc. can also be raised with advantage for reclaiming these areas. The chief factors which determine the nature of vegetation in these areas are: (i) proportion of fine clay, (ii) salinity status and (iii) lack of humus. Out of these salinity of water is a more potent factor. One possible method is to raise the soil in the form of mounds;

or ridges and after washing out the salts in two rainy seasons, suitable species may be planted. *Diospyros* and *Lannea Grandis* have come up well in this manner. *Casuarina* may also be planted on artificially prepared mounds.

Fruit trees

As a rule, perennial fruit trees should not be grown in areas which are liable to water-logging at one period or other. However, according to literature some fruit trees such as pears, are reported to withstand flooding. Coconut is known to grow well in areas of high rainfall and running water. Guava and banana may also grow under conditions of high water table.

Grasses, Sedges and other plants

The following plants would stand water-logging conditions:—

- (i) Para grass (for fodder purposes).
- (ii) Dallis grass (for fodder purposes).
- (iii) Napier grass (for fodder purposes).
- (iv) Guinea grass (for fodder purposes).
- (v) Korai (for preparing mats).
- (vi) Murta (for preparing mats).
- (vii) Sachharum munja (for thatching).

(i) *Para grass (Brachiaria mutica)*.—It is a heavy yielding perennial grass well adapted to wet areas and can also be grown in water-logged low lying land. It can be propagated from stem cuttings. Each cutting having 2 or 3 joints is buried in well manured moist soil in the end of February (in Delhi conditions). Ten to twelve maunds of planting material is required per acre. Planting may be done in rows two feet apart to facilitate inter-culture. First cutting is ready in 2 to 2½ months' period from planting and 8 to 9 cuttings can be obtained per year. The grass is liked by cattle.

(ii) *Dallis grass (Paspalum dilatatum)*.—This is a pasture grass suitable for grazing. The grass is low growing and very leafy and is well relished by the cattle. It is propagated both by seed and root slips. The grass is well suited to humid and very humid regions and can withstand water logged conditions. Under semi-humid conditions it responds to frequent irrigations. Under optimum conditions, the grass, if cut, gives 8 to 9 cuttings per year, yielding as most as about 900—1000 maunds per acre. It is a profuse seed setter

(iii) *Napier or Elephant grass (Pennisetum purpureum)*.—This grass is tall growing and is suitable for cutting. It can also be grazed when 12—15" tall. If the grass is not cut at proper stage, it becomes fibrous and is not relished by the cattle. It can be grown in soils where water table is 1 to 2 feet of the surface. Under normal conditions, the grass responds very well to frequent irrigations and high doses of nitrogen. It gives about 8—10 cuttings and yields about 1200 to 1500 mds. of green fodder per year per acre. The grass is propagated vegetatively and does not produce seed under local conditions.

(iv) *Guinea Grass (Panicum maximum)*.—This is similar to elephant grass.

(v) *Korai (Cyperus corymbosus)*.—This sedge species is used for manufacturing mats. Slips with bulbs having about 9 of shoot are selected and planted 4 to 5" apart in well manured and levelled fields. First cutting is ready after about 10 months from the time of planting. Two cuttings per year are taken in subsequent years. The flower heads are cut off and the clumps are dried up and sorted out into different lengths for weaving mats.

(vi) *Murta (Clinogyne dichotoma)*.—This tall growing species of the family *Marantaceae* is cultivated in marshy lands in parts of Assam, Bengal and (Cachar, Sibsagar, Lakhimpur) Coromandal Coast for manufacture of various types of attractive looking mats called 'Sitalpatti'. It is learnt that the Assam Government is encouraging the cultivation of this plant to develop a cottage industry in the State. It is propagated from suckers.

(vii) *Saccharum munja*.—A tall grass used for thatching is also grown widely in water-logged areas.

Research Needs on Water-logged Land for growing trees and grasses

Reclamation of water-logged areas through afforestation practices, has become a vital need. It is further estimated that creation of such plantations will not only provide fuel and timber, but the active transpiration from well-wooded areas may lower down the water-table within reasonable limits for the general well-being of agriculture.

Similarly growing suitable grasses in water-logged areas is also very useful in the utilization and reclamation of such areas.

Water-logged lands received only scanty attention in the past. Therefore, there is not much literature on the subject so far as the Indian conditions are concerned. The available information is given

above. To be sure of planting practices, it is essential that the water-logged habitats be examined and studied in detail. The research projects in this regard are:

Field Research

(i) *Survey of species found to grow naturally under varied conditions of water-logging.*—Water-logged sites are spread throughout the country under varied conditions of climate and soil. Also, the water-logged conditions themselves are not constant. In some sites water-logged conditions prevail throughout the year, whereas in others they recur only for a brief period during the rains. Variations in between these two extremes are plentiful. In many of these water-logged sites, some vegetation of economic value exists. This project, therefore, contemplates to study all such sites throughout the country and collecting data on climate, soil conditions of water-logging and flourishing species. Data so collected will be of immense value in tackling sites of similar nature. Thus, the afforestation practice will be based on sound footing so far as the indigenous species are concerned. Also, the locality data collected will go a long way in choosing appropriate exotic species belonging to the genera *Eucalyptus*, *Taxodium*, *Salix* and *Acacia*, etc.

(ii) *Root Development studies of dominant species in relation to water-table fluctuations, aeration and nutrients.*—Root development studies in the field, particularly in respect of the dominant species, and related to water-table fluctuations, aeration and nutrients, will go a long way in devising correct afforestation practices.

Laboratory Research

It will help in the correct choice of species. The projects are:

- (i) Growing of species, known to be tolerant to water-logged conditions, under artificial water-logging conditions of varying degree.
- (ii) Status of soil air under varied conditions of water-logging.
- (iii) Release and availability of nutrients under varied conditions of water-logging.
- (iv) Root development.

CHAPTER XII

Crops suitable for water-logged areas and fish culture in paddy-fields.

Water-logging in soil is defined as condition of the soil where both large and small pore spaces are filled with water. Soils may be intermittently water-logged because of fluctuating water table or water-logged for short period after rains. Under conditions of prolonged water-logging and flooding, perhaps no crop could grow successfully except the aquatic plants or a semi-aquatic crop such as rice. Even in the case of rice it has been observed that upland rice is damaged by incidental flooding during flowering stage. Temporary flooding at certain stages of growth can be tolerated by certain crops, which have the capacity to form adventitious roots, as in the case of some sugarcane varieties. In some plants, tolerance to submergence is related to their capacity to develop inter-cellular spaces. A list of the crops and grasses of economic importance, which can tolerate varying degrees of water-logging is given below:

Extent of water logging	Field crops and vegetables
I. Prolonged flooding	Rice (Deep water paddy) (<i>Oryza sativa</i>).
(a) Deep water	Water chestnut (<i>Trapa bispinosa</i>). Water lily (Lotus) (<i>Nelumbium speciosum</i>)
(b) Shallow water	Paddy.
II. Flooding in later stages of crop growth .	Paddy. Jute (<i>Corchorus capsularis</i>).
III. Wet soil but occasional stagnation of water or no stagnation of water. .	Paddy, Jute, Sugarcane (<i>Saccharum Officinatum</i>), dhaincha (<i>Sesbania bispinosa</i>) and Arvi (<i>Colocasia esculenta</i>).
IV. High water table occasionally rising to ground surface.	Paddy, jute, sugarcane, dhaincha and arvi.

Short notes on the different crops, which could be grown under water-logged conditions are given below:

(i) Water chestnut—*Singhara* (*Trapa bispinosa*).—It is an annual aquatic plant and is cultivated extensively in lakes, tanks, ponds and fresh water reservoirs in Kashmir, Delhi, U.P. and Central Indian States. The seed nuts are sown thickly in nursery pond during January-February in a part of pond and are later transplanted. About 82 lbs. of fruit are required for 1/80th acre nursery, to produce sufficient transplants for covering one acre area. The seedlings are transplant-

ed once or twice and are set 5 feet either way. Flowering starts during August to September. Harvest usually starts from September to October and continues upto December-January. The average yield is about 20 to 50 mds. per acre.

(ii) Water Lily (*Nelumbium speciosum*).—It is a large aquatic herb with peltate leaves and handsome red or white flowers found all over India. The stem can be used as vegetable called 'bhen'.

(iii) Jute (*Corchorus capsularis*).—It is grown mainly in W. Bengal, Assam and Bihar. The crop is generally sown between mid February and mid May in well-prepared seed beds and is harvested between July and September, after the flowering stage. The crop does well on inundated areas which are not, however subject to flooding in the first two months of crop growth. Thus, the crop can stand water-lagging in the latter stages but early flooding renders the fibre coarse in the sub-merged portions.

(iv) Sugarcane (*Saccharum officinarum*).—Although the crop yield and quality of juice is likely to be impaired under prolonged water-logging, this crop can stand water-logging better than most of the other crop plants. Being long duration crop, it is subject to water-logging during the monsoon season in many areas, particularly low lying lands. One of the reasons for its extensive cultivation in north India, in spite of the short growing season there as compared to South India, appears to be the ability of this crop to grow on soil, which is subject to water-logging where most of the other crops will fail. Some varieties appear to stand water-logging better than others. Among these mention may be made of the following:—

Punjab	Co. 285, Co. 356
Andhra Pradesh	Co. 975
Bihar	B.O. 3, B.O. 29

(v) Dhaincha (*Sesbania bispinosa*).—This is a legume which can be grown under conditions of water-logging for green manuring purposes. This is more suited for green-manuring the paddy crop. Sowing may be done with the early pre-monsoon showers and the crop buried before transplanting paddy.

(vi) Arvi (*Colocasia esculenta*).—Tubers are planted in the month of January and the crop is harvested in August to October. *Colocasia* is exposed to hot and dry conditions till the onset of monsoon but thereafter the crop is subject to excess water in the monsoon season. It can stand conditions of excess water during this period when most other crops will fail to survive. A wild form of *colocasia* grows in marshy places and its leaves are used as green.

It may be mentioned that in the areas which are subject to inundation and water-logging during the monsoon season, rabi crops can be grown successfully after the flood water recedes and the soil is in condition for sowing. For example, in Patna city area about 4000 to 5000 acres of heavy soils which are inundated during the monsoon season, are used to grow potatoes.

7. Rice (*Oryza sativa*).—Of all the important crops grown, rice is unique in that it can stand water-logged conditions. This property is attributed to the mechanism of oxygen supply to the roots from the leaves. Of the three crops generally grown in India (autumn, winter and summer), autumn crop sown in May to June and harvested in September to October and the winter crop sown in June to July and harvested in November to December are subject to water-logging during the monsoon season.

Deep water Paddies

There are a considerable areas in certain States, notably in Assam, West Bengal, Orissa, Madras, Kerala, Andhra Pradesh and U.P. which get flooded. The deep water rices are grown in different conditions existing in these areas. For instance, there are areas just like in Assam where the crop is exposed to floods which may be intermittent at different phases of crop growth. The other areas are where water accumulates and rises to heights as much as 20 feet and fields remain submerged for a long time. Along the sea coast, besides flood water, the rice grower has to contend with salinity as well. Besides, there are ponds, tanks, burrow-pits along with railway lines, lakes and reservoirs of irrigation projects where deep water rice can be grown.

In the low-lying tracts of the Brahmaputra and Surma valleys in Assam, floods occur regularly and in these areas deep water rices are commonly grown. These are usually sown broadcast between March and May with the first showers. The plants are firmly established by the time of the flood water rises which reaches its peak by July or August and begins to recede by October. The deep water rice grown under such conditions, have a capacity to elongate rapidly and keep pace with the rise of the flood water. There have been instances, where plants have grown at the rate of one foot per day.

In the States of Orissa and West Bengal, summer crop of rice is grown in the low-lying flooded areas. The cultivation of these crops start in November-December when the flood water recedes. The

land is puddled and the seedlings of short or medium duration varieties are transplanted from periphery inwards. The crops is irrigated as and when required from the low-lying areas which remain under water.

In the State of Andhra, about 1.5 lakh acres are subjected to submersion of various depths during the period of May-June and October. About one lakh acres are in Collair lake, situated in between two major irrigation systems of Godawari and Krishna. Floods occur in the month of August and recedes by about the end of October. The depth of water in this lake extends from one foot at periphery to 6 to 8 feet at the centre. In the main crop season rice cultivation is confined to the region near the periphery of the lake where the water depth does not exceed 3 feet when flood occurs, Since the occurrence and the duration of the flood is uncertain, the first crop is a gamble. When the water recedes, the rice cultivation is taken up in the second crop season i.e., January to April.

In Kerala about 30 per cent of the total area of 4.2 millions acres is damaged by flood water in the low-lying areas of Kuttanad.

In the multipurpose project areas, large areas are periodically submerged in the reservoirs. In the periphery of these reservoirs, the deep water rice can be successfully grown.

Present position.—Varietal differences, with regard to capacity to withstand submersion and the capacity of plants to grow fast with the rise of water have been noted. Therefore, breeding projects with the object to evolve suitable varieties of rice for such flooded areas were initiated the inception of the Indian Council of Agricultural Research. As a result of breeding work in States and under the I.C.A.R. Schemes, some promising varieties have been evolved which can withstand the adverse conditions existing in flood affected and water logged areas.

In Assam, at the Deep Water Paddy Station, Habibganj (now in Pakistan), four long-stemmed strains, Habibganj 1, Habibganj 2, Habibganj 3 and Habibganj 4 were evolved. The strains could grow in 5 to 7 feet, 8 to 10 feet, 10 to 14 feet and 8 to 10 feet of water, respectively, and yield higher than the local varieties. At the new research station at Rohu, a programme of selection and hybridization for the evolution of high-yielding deep water and flood-resistant varieties has been taken up. Two strains, E.B. 1 and E.B. 2, which can stand 10 to 15 feet and 1 to 10 feet of water respectively, have

✓ been isolated, and are under trial. Three strains of bao rice, Ar. 1., Ar. C. 353-148 and Ar. 614-250, which can stand 2 to 6 feet of water have been released from the Karimganj Research Station.

Work is in progress on the evolution of floodresistant varieties at the Deep Water Rice Research Station at Pulla in Andhra Pradesh. Work so far done has brought to light a variety (an introduction from Burma) which can withstand intermittent flooding up to 3 feet, and a variety, Ar. 108, which can stand continuous flooding, varying from 4 to 6 feet. A selection, DWP-1311 obtained from a cross between Mtu. 16 and Ptb. 15, is promising. This selection can withstand flooding up to 3 feet.

In Madras, three strain have been found to withstand submersion to some extent. Co. 14, yielding, 3,000 to 4,000 lb. per acre is reported to stand submersion to a depth of 3 to 4 feet if sown early. Adt. 17, yielding 3,700 lb. per acre, can also stand submersion to some extent. Ptb. 15 yielding 3,000 lb. per acre is suitable for growing in submersible areas.

Three districts of Orissa—Puri, Cuttack and Balasore—are liable to be inundated in the lower regions of the delta. Several flood-resistant strains, FR. 44A, and FR. 44B were isolated by pure line selection from among the surviving plants in the flood-effected areas. Of these, FR. 13A and FR. 43B were released as flood resistant strains. FR. 43B is reported to have the characteristic of regeneration by secondary tillering even after all the primary tillers perish in the flood.

In West Bengal, two flood resistant strains of Orissa, FR. 13A and 43B, locally called Chin. 41 and Chin. 43 respectively, have also been found suitable. Hybrid 84 (from AS. 108 1 X Patnai 23) is reported to be fairly resistant to flood with capacity to stand 6 feet of water.

Investigations undertaken by D.V.C. in Tilaiya reservoir in Bihar has shown that it is possible by adopting suitable cultural practices and growing deep water rices to obtain yields of 15—35 mds. per ✓ acre in the low lying areas which are exposed to submergence. Varieties *Jaisurio*, *Tundia*, *Aman No. 1* and *Aman No. 138* and *Singara* were found suitable in the area.

Possibilities of Fish Farming in water logged rice areas.

Fish culture, in irrigated and flooded rice fields, is being carried out in several countries of South-East Asia particularly in Japan, Indonesia, Thailand and Malaya. Since the water in the low lying

rice areas remains from three to six months which is sufficient time for some kind of fish for achieving substantial growth, these rice fields can be used for fish culture. This practice can be of advantage not only because of the fish catch which can be taken from these waters but also because the presence of the fish in the rice fields has a definitely beneficial effect upon the yield of rice.

Fish production in rice fields can be classified as follows:

(i) *Catch on Irrigated Rice Fields*.—The simple but widespread practice of retaining and harvesting wild stock which enters the rice fields with flood or irrigation water. The yield of such fish is about 3 Kg. per hectare in six months' period.

(ii) *Fish Rearing as a Secondary Crop*.—This method signifies an alternate raising of two different crops on the same piece of land as is done in Kerala where prawns and brackish water fish are cultivated in paddy fields.

(iii) *Fish Culture between Harvest and Planting*.—In West Java, there is arrangement for perennial irrigation, hence the fields can be used continuously. Usually, three harvests are taken every two years. The interval between harvesting and planting is partly used for drying up the fields and partly for short-term fish culture.

(iv) *Mixed Rice Cultivation and Fish Culture*.—In this system, fish is reared as a "catch crop" during a longer or shorter period on the paddy field whilst the rice is actually growing. The fish fry or fingerlings are introduced in rice fields every year and 4–6 months old marketable fish is collected which gives a yield of about 100 Kg. per hectare. The yield of fish would, however, vary considerably. The natural food for carp fry in rice fields consists mainly of minute crustaceans, and the quantity of these has a considerable influence on the production of carp.

It has been found that the carp reared in rice fields, in addition to performing useful tillage, eat weeds and insects which cause damage to rice plants; furthermore, the remains of food provided for the carp and the excrement of the fish have a fertilising effect on the rice. Thus rice and fish culture have a symbiotic relationship.

Several attempts have been made to popularise fish culture in low-lying areas in the country. In a developmental scheme in 24 Parganas in Bengal, during the year 1945, paddy-cum-fish culture was demonstrated. Suitable areas were selected where the field

bunds were strengthened for fish culture and free supply of fry was arranged. The farmers were allowed to harvest fish free of cost. By a random sampling it was found that *Catla* (*Catla Catla*) had grown to 5"-8.3" Rohu (*Laboo rohita*) to 3½-7" and (*Cirrhina mrigala*) to 3"-5½" by the 15th November. It was observed that the fish showed a more rapid growth in paddy fields than in ponds. Experiments carried out in Bihar have shown an average yield of fish of 80 lbs. per acre. The slight increase in the yield of paddy is also claimed in these fields. The results of experiments conducted at Cuttack by the Central Inland Fisheries Research Sub-Station with the co-operation of Central Rice Research Institute have shown yield of 15 to 85 lbs. of fish per acre.

CHAPTER XIII

Review of work on soil conservation and reclamation done during the First and Second Plan periods, and the schemes of the Third Plan.

Since the beginning of the era of planning it had been emphasised that if agricultural production is to be stepped up, measures to improve the soil must be undertaken. The emphasis on irrigation facilities through canals has unfortunately led to an increase in area under the water-logged conditions, thus resulting in salinity and alkalinity of the soil.

It has been estimated that about 200 million acres of land were exposed to hazards of wind and water erosion, and of lands actually under cultivation, about 100 million acres were vulnerable to erosion. The Western desert alone accounted for 50 million acres. In hilly areas about 50 million acres of land occupied by pastures, waste lands and ravines, including catchment areas of river valley projects, required levelling, terracing, gully plugging, and planting of shrubs and trees.

While framing the First Five Year Plan the need to conserve soils from wind and water erosion and also from evil effects of irrigation was realized, and it was proposed to establish a Soil Conservation Branch at Forest Research Institute, Dehra Dun at which research on various problems connected with soil conservation would be undertaken. In addition, six research and demonstration centres were to be established in different parts of the country. Each of these centres was to be located in an area of wide-spread erosion, and one which has been chosen for a soil conservation programme during the period of the Plan. Data on soils, land-use, rainfall, runoff under different conditions, and effectiveness of various types of vegetation cover in arresting soil erosion was to be collected.

It was pointed out that hilly regions suffer more from erosion, thus rendering permanent improvement almost impossible as fertile soil was washed away. Similarly in case of projects located in arid and semi-arid areas (Rajasthan), afforestation and creation of vegetable belts composed of trees and soil binding grasses formed part of the programme.

Table 43 shows the magnitude of the area affected by soil erosion of various types in each State and thus gives in quantitative terms the magnitude of the problem, the Table 144 gives the financial outlay during various Five Year Plan periods for soil conservation schemes. It will be observed that no financial provision was made for problems of water logging, salinity and alkalinity during the First and the Second Five Year Plans. Even the outlay as given for Third Plan is not adequate enough to make any significant contribution to ameliorate the conditions of soil. The problems of salinity, alkalinity and water-logging if not properly checked now, will become very acute in near future. In the succeeding pages a brief account of the schemes of soil conservation and reclamation proposed during various plan periods and a short review of the achievements during First and Second Plan is given.

The First Plan emphasised the need of soil conservation in catchment area of every river valley project. Adequate steps for soil conservation in catchment areas are as essential to the proper development of water resources as construction of dams and reservoirs on the rivers. If these measures are not taken and erosion goes on unchecked, the catchment areas will be reduced in their productivity. The high silt loads resulting from erosion will increase cost of operation, impair efficiency, and reduce the life of dams and reservoirs. The danger of damage to dams and other structures by suddent and violent floods will also be greatly increased. Measures for control of vision and improvement of land-use should, therefore, form an integral part of the work in every river valley project. In the case of certain catchment like that of the Kosi, in which the rate of silting is known to be very high, adequate soil conservation measures are a pre-requisite to the undertaking of the project itself.

Table 43
Showing problem soils in States

(Area in '000 hectares)

State	Area affected by soil erosion			Salinity and Alkalinity	Total
	Water erosion	Wind erosion	Water logging		
1. Andhra Pradesh	8093.72 (200.00)	..	..	..	8093.72 (200.00)
2. Assam	212.46* (5.25)	..	N. A.	..	N.A.
3. Bihar	1944.11 (48.04)	16.59 (0.41)	..	..	1960.70
4. Gujarat	7301.75 (180.43)	..	..	..	7301.75 (180.43)
5. Himachal Pradesh	218.5 (15.40)	..	..	..	218.50 (5.40)
6. Madhya Pradesh	N.A.	..	N.A.	N.A.	1015.62 (251.00)†
7. Maharashtra	13861.30 (342.52)	..	..	..	13861.30 (342.52)
8. Mysore	8095.72 (200.02)	..	20.23 (0.50)	20.23 (0.50)	8134.19 (201.00)
9. Orissa	3112.84** (76.02)	..	..	N.A.	N.A.
10. Punjab	3023.43 (50.00)	809.37 (20.00)	N.A.	N.A.	N.A.
11. Uttar Pradesh	3642.17 (90.00)	607.03 (15.00)	1214.06 (30.00)	1234.29 (30.50)	6697.55 (165.50)

NOTE.—The extent of area affected is not available for Kerala, Madras, Rajasthan and West Bengal.

*About 212.46 thousand hectares are affected annually, mainly due to shifting cultivation.

**Roughly 3112.84 thousand hectares suffer from water erosion in hilly areas because of shifting cultivation.

†Problem-wise area is not available, estimates for the total affected area are available.

Source : P. E. O. Report 1962. Soil Conservation Programme.

Table 44

Statement of outlay, Expenditure and Achievement in the first two Plans and Programmes in the Third Plan.

Sl. No.	Items	First Plan	Second Plan	Third Plan
1.	Outlay (Crores)	2.00	20.00	72.00
2.	Expenditure (Crores)	1.60	18.00	
3.	Achievements :			
i.	Regional Research-cum-Demonstration Centre (Nos.)	8	..	2*
ii.	Desert Afforestation and Research Centres (Nos.)	11	..	..
iii.	Pilot Soil Conservation Demonstration Projects (Nos.)	1	..	..
iv.	Personnel trained in soil conservation methods (Nos.)	250	170 (Officers) 900 (Assistants)	..
v.	Trenching and check damming (Lakh acres)	4382	..	..
vi.	Afforestation in catchment area (Lakh acres)	0.05	1.20	10.00
vii.	Planting of trees along the roads (Miles)	150	..	..
viii.	Area covered under pasture improvement and experimental plantations (sq. miles)	100	..	..
ix.	Soil conservation and land use survey (Lakh acres)	..	120.00**	15.00
x.	Area covered under contour bunding and terracing (Lakh acres)	..	20.00	..
xi.	Demonstration projects of 1000 acres each (Nos.)	..	21	..
xii.	Stabilization of sand dunes (Acres)	..	0.02	..
xiii.	Paddocks of 200 acres each developed on pasture improvement and management (Nos)	..	50	..
xiv.	Contour bunding (Lakh acres)	..	..	110.00
xv.	Dry farming techniques (Lakh acres)	..	..	220.00
xvi.	Reclamation of waterlogged, saline and alkali lands (Lakh acres)	..	..	2.00
xvii.	Reclamation of ravine lands (Lakh acres)	..	..	0.40
xviii.	Soil conservation measures in desert areas including afforestation and pasture development (Lakh acres)	..	..	1.00
xix.	Extension of afforestation and pasture development to cover hilly areas, denuded forests and wastelands (Lakh acres)	..	..	7.00
xx.	Survey and preparation of topographic maps of ravine areas and undertaking of survey and pilot reclamation work in certain desert lands.	..	..	..

(Rs. 50 lakhs provided)

Notes: *For study of problems of red soils.

**20 lakh acres in catchment areas of river valley projects Central Government provision only.

(Source : Second and Third Five Year Plans).

During the First Five Year Plan period, a number of regional soil conservation research stations were established. The Dehra Dun centre is concerned with erosion problems in the Himalayas and in particular in the Siwalaks. The centre at Kotah is concerned with gully and ravine formation on river banks in alluvial soils, and the Centre at Ootacamund with problems of hillside erosion in the Nilgiris. The problems of ravines in Gujerat area are dealt with by the Centre at Anand. It has been estimated that about 11,256 acres of denuded land has been contour-bunded or afforested. In Bombay contour bunding covered an area of 600,000 acres. Contour bunding, gully-plugging, contour cultivation, etc. were carried out on over 7,000 acres in Anantpur and Kurnool districts of Andhra Pradesh. In order to check soil erosion on wastelands, an area exceeding 12,438 acres were afforested. In Gujerat (formerly Saurashtra) a large number of check dams and bunds were put across rivers and rivulets to prevent erosion.

During the first five year Plan land reclamation and development programmes were carried out by the Central Tractor Organisation, by State Tractor Organisations and with Government assistance by private farmers. The C.T.O. reclaimed 11.86 lakh acres of land compared to the targets of 11.1 lakh acres. The area reclaimed from Kans, a pernicious weed which renders the land unfit for cultivation, was distributed over four States, namely, U.P. (208,267 acres), Madhya Pradesh (369,594 acres), Madhya Bharat (289,974 acres) and Bhopal (268,187 acres). Jungle clearance was undertaken in U.P. (41,221 acres), Bhopal (7076 acres) and Assam (1,820 acres). Reclamation work began on a small scale in 1947-48 and proceeded at the rate of 200,000 acres or more per year during the period 1950-51 and 1954-55 and tapered off towards the end of the plan.

Among important reclamation schemes undertaken by States during the first plan reference may be made to the reclamation of *Khar* and *Khajan* lands in some of the coastal districts of Bombay which suffer from encroachments from sea waters on agricultural lands. The Government of Bombay set up a Khar Lands Development Board and drew up a programme for reclaiming 125,000 acres in the districts of Thana, Kolaba, Ratnagiri, Broach and Surat. In all 68,000 acres of land were reclaimed during the plan period. In U.P. in the Terai area at the foothills of the Himalayas in the Nainital district and in the rivers in tracts known as the Ganga-Khadir about 55,200 acres of land were reclaimed. The U.P. Government established 16,500 acres State farm in the Terai area.

While formulating the schemes of soil conservation for the Second Five Year Plan period, there were in existence a number of regional

Soil Conservation Research stations looking after particular problems of each region.

Extension Workers were trained to undertake the work of educating farmers in soil conservation work. It may, however, be mentioned that during the First Plan the work on Soil Conservation was broadly: construction of check-bunds, contour bunding, prevention of gully and ravine formation and checking wind and water erosion in hilly slopes. Physically the achievement was not commensurate with the magnitude of the problem and the period of five years was hardly enough for any significant achievement. In the schemes in the Second Plan greater attention was paid to each type of regional problem like deserts and coastal sand dunes, river valleys, hilly regions, ravine lands, sea eroded lands. It is for the first time that a programme of reclamation of waste lands which were under active erosion due to misuse was taken up.

Brief account of the various schemes included in the Second Five Year Plan is given below:

Second Plan Programme

Deserts and coastal sand dunes.—Due to pressure of population, both human and cattle, in desert areas in Kutch and in parts of Rajasthan vegetation has been fast diminishing. This leads to further desert formation and affects the fertility of agricultural lands in U.P., the Punjab and in other parts of Rajasthan. In addition there are local sand dunes and coastal sand dunes which also require to be controlled. Measures for the control of shifting sands and sand dunes, such as the creation of nucleus centres for the spread of vegetation, the introduction of improved dry farming practices and animal husbandry, improvement of pastures by seeding, fencing and rotational grazing, afforestation and village plantations for fuel and fodder, will be undertaken over an area of about 350,000 acres.

River valleys.—The practice of shifting cultivation has impaired forest wealth in Chhotanagpur, Orissa, Assam, and the Nilgiris which form the catchment areas of important river valley projects. Soil conservation in the upper reaches of river valleys is essential for preventing silting in dams and rivers. Soil conservation measures such as afforestation, fire control in forests and wastelands, pasture management, contour bunding, contour cultivation and strip cropping, gully control, stream-bank erosion control, head water dams and bench terraces will be undertaken during the second Plan over an area of 330,000 acres.

Hilly regions.—Due to pressure of population and over-grazing, specially by goats, steep slopes in the foot hills of the Himalayas from Punjab to Assam, in the Nilgiris, in the Eastern and Western Ghats, and in other hilly areas are being gradually deforested. Forests in the village common lands of the Siwalik hills in Punjab and Himachal Pradesh have suffered over a long period. From these bare and barren hills sand has been carried down by hill torrents into the plains below and has destroyed thousands of acres of valuable agricultural land. In the Assam hills, large tracts have been laid bare by shifting cultivation. In the Nilgiris forests on steep slopes have been cut down to make room for potato cultivation which has caused serious erosion. In Kerala certain hill forests were cleared for growing tapioca. Such practices result in soil erosion and land slides and are likely to affect dams, channels and river beds. In hilly regions, soil conservation measures over an area of about 170,000 acres are to be undertaken during the second plan period.

Ravine lands.—Lands situated along rivers such as the Jamuna, the Chambal, the Sabarmati, the Mahe and their tributaries are being eroded steadily and are going out of cultivation. It is necessary to reclaim such lands by afforestation, check dams, and terraces and other soil conservation measures in the watersheds of these rivers. Large-scale bunding operations for holding rain water are also needed. It is proposed to take soil conservation measures in ravine lands over an area of about 150,000 acres.

Waste lands.—There are large tracts of waste lands which are at present under active erosion due to misuse. This is seen, for instance, from the naked roots of trees and shrubs often found on waste lands. Some of these lands should be afforested to supply fuel and fodder and the rest put under improved pastures. During the plan period, soil conservation measures in waste lands are to be taken up over an area of about 100,000 acres.

Sea-eroded lands.—Mention may also be made here of a scheme which though not part of the soil conservation programme proper will help protect coastal areas in Kerala. Portions of the coastal area of this State are subjected to sea-floods periodically, which causes soil erosion. It is proposed to take protective measures at points which are damaged by such floods. The programme for the second Plan covers about 45 miles of the coast. Work on the construction of a long sea-wall parallel to the coast with groynes 200 feet long at 660 feet intervals has been begun.

Soil Conservation

During the First Five Year Plan the Central Soil Conservation Boards was established in 1953 and some spade work was done. During the Second Plan, soil conservation programmes were taken up in agricultural lands, catchment areas of river valley projects, ravine and waste lands on a planned basis. A sum of Rs. 18 crores was utilised in the second Plan on soil conservation as against Rs. 1.6 crores spent during the First Five Year Plan. Assessment of work done during the Second Five Year Plan on the different problem areas is given below:

- (i) *Agricultural Lands.*—Soil Conservation in agricultural land made good progress and the target of 2 million acres for contour bunding, terracing etc. was achieved. Notable progress was made in the erstwhile State of Bombay which accounts for three-fourths of the total achievement and where the soil conservation organisation is very well developed. In Madras and Mysore also a considerable amount of work was done. The achievement can be regarded as fair in the States of Andhra Pradesh, Bihar, Orissa, Uttar Pradesh and Madhya Pradesh, whereas little progress has been made in Assam, Kerala and West Bengal. The disparity in achievement of targets in the different States is generally related to the effectiveness of the soil conservation organisation and availability of trained personnel.
- (ii) *River Valley Projects.*—Emphasis was laid on undertaking of soil conservation measures in the catchment areas of river valley projects for prolonging their life and for controlling of floods. Work was carried out on pilot basis, and in all about 1.4 lakh acres were tackled during the Second Plan.
- (iii) *Other areas.*—As a result of neglect and indifference on the part of people, unsystematic felling of trees and over-grazing has been taking place in the hilly areas leading to erosion and land slides. During the course of the Second Plan, about 1.3 lakh acres have been covered under various soil conservation measures in the hilly tracts. To check the march of the desert about 35,000 acres were treated. A modest beginning was also made in reclaiming the ravine, waste and barren lands.

Soil and Land use Survey.—Survey, research, demonstration and training which are the basic requisites for efficient formulation and

implementation of soil conservation programmes were the responsibility of the Centre. Soil and land use survey was taken up in the catchment areas of major river valley projects. Against the target of 125 lakh acres, 118 lakh acres were surveyed in the catchment areas.

Research and Demonstration.—Research was continued at the 9 soil conservation research-cum-demonstration training centres located at Dehra Dun (Himalayan region), Chandigarh, (Siwalik region), Ootacamund (Hilly cultivated areas), Kotah (Chambal ravine—Rajasthan), Agra (Jamuna ravine—Uttar Pradesh), Vasad (Gujarat ravine), Bellary (deep black soils), Chhatra (watershed management), and Jodhpur (Rajasthan desert). In addition, a scheme on pasture development was also started in Rajasthan for devising ways and means for the reclamation and stabilisation of drifting sands. The results of the research conducted at the centres have provided valuable information. For instance it was revealed that contour cultivation increased crop yield by an average of 15 per cent. on deep black soils. In hilly areas in Ootacamund, bench terracing has checked soil erosion and increased the yield of potatoes considerably. At Jodhpur methods were evolved for stabilisation of sand. These methods were applied over 1800 acres during the Second Plan period. The use of phosphatic fertilisers increased the yield of crops on eroded lands in Siwalik region. At Vasad research station, it was found that the practice of sowing sunthemp for use as green manure for cotton and tobacco was helpful in reducing soil erosion and run off losses. Methods were developed at Agra and Vasad for reclamation of ravines and these were applied over 180 acres in Agra on eroded and ravine areas.

For popularising the various soil conservation measures among the cultivators, 40 contour bunding and dry farming demonstration projects were approved during the latter part of the Second Plan. Due to administrative delays and organisational difficulties work could, however, be initiated only in respect of 21 projects.

The overall progress during the Second Plan was quite satisfactory and the targets envisaged were almost achieved. However, in view of the vast magnitude of the problem, there was much to be desired for effective implementation of the various programmes. The soil conservation programme in the Second Five Year Plan started with initial organisational difficulties at the Centre as well as in the States. The dearth of trained personnel, reorganisation of States, administrative delays and lack of proper appreciation of soil conservation measures were impediments which were responsible for limiting the programme as well as for the slow progress of work on the field during

the Second Five Year Plan. Considerable difficulties were experienced in execution of soil conservation measures in the catchments of river valley projects especially where two or more States were involved and where the catchments was in one State but the benefits from the project actually accrued to another State. For the proper execution of the programme, a Soil Conservation Directorate was set up in the Ministry of Irrigation and Power and it was recommended to constitute River Boards in the concerned States.

Subsidies were given for training and for maintaining leave reserve to the States to enable them to send adequate number of persons for training. The position in regard to this has somewhat improved recently. The States of Maharashtra, and Gujarat have special Soil Conservation Organisations. The Agriculture Department in number of States, such as, Madhya Pradesh, Punjab, Orissa, Mysore, Uttar Pradesh, Rajasthan have separate officers to look after soil conservation work. There is, however, a considerable scope for organisational reform so that the soil conservation programme can be vigorously pushed forward.

Third Plan Schemes.

Research work carried out at various research centres has yielded useful results. Methods for the reclamation of shallow ravines for agricultural purposes were worked out for Gujarat ravines. Techniques developed for the economic utilisation of deep and narrow ravines for horticultural crops, forest plantations and pasture improvements have given promising results. Experiments conducted in deep black soils have shown that contour cultivation increases the yield by 60 to 70 lbs. per acre in the case of jowar grain and about twice that much amount in the case of fodder. At Jodhpur, techniques were developed for stabilising moving and dunes and stifling sands, and about 1800 acres of sand dunes were stabilised. Studies on pasture development have indicated that closure and rotational grazing helped to increase materially the yield of grasses.

Reclamation of alkali and usar lands.—An important cause of deterioration of irrigated lands is the rise in sub-soil water level and the development of saline and alkaline soils. Out of about 12 million acres of such lands, a third of the area is damaged by water-logging and soil salinity, another third is affected by salinity and alkalinity with low sub-soil water table, and the balance of the area is threatened by the water table rising to less than ten feet from the surface. Expansion of irrigation increases the risk of damage to soil. Provision for drainage in areas affected by water-logging is therefore essential. A target of about 200,000 acres has been proposed during the Third Plan for reclaiming waterlogged, saline and alkali lands, mainly

in Punjab, Uttar Pradesh, Mysore, Gujarat, Maharashtra, Rajasthan and Delhi. As a result of experiments conducted at the Banthra Farm near Lucknow and at other centres encouraging results have been obtained, and further studies are being undertaken.

Problem of ravine lands.—Large areas of lands along rivers such as the Yamuna, the Chambal and the Mahi and their tributaries have been badly eroded and transformed into ravines. The march of ravines is progressing unabated, resulting in loss of productive lands. About 3.5 million acres in Uttar Pradesh and about 800,000 acres each in Madhya Pradesh, Rajasthan and Gujarat are badly affected by ravine erosion. Work at research centres has emphasised the importance for the reclamation of the ravine lands by the adoption of controlled grazing, afforestation, terracing and other soil conservation measures in the catchment areas. Surveys to determine the severity of the problem in various areas and the action to be taken are, however, an essential preliminary. It is proposed to undertake the survey and preparation of topographical maps of ravine areas with a view to the formulation and execution of reclamation projects. A provision of Rs. 50 lakhs has been made for this purpose and for the survey and pilot work in connection with the reclamation of ravines, and pilot projects were set up in Madhya Pradesh and Gujarat. Programmes for the Third Plan at present provide for the reclamation of about 40,000 acres of ravine lands.

Desert Areas.—Overfelling of trees, excessive grazing and improper land use have accentuated the formation of desert. The desert in India extends from the Rann of Kutch to large stretches of arid tracts to the north in Gujarat and Rajasthan. Since the major occupation of the bulk of the population in these areas is rearing of cattle and breeding of sheep and goats, the wind erosion problem is linked with the problem of the pastoral areas. The Central Arid Zone Research Institute has taken up research in these and other related problems. A pilot project is also proposed to be undertaken for examining the methods and economics of reclaiming desert lands in a portion of the Rann of Kutch. It is proposed to bring about 100,000 acres of desert areas under suitable soil conservation measures including afforestation and pasture development in different States.

Hilly areas and other wastelands.—From the point of view of soil erosion, hilly areas, denuded forests and wastelands pose a serious problem. Soil erosion taking place in these areas has adverse effects on agriculture in the hills and in the plains. Overgrazing, shifting cultivation and indiscriminate felling of trees have led to this situation. To control soil erosion and to restore productivity for normal utilisation, afforestation and pasture development will be extended to about 700,000 acres covering hilly areas, denuded forests and wastelands.

CHAPTER XIV

Use of Aerial Photography in Soil Mapping and Land use classification with particular reference to wasteland saline alkali and water-logged lands.

Aerial photographs are fast replacing other base maps in soil survey and are extensively employed in detailed soil surveys, and land use classification. The geographical features which could only be mapped at great expense and time may conveniently be located in the aerial photos, which may be placed on the plane table and the location of soil profile pits, spot checking positions and surveys boundaries may be determined by observation of directions from three known features in the landscape.

For scientific interpretation of the air photos a close study should be made of the shape, size and pattern and shadow cast by the landscape feature and the tone and texture which have been produced on the photographs in order to get a correct idea of the land forms. The scale of the photography generally used for soil survey is 4 inches to a mile or 1:15000. The soil surveyor maps the field data (soils, slope texture and structure) with a multi-coloured pencil. Grass and bush-covered areas show marked seasonal variations; for example grass produces grey shades on the photograph in the dry season. Variation in shapes and colouration helps to identify different species of trees and plants, e.g. teak has a typical crown shape and colouration.

Land Forms

Landscape is the most general element of the soil pattern and assists the soil surveyor in establishing the parent material of the soil. Ridges are less distinct than the streams. The summits of the ridges are comparatively out of the focus as compared to the datum plane of the photography and may stand out in sharp outline casting enough shadow. The terrain characteristics of a region can be closely determined by a correlation of the principal erosive process with the bedrock, climate and vegetation. Soils as such are not commonly distinguishable on the air photos unless marked by some surface features but the interpretive use of the photographs assists in the demarcation of soil boundaries by an indicator study of the

topographical, ecological and hydrological data and its representation on the air photos in their characteristics groups.

Interpretation of soil and land features

By the use of stereoscopic devices aerial photo interpretation provides qualitative information regarding land including location, origin and general texture of various soils and unconsolidated deposits; location and general evaluation of sand, gravel, clay and boulder deposits; type and structural characteristics of bedrock; delineation of areas having good internal drainage, imperfect drainage and water-logging; indication of springs, land slides and salinity. One of the most important items for consideration in land use is drainage which is sometimes difficult to investigate by ground methods. Drainage generally includes the surface pattern (the water that runs or stays above ground after rain), and the infiltration sub-surface pattern (that part of the rainfall that soaks into and moves into the soil). Advanced and accurate knowledge of drainage is essential for prudent land use planning; streams of surface flow must be diverted, severed, bridged, or tunnelled, if they lie in the paths of the roads or other developments. The detachment areas must be known in order to select correct culvert, sewer, bridge-opening sizes, thereby avoiding local flooding by back-water at restricted openings. Aerial photography is an inexpensive substitute for large-scale topographic mapping of flat areas.

Vegetation types are distinguished on the aerial photos with different shapes and may be used as indicators of soil characteristics. The overall patterns of grey formed on the photograph by different types of vegetation provide a clue to other soil forming factors, namely climate, soil and ground water conditions. Dark grey patches on the photograph indicate forested areas; single dark spot indicates isolated trees. The vegetational roof reflects the characters of the land surface and its topography.

The different shades of grey tones indicate various moisture conditions and point out the difference between well-drained and poorly drained soils. Each of the common soil colours, red, white and black, is rendered in its characteristic tone on the photograph, e.g. the black shade indicates deep, wet and silty clays, while the lighter tones indicate a higher silt content.

The drainage pattern can be used as an indicator of the soil texture. The shape and cross-section of the micro-relief provides a clue to the textural differences within the soil profile. A close stereoscopic study of the air photos can reveal the structure patterns,

which are formed by the local weathering and development of the soil profile. Under familiar conditions, soil types may be distinguished directly on air photographs. Generally an adequate knowledge of the ground condition is necessary by means of field checks in order to properly interpret the soil types on the air photos.

Once the soils are interpreted and the boundaries marked the areas are usually determined with the planimeter. Air photographs are very useful in mapping erosion conditions, since the ground conditions from the origin of a fall to the final line are visible in the one sight. The different types of drainage conditions produce greater patterns of various shades and shapes on the air photos. Large rivers follow sweeping curves, and canals produce a straight pattern. A lake is generally circumscribed by a light riband on account of sandy shores. Swamps produce a dark gray as compared to the surrounding land. A sea or an ocean can be recognised by a wave pattern.

In a landscape, drainage pattern is a direct function of the soil permeability and slope and the soils can be interpreted in context of the drainage pattern they form. A dendric drainage system indicates poor internal drainage. The density in a drainage pattern is an index of the survey in the soils. Sandy soils absorb the moisture to penetrate easily and form a drainage pattern of a density matching with the permeability of the clayey soils. Percentage slope directly reflects itself in the drainage conditions. Moist spots, standing water, and meandering streams indicate comparatively flat ground. Sometimes the local soil pattern in combination with a local drainage condition produces a local slope or small incline and decline known as micro-relief. These micro-relief features produce their characteristic grey pattern on the air photos and assist in the interpretation of soils. Gradual slopes are generally associated with soils of relatively high clay content.

Erosion is a direct function of soil profile in context of its slope and drainage and develops a characteristic erosion pattern. 'U' shaped gully indicate silts and sands, while a 'V' shaped gully indicates a granular soil material. Thus the various shapes and sizes of the gullies can be interpreted in terms of soil conditions. If necessary these patterns can be enlarged in the cartographic camera for a study of the details of the pattern.

Cultivated areas produce a pattern on the air photo that are easily identified by the soil surveyor e.g. rice field produces a characteristic photographic pattern. The photographic patterns produced by contour ploughing, terracing and strip-cropping would also give a clue to the forms of erosion and would assist in the planning of check dams.

The use of aerial photos coupled with the visual reconnaissance can provide a large quantity of basic data which are required to determine the proper land use, erosion control and land reclamation. The present land use can be very well interpreted from the various photographic greys e.g. harvested crops can be detected by patterns pointed by stock formations. Various types of crops and natural vegetation produces patches of different tones on the photographs, e.g. hilly terrain.

Air photos of various scales are used for land classification. In U.S.A. usually a scale of 4-1 mile or 1:1500 is used. In India generally a scale of 2.5-1 mile scale of aerial photo is used. The contact print of this size is however considered to be too small for study by planimeter and it has been agreed, after discussion with the Surveyor General of India and other concerned agencies, that in future aerial photographs in India should be made in the scale 1:15000 which will be used for soil and land use survey.

CHAPTER XV

The economics of reclamation of waste lands in India

There are no other data on the economics of reclamation of waste lands in India except those given in the reports of the Wastelands Survey & Reclamation Committee. The Wastelands Survey and Reclamation Committee has so far submitted its final report on the location and utilisation of wastelands in the States of Punjab, West Bengal, Bihar, Madhya Pradesh, Andhra Pradesh, Mysore, Kerala, Madras, Jammu & Kashmir, Uttar Pradesh and Maharashtra. The scope of the study includes.

- (i) general characteristics of the wastelands;
- (ii) measures necessary for bringing the wastelands under cultivation;
- (iii) cost of reclamation;
- (iv) suggestions for follow-on cultivation and resettlement operations; and
- (v) estimated additional production from the reclaimed areas and priorities between different categories of reclaimable lands.

Broad outlines regarding the areas proposed for reclamation, the cost of reclamation, additional food production, etc. in respect of each State are discussed in the following paragraphs, while full details are tabulated in table 45.

Punjab.—A total area of 3,16,650 acres has been recommended for reclamation in the State at a total cost of Rs. 5.43 crores, which gives an average cost of Rs. 171 per acre. The estimated additional annual production from the reclaimed lands is 1.32 lakh tons valued at Rs. 3.85 crores. Among the different categories of reclaimable wastelands in the State, jungle lands comprising 41,850 acres have been assigned the top-most priority, as the areas have perennial irrigation and are capable of producing two crops in the year. Next in the order of priority are the degraded lands as the cost of land improvement is the lowest in these areas (Rs. 60 per acre) and there are large areas of eroded lands where contour bunding combined with dry farming methods of cultivation can produce quick and beneficial results. Although 2 million acres of such lands are

reported to be available, the Committee has recommended that contour bunding operations may be undertaken over only 1,25,000 acres as the State Department of Agriculture has no specially trained staff for undertaking the work. Similarly, reclamation over 50,000 acres of saline and alkali lands only has been suggested for the Third Plan period although large areas of such lands are reported to be available. The bet or riverain areas comprising 99,800 acres have been assigned the lowest priority in view of the fact that these lands although fertile, are subject to flood hazards which make cultivation rather precarious.

West Bengal.—The total extent of wastelands in large-sized blocks is 1,13,640 acres. The cost of reclamation will be Rs. 1.32 crores, and the estimated additional annual production from the reclaimed lands will be Rs. 42,895 tons valued at Rs. 1.40 crores. Eroded lands have been given the highest priority for reclamation as large tracts of lands are available (85,379 acres) and, when reclaimed, will materially assist in increasing agricultural production in the State. Next in the order of priority are *char* lands (12,594 acres) which are fertile and are capable of producing good crops of paddy, sugar-cane, jute, etc. The cost of reclamation of these areas is also low i.e. Rs. 100 per acre, but large-scale settlement in the areas is not possible due to flood and erosion hazards to which they are subject. Reclamation of *terai* lands comprising 13,609 acres has been assigned the lowest priority as these lands are poor in fertility and do not retain moisture for long. Saline lands in large sized blocks comprise only 1,798 acres in the State.

Bihar.—The extent of wastelands recommended for reclamation is 72,196 acres—57,396 acres of eroded lands in the lateritic belt of South Bihar and the Chotanagpur plateau and 14,800 acres of *terai* lands in North Bihar. According to the State Government, the figure of 57,396 acres does not indicate the actual position regarding the availability of eroded lands as it relates only to such blocks which could be surveyed with the help of local staff and about 2 million acres of wastelands may be available in sizeable blocks in the State. The cost of reclaiming 72,196 acres comes to about Rs. 1.07 crores, i.e. Rs. 148 per acre. The estimated additional annual production from the reclaimed lands is 20,746 tons valued at Rs. 45.31 lakhs.

Madhya Pradesh.—The extent of available wastelands in large-sized blocks is estimated as 2,01,625 acres. Bulk of these wastelands are situated in an undulating tract, where the rainfall ranges from 30 to 60 inches. No irrigation is available for any of these areas. The cost of reclaiming 2,01,625 acres of wastelands comes

to about 2.51 crores, i.e. about Rs. 125 per acre. The estimated additional annual production from the reclaimed lands is about 46,000 tons, valued at about Rs. 1.52 crores.

Andhra Pradesh.—The total area of waterlands in large sized blocks recommended for reclamation is 1,37,710 acres. The cost of reclaiming these lands is Rs. 1.74 crores, i.e. Rs. 126 per acre. The estimated additional production from the reclaimed lands is 43,329 tons, valued at Rs. 1.18 crores. Of the three categories of wastelands located for reclamation, saline lands comprising 32,751 acres have been assigned the highest priority as the areas including in this category can yield about 20 mds. of foodgrains per acre for an expenditure of Rs. 190 only on their land improvement. Dry lands comprising about one lakh acres also offer great promise for increasing agricultural production. Some of the dry lands, particularly those in the Nellore district, which is likely to receive the benefits of irrigation from the Nagarjunsagar projects have also been given high priority in the programme of reclamation in the State. The jungle lands comprising 5,765 acres are assigned the lowest priority in view of the high cost of reclamation involved.

Mysore.—The total area recommended for reclamation in the State is rather small i.e. only 68,820 acres. This, however, excludes areas located in the districts of Chikmagalur, Shimoga and South Kanara where large areas of wastelands are reported to be available. The cost of reclamation of these areas is rather high, but it has not been possible to study the economic aspects of reclaiming these lands with reference to the cost of reclamation and the estimated additional production. The cost of reclaiming 68,820 acres of wastelands comes to about Rs. 1.65 crores i.e. about Rs. 236 per acre. The estimated additional annual production on the reclaimed lands is 20,520 tons valued at Rs. 67.30 lakhs. Of the total area of 68,820 acres suggested for reclamation, *khar* (saline) lands comprise 7,832 acres, jungle lands 53,957 acres and eroded lands 7,031 acres. *Khar* lands have been assigned the highest priority as these areas can yield, after reclamation, about 12 maunds of foodgrains per acre for an expenditure of Rs. 120 per acre on land improvement. Jungle lands have also been given an equally high priority. Eroded lands have been assigned the next order of priority.

Kerala.—The total area recommended for reclamation in this State is very small i.e. only 5,323 acres. The cost of reclaiming these lands is about Rs. 22.80 lakhs i.e. Rs. 400 per acre. The estimated additional annual production is valued at Rs. 7.43 lakhs.

Madras.—The total area proposed for reclamation in this State is also small i.e. only 25,646 acres. The cost of reclaiming these

lands is Rs. 30.30 lakhs or Rs. 118 per acre. About 12200 acres of these lands can, after reclamation, be utilised for growing highly remunerative crops like rubber, etc. Excluding the value of these crops, the value of additional annual production is estimated at Rs. 19.51 lakhs.

Jammu & Kashmir.—The total area proposed for reclamation is 12,932 acres only. They are mostly located along the creeks of the rivers with the result that the areas remain flooded during the rainy season and any large scale habitation becomes somewhat precarious. No flood control schemes are in operation. Even after the flood protection measures are taken and the areas are cleared of weeds, it would be necessary to arrange for mechanical cultivation of reclaimed lands. Further, since the areas are located along the cease-fire line with Pakistan, security arrangements will also be necessary. In view of these difficulties, an area of only 1,340 acres is recommended for reclamation. The average annual yield from these lands is estimated at 8 maunds per acre valued at Rs. 96 as against the cost of Rs. 80 towards reclamation.

Uttar Pradesh.—The State Government has estimated the total extent of *usar* lands in large sized blocks to be over 6 lakhs acres, on the basis of certain surveys carried out in the State. Of this area, 50,000 acres of easily reclaimable type are proposed for reclamation together with 11,018 acres of lands infested with thick growth of jungle and bushes, during the Third Plan period. The cost of reclamation of *usar* land is estimated at Rs. 325 per acre while the cost of reclamation of land belonging to the latter category is about Rs. 94 per acre. The value of estimated additional annual production is Rs. 83.69 lakhs. The *usar* lands particularly those which are easier to reclaim at an economic cost are assigned the highest priority because large tracts of such lands are available in the State and these lands, after reclamation, can be used for the rehabilitation of the poorer sectors of rural community. The wastelands belonging to the other category have also been assigned a high priority.

Maharashtra.—The total availability of wastelands in large-sized blocks suitable for reclamation is reported to be only 35,584 acres, comprising 29,586 acres of dry lands and 5998 acres of lands infested with thick growth of bushes and jungle. The cost of reclamation of the first category is estimated at Rs. 94 per acre, while that for the latter is Rs. 171 per acre. The total estimated additional production is estimated at Rs. 14.26 lakhs. In view of the low cost of reclamation of dry lands, this category has been assigned the highest priority for reclamation.

To sum up, it may be stated that the total extent of wastelands available for reclamation in the eleven States, for which reports have been finalised, comes to about 10·4 lakh acres. The total cost of reclaiming these lands is estimated at Rs. 16·35 crores i.e. Rs. 160 per acre. The additional annual production is worked out as 90·68 lakh tons valued at Rs. 10·3 crores. Thus, it would be clear that the value of production would cover the cost of reclamation in two crop seasons, which can be considered as economic.

Table 45

Details regarding areas recommended by the Waste-lands Survey and Reclamation Committee for reclamation in the different States including cost of reclamation and additional production per year

State	Description	Area proposed for reclamation (acres)	Average cost of reclamation per acre (Rs.)	Total cost of reclamation (Rs. in lakh)	Additional production per acre per year (maunds)	Total additional production per year (maunds)	Value of additional production per year (Rs. in lakh)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Punjab	Lands overgrown with jungle and shrubs.	41,850	140	58.59	20	8,37,000	100.44
	Bet or river in lands	99,800	170	169.72	10	9,98,000	119.76
	Saline & Alkali lands	(a) 4,000 (b) 46,000	(a) 250 (b) 500	(a) 10.00 (b) 230.00	15	7,50,000	90.00
	Eroded lands	1,25,000	60	75.00	5	6,25,000	75.00
	TOTAL	3,16,650	..	543.31	..	32,10,000	385.20
West Bengal	Eroded lands	85,379	120	102.61	8	6,83,032	81.96
	Char lands	12,594	100	12.59	30	3,77,820	45.34
	Flat (Terai) lands	13,689	100	13.87	6	83,214	9.98
	Saline lands	1,798	160	2.88	15	26,970	3.24
	TOTAL	1,13,640	..	131.95	..	11,71,036	140.52
Bihar	Eroded lands	57,396	160	91.83	6	3,44,376	27.55
	Terai lands	14,800	100	14.80	15	2,22,000	17.96
	TOTAL	72,196	..	106.63	..	5,66,376	45.31

Table 45 (Continued)

State	Description	Area proposed for reclamation (Acres)	Average cost of reclamation per acre (Rs.)	Total cost of reclamation (Rs in lakh)	Additional production per acre per year (maunds)	Total additional production per year (maunds)	Value of additional production per year (Rs. in lakh)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Madhya Pradesh	Lands overgrown with jungle, shrubs and bushes.	2,01,625	125	251.24	6	12,68,904	152.26
Andhra Pradesh	Lands overgrown with jungle, shrubs and bushes.	5,765	224	12.91	6	34,590	3.46
	Saline lands	32,571	191	62.44	20	6,51,420	65.14
	Dry lands	99,374	99	98.47	5	4,96,870	49.69
	TOTAL	1,37,710	..	173.82	..	11,82,880	118.22
Mysore	Eroded lands	7,031	167	11.73	5	35,155	4.22
	Lands overgrown with jungle, shrubs and bushes.	53,957	267	144.87	8	4,31,656	51.80
	Khar (saline) lands	7,832	120	9.38	12	93,984	11.28
	TOTAL	68,820	..	165.18	..	5,60,795	67.80
Kerala	Lands overgrown with jungle, shrubs and bushes.	5,323	400	20.80	7 (approx.)	37,500	7.43
Madras	Dry lands	24,446	112	27.30	8	1,95,186	19.51
	Lands infested with thick growth of bushes and jungle.	1,200	250	3.00	(c)]	(c)	(c)]
	TOTAL	25,646	..	30.30	..	1,95,186]	19.51

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Jammu & Kashmir		Please see the text in the Chapter.					
Uttar Pradesh.	Usar	50,000	325	162.50	12	6,00,000	72.00
	Land infested with thick growth of jungle and bushes.	11,018	100	11.10	9	97,465	11.69
	TOTAL	61,018	..	173.60	..	6,97,465	83.69
Maharashtra	Dry land	29,586	94	27.95	4	1,18,344	9.46
	Lands infested with thick growth of bushes and jungle.	5,998	171	10.25	10	59,980	4.80
	TOTAL	35,584	..	38.20	..	1,78,324	14.26
	GRAND TOTAL	10,38,212	160	1,635.03	9	90,68,466	1,033.77

(a) for areas with low water table.

(b) for areas with high water table.

(c) fit for growing crops like rubber etc. which are highly remunerative.

CHAPTER XVI
RECOMMENDATIONS

Sl. No.	Recommendations	Action to be taken by
I	<i>General</i>	
	(i)(a) There are large gaps in our knowledge of land resources. To obtain quick results, it is necessary that land surveys using photogrammetric techniques (aerial photographs) should be undertaken, and data on land use, land improvement, reclamation of water-logged, saline and alkali lands and their productivity should be collected in a systematic manner with a view to drawing up future plans.	Survey of India and State Governments through the Ministry of Food and Agriculture.
	(b) It is recommended that the Ministry of Food and Agriculture may set up a small working group of 2 or 3 persons for drawing up a practical scheme for resettlement in bigger plots, indicating priorities and phasing the programme, taking into consideration the limited available funds. The basis of financing may be Rs. 1000/- per family including supply of water, provision of road, residence, etc. etc. apart from the cost of reclamation of land which may be put at Rs. 150/- per acre amounting to Rs. 1050/- for reclaiming 7 acres of land, the total cost per family being about Rs. 2000/-. For smaller plots Rs. 500/- per family may be taken as the initial expenditure.	Ministry of Food and Agriculture.
	(ii) It is recommended that a Land Development Sub-Committee may be set up under the Agricultural Production Committee in the States for looking after the land development work.	State Governments through the Ministry of Food and Agriculture.
	(iii) In view of rapidly expanding area under irrigation, it is necessary to establish a suitable central organisation to conduct intensive investigation in the field of irrigation, drainage and anti-waterlogging.	Ministry of Irrigation and Power jointly with the Ministry of Food & Agriculture.
	(iv) Co-ordinated studies on land records in different States should be conducted so that they provided a sound basis for agricultural planning. Even today agricultural statistics are not available for about 86 million acres of land, and among those which are in the reporting category, statistics for over 90 million acres are rough estimates.	State Governments through the Ministry of Food & Agriculture.
	(v) There is primary need for establishing agency to implement the programme and land development for irrigation to carry out works such as provision of field channels, grading and levelling of land and extension of sound irrigation practices. This should be made the primary responsibility of the State Land Development Sub-Committee under the Agricultural Production Committee.	Ministry of Irrigation and Power and Ministry of Food and Agriculture.
	<i>Waster lands:</i>	
	(i) The Ministry of Food and Agriculture should take effective steps for early implementation	Ministry of Food and Agriculture

Sl. No.	Recommendations	Action to be taken by
	of the recommendations of the Wastelands Survey and Reclamation Committee and also of the centrally sponsored schemes for the survey of wastelands in blocks of less than 250 acres, by establishing a cell in the Ministry.	
	(ii) In respect of reclamation of <i>kans</i> -infested wastelands, enquiry may be made from the States to find out what help they want for such reclamation work and how far the work may be carried out without foreign exchange and subsidy.	Ministry of Food and Agriculture.
	(iii) Large tracts of wasteland are found in the riverain belts along the beds of rivers. The reclamation of such areas should be assigned high priority. It is recommended that comprehensive schemes should be prepared for reclaiming these tracts, which should include the construction of roads provision of electricity for pumping water for irrigation and grant of loans to cultivators for purchasing tractors for cultivation and pumping sets.	State Governments through the Ministry of Food and Agriculture.
	It was agreed that the programme of work may be co-ordinated with the scheme of rehabilitation in big plots which will be drawn up by the working group of the Ministry of Food and Agriculture proposed under Recommendation (i).	
	(iv) There should be balanced use of wastelands. Definite areas of waste lands should be reserved for the production of fire-wood and fodder according to land capability classes.	State Governments through the Ministry of Food Agriculture.
	(v) Agricultural wastelands in the country are mostly held by small owners who are not in a position to meet the cost of their reclamation. Such wastelands total to a considerable area. The reclamation of such wastelands may be subsidised by Government who should bear a larger proportion of the reclamation cost than at present.	State Governments through the Ministry of Food and Agriculture.
	(vi) Before allotting wastelands for cultivation, these lands should be reclaimed by the State Governments and appropriate soil and water conservation measures carried out consistent with their land capabilities. The Governments should take adequate steps to ensure that appropriate follow on practices are adopted by the allottees.	State Governments through the Ministry of Food and Agriculture.
3	<i>Saline and alkali lands</i>	
	(i) For fundamental work on saline and alkali soils, three regional salinity laboratories are to be set up under the Third Plan, and it is recommended that these laboratories should be established without any delay. One of these laboratories should be established in the existing agricultural institutes.	Ministry of Food and Agriculture.

Sl. No.	Recommendations	Action to be taken by
(ii)	For the successful reclamation of saline and alkali lands, cooperation between various professional groups including agricultural chemists, irrigation engineers and drainage specialists is essential and should be ensured.	State Governments through the Ministry of Food and Agriculture.
(iii)	Sufficient information is available on the methods of reclaiming saline, saline-alkali and alkali lands. What is now needed is to demarcate these areas in each State, based on their soil characteristics. For this purpose, it is necessary to print large-sized maps of the districts, showing the location of saline and alkali lands of different categories. Detailed information regarding such lands in blocks of 5 acres or more, should also be obtained for the different tehsils in the district, and for this purpose, surveys may be conducted.	State Governments through the Ministry of Food and Agriculture.
(v)	The reclamation of saline and alkali soils on a national basis has already been recommended by the Crops and Soils Wing of the Board of Agriculture and Animal Husbandry in India during its meeting in Simla held in 1956. This recommendation should be given high priority under the Fourth Five-Year Plan programme. The expenditure on this account can be met partly from the provision made for the reclamation of saline and alkali lands and anti-soil erosion by the Ministry of Food and Agriculture and partly from the amount earmarked by the Ministry of Irrigation and Power for flood control drainage and anti-water-logging where salinity is accompanied by water-logging.	Ministry of Food and Agriculture and Ministry of Irrigation and Power.
(vi)	Detailed soil surveys of the saline and alkali lands should be carried out before undertaking reclamation measures.	State Governments through the Ministry of Food and Agriculture.
(vii)	For the reclamation of saline-alkali soils, the cultivation of <i>dhaincha</i> (<i>Sesbania aculeata</i>) and the addition of fertilisers and manures and gypsum to the soil are very useful. <i>Dhaincha</i> seed should be supplied free of cost, and gypsum and fertilisers at concessional rates for reclamation.]	State Governments through the Ministry of Food and Agriculture.
(viii)	The growing of salt-tolerant bushes and trees, such as kikar (<i>Acacia arabica</i>), and (<i>Prosopis juliflora</i>) and frash (<i>Tamarix articulata</i>) etc. is very helpful in the amelioration of <i>Kallar</i> -affected soils. It is recommended that these plants should be extensively grown on lands which are lying waste.	Do.
(ix)	Intensive studies are needed on the improvement of black soils in Andhra Pradesh, which have been rendered unfit for cultivation of Virginia tobacco due to the development of salinity.	State Government of Andhra Pradesh and Central Tobacco Research Institute.

Sl. No.	Recommendations	Action to be taken by
	(x) There is evidence that saline water containing small amounts of plant nutrients like nitrate and potash can be used for raising successful crops. This suggests that with the more intensive use of fertilisers and manures, it may be possible to use saline water for irrigation in marginal lands.	Indian Council of Agricultural Research.
	✓(xi) Since irrigation is the cause as well as the cure of salinity and alkalinity, there is a need for intensive research on irrigation methods and their relationship to soil and cropping.	Do.
	(xii) Most of the work done to establish critical limits for salinity and alkalinity in soils has been carried out in countries where the average yield per acre is much higher than that in India. Accordingly, it is recommended that similar studies should be conducted in India for the purpose of establishing suitable limits for Indian conditions.	Do.
	✓(xiii) It is generally recognised that agroclimatic conditions, drainage and physical and chemical characteristics of the soil determine the suitability of a method of soil reclamation. Detailed investigations should be conducted to ascertain as to which of the methods in vogue are economically feasible.	Do.
4	(i) Despite the extension of canal irrigation, ground water is an important source of irrigation supply. |	State Governments through Ministry of Irrigation and Power.
	It is recommended that a reconnaissance survey of ground water resources should be carried out, particularly in the Punjab, Delhi, Uttar Pradesh, Rajasthan, Madhya Pradesh, Gujarat and Maharashtra,—wherever good quality of ground water is found in sufficient quantities as a supplement to irrigation from canals. This will not only ensure better utilisation of natural resources, but will also help in mitigating the menace of water-logging.	
	(ii) It is desirable that the Ground Water Division of the Geological Survey of India, should work in close collaboration with the Agriculture and Irrigation Departments of the different States, and plan its activities in consultation with these Departments.	Geological Survey of India and the State Governments.
	(iii) The system of analysis of irrigation water and the interpretation of results, as recommended by the Technical Committee on Quality of Water set up by the Central Water and Power Commission, should be followed all over the country, so that the results are comparable.	State Government; through Ministry of Irrigation & Power.
	The use of tube-well water for irrigation should be made economical by (i) charging the water	

Sl. No.	Reclamations	Action to be taken by
	<p>on volumetric basis, and (ii) making irrigation water charges for both canal and tube-wells uniform. It is understood that the Maharashtra State is doing some work in this direction. A small group representing the Ministry of Irrigation and Power and the Ministry of Food and Agriculture may visit the Maharashtra State to see what has been done in that State and what could be done for other States in the light of the experience gained in Maharashtra State.</p>	
	<p>(iv) The ground water quality should be considered an integral part of soil survey and the suitability of water for irrigation should be determined with respect to the soil and crops.</p> <p>(v) In some States the changes in the ground water table of the soil are being investigated by the Irrigation Departments. Similar studies should be made in other States.</p>	<p>Ministry of Food and Agriculture.</p>
5	<i>Water-logging</i>	
	<p>(i) The drainage of water-logged lands should be planned on the watershed basis.</p>	<p>State Governments through the Ministry of Irrigation and Power.</p>
	<p>(ii) Perennial canal irrigation should be avoided in areas where the water table is already high or tending to rise and in such areas recourse may be had to a system of canal closures.</p>	<p>State Governments through the Ministry of Irrigation and Power.</p>
	<p>(iii) Encouragement and subsidy should be given to cultivators for using water from tubewells or open wells within the ayacut of an irrigation system. This would help to control the rise of the subsoil water table in the area. A certain percentage of the irrigated tract depending on the type of soil, sub-soil water level etc. should be reserved exclusively for lift irrigation.</p>	<p>Do.</p>
	<p>(iv) Use of shallow tubewells for depressing the subsoil water table as an anti-waterlogging measure should be given extensive field trials.</p>	<p>State Governments through the Ministry of Irrigation and Power.</p>
	<p>(v) The scope of vertical drainage to recharge drier strata of the underground for reclamation of water-logged areas should be investigated.</p>	<p>Do.</p>
	<p>(vi) In the States in which there are sizeable water-logged areas, the Indian Council of Agricultural Research in collaboration with State Governments concerned may take up research on crops suitable for such areas.</p>	<p>State Governments through the Indian Council of Agricultural Research.</p>
	<p>(vii) Feasibility of planting deep rooted trees having high water consumption in areas where the water table shows a rising tendency requires to be studied as it might be helpful in averting the rise of the water table.</p>	<p>Do.</p>

Sl. No.	Reclamation	Action to be taken by
	✓(viii) Reclamation of swamps and water-logged areas by drainage should be possible in many tracts. But, a careful survey should be made as some of these areas should be better developed for fish culture or for recreation and preservation of wild life.	State Governments through the Indian Council of Agricultural Research.

6 Drainage

- (i) Drainage problems have received inadequate attention in the past. The subject requires serious consideration from the investigation and also from development point of view. Studies should be undertaken for assessing drainage requirements, optimum depth and spacing of drainage and economics of drainage system.

Ministry of Irrigation and Power.

- (ii) Intensive surveys should be initiated throughout the country jointly by experts in flood control, transport engineers, agriculturists and soil scientists, to locate areas which are subject to drainage congestion. These investigations should preferably be carried out in a self-contained "doab" and a Master Plan clearly demarcating the different regions should be prepared. These programmes should contain clearcut programmes of construction priorities, and indicate the economic benefits of draining out different tracts. Such a scientifically designed plan will indicate the best use for which each tract is naturally suited—whether it can advantageously be utilised for agriculture, pasture, forestry, colonisation, etc.

Jointly by the Ministry of Irrigation & Power and Ministry of Food and Agriculture.

While surveys and investigations are in progress and before actual implementation of the Master Plan of the "doab" is taken up, information should be widely disseminated regarding the cultivation of crops by way of field experiments on an extensive scale. All the available knowledge in respect of canal lining, including the experience of the Nangal Power Channel, the Rajasthan Canal, etc., should be collected and made available for use in future works.

- (iii) The efficacy of providing sub-surface drainage should be investigated and field trials conducted to assess the economic feasibility of the measure. Also experiments to standardise the material, size and shape of the sub-surface drain should be undertaken.

Ministry of Irrigation and Power.

- (iv) Field demarcation (through the Community Development Organisation) should be laid out throughout the country, to educate the public in general and the farmers in particular, on the importance of drainage and dangers of the extravagant use of irrigation water.

Ministry of Community Development, Panchayati Raj and Co-operation.

- (v) The possibility of making it obligatory for village panchayats to keep water courses in proper shape and also, if possible, to have them lined, needs to be carefully investigated.

Do.

Sl. No.	Reclamation	Action to be taken by
(vi)	There should be common land for providing natural drainage along roads, railways and canals, including chos. Where consolidation of holdings has not taken place, common lands must be set apart for natural waters; where consolidation of holdings has already been done, the land along the sides of the natural drains should be acquired and afforested.	State Governments through the Ministry of Irrigation and Power.
(vii)	Work on the execution of drainage projects which are technically sound and economically feasible should be taken up forthwith.	Do.
(viii)	The borrow pits along highways, railways and canals should be connected and properly shaped so as to facilitate the movement of storm water.	State Governments through the Ministry of Irrigation and Power.
7	<p>✓ The Ministry of Food and Agriculture may set up a technical group representing the Ministry of Food and Agriculture, Ministry of Irrigation and Power and the Planning Commission which will scrutinise these recommendations and classify them into two categories viz. (i) which recommendations can be implemented; in the Third Plan without any foreign exchange and extra allotment of funds, and (ii) which recommendations may be taken up during the Fourth Plan. After this scrutiny has been made, the report with modifications made at this meeting along with a suitable covering letter will be issued to the States by the Secretary, Ministry of Food and Agriculture (Department of Agriculture).</p>	Ministry of Food and Agriculture.

Bibliography

- | | | |
|-------------------------------------------------------|------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1. Agarwal, R. R. | 1957 | Alkali soils, Indian Farming, December. |
| 2. Agarwal, K. K. | 1959 | Potential and Economic aspects of utilisation of saline alkali soils, Proc. of Seminar on recent advances in Agron. and Soil Sci. held at Simla. |
| 3. Agarwal, R. R. and Mehrotra, C.L. | 1952 | Soil Survey and Soil work in U.P. Vol. 2. Superintendent of Printing and Stationery U.P., Allahabad (India).] |
| 4. Agarwal, R. R. and Mehrotra, C. L. | 1953 | Soil Survey and soil work in U.P. Vol. 3. Superintendent of Printing and Stationery, U.P., Allahabad (India) |
| 5. Agarwal, R. R., Mehrotra, C.L., and Gangwar, B. R. | 1956 | Quality of irrigation waters in Uttar Pradesh Indian J. Agri. Sci., 26, pp. 361—371. |
| 6. Agarwal, R. R., Mehrotra, C. L. and Gangwar, B. R. | 1958 | Soil survey and soil work in U.P. Vol. 4. Superintendent of Printing and Stationery, U. P., Allahabad (India) |
| 7. Agarwal, R. R., Yadav, J. S. P. | 1956 | Diagnostic techniques for Saline and Alkali soils of the Indian Gangetic alluvium in Uttar Pradesh, J. Soil Sci. 7, pp. 209—221 |
| 8. Agarwal, R. R. and Yadav, J. P. S. | 1954 | Saline and alkali soils of the Indian Gangetic alluvium in Uttar Pradesh. Jour. Soil Sci. 5, pp. 300—306 |
| 9. Agarwal, R. R., Mehrotra C. L. and Gupta, R. N. | 1956 | Genesis and pedo-chemical characteristic of Karail black clayey soils in the lower Gangetic basis of Uttar Pradesh. Jour. India Soc. Soil Sci. Vol. 4 (No. 2) pp. 65—71 |
| 10. Agarwal R. R., Das, S. K. and Mehrotra, C. L. | 1961 | Interrelationship between electrical conductivity of 1:5 and saturation extracts and total soluble salts in saline-alkali soils of the Gangetic alluvium in U.P., Indian Journal Agri. Sci. 31, pp. 284—294 |
| 11. Asghar, A.G., Dhanwan, C. L. | 1945 | Percolation of water through Soils, Punjab-Irrig. Res. Inst. Res. Publ. 4 No. 13, p. 8. |
| 12. Auden, J. A. <i>et al.</i> | 1942 | Memoirs, Geological Survey of India 77, Paper I. |
| 13. Bannerji, A.E.R. | 1956 | Review of the method of reclamation of saline soils in West Bengal. Proceedings of the Eleventh Meeting of the Crops and Soils Wing of the Board of Agriculture and Animal Husbandry in India. |
| 14. Banerjee S. | 1959 | Some aspects of salt affected soils of West Bengal. Soil Sci. 83, pp. 45—50. |
| 15. Basu, J. K. | 1950 | Problems of Saline Soils in the Bombay State, India Trans. Fourth Inter College-Soil Science, 3, 169—171. |

16. Chibber, R. K. and Satyanarayana, K. V. S. 1962 A note on the Reclamation of Saline and Alkali soils in Delhi under restricted drainage facilities. *Science and Culture* 28, pp. 176-177.
17. Dalip Singh and Nijhawan, S. D. 1932 A study of the physico-chemical changes accompanying the process of reclamation in alkali soils. *Indian Jour. Agr. Sc.* 2, pp. 1-18.
18. Das, B and Biswas, T.D. . 1962 Effect of Tile Drainage in the lowering of soil salinity and pH (presented at the Seminar on Salinity and Alkali Soils problem, IARI.)
19. Desai, S. V. and Sen, A. . 1953 *Indian Jour. Agr. Sci.*, 23, pp. 187-202.
20. Dhar, N. R. and Mukherji, S. K. 1936 Alkali soils and their reclamation, Part I, *Agric. Livestock India*, Vol. VI, pp. 854-855.
21. Dhar, N. R., Mukherjee, S. K., and Biswas, N. N. 1938 Alkali soils and their reclamation, *C.R. Acad. Agr. Sci.*, 23, pp. 770-774.
22. Dhar, N. R. 1939 Molasses and pressmud in Usar (alkali) Land reclamation, *J. Ind. Chem. Soc.* 2, pp. 105-111.
23. Dhawan, C. L. 1955 Reclamation of saline alkali soil. *Annua Bull of the International Commission Irrigation and Drainage.*
24. Dhawan, C. L. Bhatnagar, B.B.L. Seng, *etal.* 1958 Role of green manuring in reclamation, *I Proc. Nat. Acad, Sci. India*, 27 A, P-168-176.
25. Dhawan, C. L., Bhatnagar, B.B.L. Seng, *etal* 1958 Reclamation of alkali soils by different crop-rotation. *Proc. Nat. Acad. Sci. India* 27A. pp. 238-252.
26. Dhawan, C. L. Bhatnagar, B.B.L., Purshotam Singh Mangal Singh; Narain Singh; Pushudew; Ishwar Dayal, Jagir Singh 1957 Pre-irrigation, soil survey of some district of the Punjab. *Ind. Jour. of Agri. Sci*, Vol. 27, Part IV.
27. Dwivedi, N. K., Gupta, P.N. 1961 Behaviour of ground waters table in Jumna Doab. Seminar on Irrigation Drainage and water Logging problems held at Bombay under the auspices of I.C.A.R
28. Godbole, N.N. 1952 Does Sambhar Lake owe its salt to Rana of Kutch? Cyclostyled copy of paper read at Indian Science Congress Session.
29. Hazari, R. M. 1962 Some comments on Irrigation and Drainage as factors in saline and alkali soil formation and reclamation (presented at the Seminar on Salinity and alkali soil problems, IARI).
30. Hooda, R. C. 1951 Irrigation and Soil reclamation in arid and semi-arid regions. A study of the physico-chemical aspects of soil behaviour. *Int. Comm. Irrig. Canals. New Delhi*, pp. 43.
31. Hooda R. C. 1958 Quality of irrigation waters. *Irrigation & Power Journal* Vol. XV, pp. 1-14.
32. I.C.A.R.. 1958 Final Report of, All India Soil Survey Scheme.

733. Iskur, R.J.] 1941 A popular exposition of the causes leading to the formation of alkali lands with suggestion for their reclamation.
34. Kanwar, J. S. and Bhamkela] 1959 Proc. of the Seminar on recent advances in Agronomy, India, Soil Sci., held at Simla.
Dr. R.]
735. Kanwar, J. S. 1961 Quality of Irrigation Water as an Index of its suitability for irrigation purposes, potash Review Subject 24, 13th Suite.
- 35A. Kanwar, J. S. and Singh 1961 Boron in normal and saline-alkali soils of the irrigated areas of the Punjab. Soil Sc, 92, 207—211
S. S.]
36. Kanwar, J.S. 1962 Green Manuring and Reclamation of Saline alkali soils (presented at the seminar on saline and alkali soil problems, IARI)
37. Kanwar, J.S. 1952 Reclamation of Saline-Alkali Soils Amendments - Kinds - Amounts and cost (presented at the Seminar on Saline and Alkali Soil problems, IARI)
38. Kanwar, J. S. 1962 Aspects of Saline alkali soil research the need modification and the by increase production—a new approach to problem of reclamation of saline, alkali soils (presented at the Seminar on Saline and alkali soil problems, IARI).
39. Kaul, K. N.] 1958 Conquest of Usar, National Botanic Gardens, Lucknow
40. Khanna, K.L. Bhattachar- 1952 Studies on the Sugarcane soils of Bihar Survey, Classification and Management, Pusa Estate, Scientific Bulletin Services Deptt. of Agriculture, Government of Bihar, No. 1, p. 12
yya, P.B. and Ray, P K.
41. Leather, J.W. 1898 Soils, the Agri. Ledge, 3 Agri. Soils, 24.
42. Leather, J.W. 1914 Investigations of Usar lands in UP, Government Report, Allahabad
43. Mann, H. H. and Tamhane,] 1910 The salt lands of the Nira Valley, Bombay V.A.
D.A. Bull, 39.
44. Mehta, M. L. 1940 The formation and the reclamation of thur lands in the Punjab. Punjab Irri. Res. Inst. 3, (4) pp. 16—17.
45. Mitra S.P. & Sankar H. . 1957 Amelioration of alkali soil by chemicals in combinations with organic matter like weeds, Soil Sci. 83, pp. 470—474.
46. Mukherjee, D.G. 1962 Reclamation of Northern sulf lakes. Indian Jour. Power and River Valley Development, Vol. XII, pp. 13—16.
47. Mukherji B. K. and Agar- 1946 Studies in Gangetic Alluvium of United Provinces I, Cultivated Soils of Unin, District. Indian Jon. Agri. Sc. Vol. XVI., pp. 263—279.
wal, R. R. Mukherjee, P.
48. Mukherji, S. K. 1958 Soils of West Bengal, Part III District 24 Parganas, Proc. Nat Acad, Sci. (Indian) Vol. XXVII Section A, part III, pp. 124—133.

49. Narayanan, B. T. 1937 Mollasses as a Fertiliser and Soil reclamation in Agriculture Proc. Soc. Biol. Chem. Assoc. India 2 (31-32).
50. Nijhawan, S. D. 1956 Proceedings of the Eleventh Meeting of the Crops and Soils Wings of the Board of Agriculture and Animal Husbandry in India.
51. Nijhawan, S. D. 1956 How to reclaim saline and alkali soils. Indian Farming, 6, No. 7.
52. Pandya, H. G., Rajani, H. J. and Haria, N. H. 1961 A preliminary study of the saline soils of Gujarat State. The Jounagadh Agricultural College Magazine, Vol. I, No 1, pp. 23-30.
53. Patil, S. K. 1956 Note on Reclamation of Saline and Alkali Soils in the Deccan Canal Area—Proceedings of the Eleventh Meeting of the crops and Soils Wing of the Board of Agriculture and Animal Husbandry in India.
54. Pillai, T. R. N. and Subramanyam T. 1941 The origin and nature of peaty soils of Travancore J. Ind. Inst. Sci. Bangalore, 14A 99.
55. Puri, B. R. 1961 Annual Report of the schemes possibilities of using charcoal in improvement and reclamation of soils I.C.A.R. scheme.
56. Raychaudhuri, S. P. and A. Sankaram. 1952 Studies on the saline soils of Delhi State I. Some typical profiles of the Jumna Khadar area (North) India J. Agri. C. Sci. 22, pp. 209-222.
57. Raychaudhuri, S. P. and Sen, N. 1952 Certain geomorphological Aspects of Rajputana Desert, Bulletin Nat Institute of Sci. of India, No. 1, pp. 249-253.
58. Raychoudhuri, S. P. and Tripathi, R. D. 1953 Studies on the saline soils of Delhi State II. Some typical profiles of the Jumna Khadar area (South). India J. Agric. Sci. 23, pp. 213-222.
59. Raychaudhuri, S. P. and Dutta Biswas, N. R. 1954 Saline and alkali soils of Asia with particular reference to India (Trans. 5th Internat Cong. Soil Sci. Leopoldville, 1, pp. 191-207.
60. Raychaudhuri, S. P. and Nimgade, N. M. 1955 Studies on saline soils of Delhi State. III Dabar (Low lying) areas Ind. J. Agric. Sci. 25, pp. 105-118.
61. Raychaudhuri, S. P. and Datta Biswa, N. R. 1955 Saline and alkali soils of India proceedings Nat. Acad. Sci. 6-11-620.
62. Raychaudhuri, S. P. and Sinha, N. S. 1957 Studies on the saline and alkali soils of Delhi State villages, Ind. J. Agri., Sci. 23, pp. 374-391.
63. Raychaudhuri, S. P. and Murthy, R. S. 1960 Genetic classification of some saline alkali soils of the India-Gangetic Alluvium Transactions. Seventh International Congress of Soil Science, Vol. IV, pp. 278-282.

64. Raychaudhuri, S. P., Agarwal, R. R., Datta Biswas, N. R. Gupta, S. P. Thomas, K. 1962 Soils of India (under publication by the Indian Council of Agricultural Research)
65. Satyanarayana, V. K. S. 1951 Studies on the Soils of Rann of Cutch, I, Description of some profiles and the distribution of salts and gypsum in the profile Ind. Soc. Soil Sci. Bill No. 6, pp. 125—153.
66. Satyanarayana, K. V. S. 1962 Salinity problems of coastal areas of India (presented at the Seminar on Salinity and alkali soil problems, held at IARI.
67. Shah, R. K., Trivedi, A. M. 1954 An investigation of the alkali soils of Gujarat. Jour. Soil Water Conserv. India 3, No. 1, pp. 28—31.
68. Shah, R. K., Trivedi, A. M. and Vora, J. C. 1961 Saline and Alkali Soils of S.W. Gujarat, Part I. Indian J. Appl. Chem., Vol. XXIV, pp. 41—45.
69. Shah, R. K., Trivedi, A. M. and Vora, J. C. 1961 Saline and Alkali Soils of S.W. Gujarat Part II, Dhandhuka — Patna Region Indian Appl. Chem. Vol. XXIV, pp. 64—66.
70. Shah, R. K., Trivedi, A. M. and Vora, J. C. 1961 Saline and Alkali Soils of S.W. Gujarat Part III, Surendranagar — Lake Nal Region, Indian J. Appl. Chem. Vol. XXIV, pp. 67—69.
71. Shah, R. K., and Trivedi A. M. 1958 Chemical properties of ground water in North Gujarat Proceedings of the symposium on ground water, Publication No. 4 of the Central Board of Geophysics held in 1955.
72. Shah, R. K., Vora, J. C. and Trivedi, A. M. 1958 Possibilities of reclamation of the Alkali Soils of the Little Rann of Cutch, Soil and Water conservation in India, Vol. 1 6, No. 3, pp. 133—137.
73. Shaligram, V. K. 1961 Standards of suitability of under-ground irrigation waters with special reference to tube wells in North Gujarat. Seminar on Irrigation Drainage & Water logging held at Bombay under the auspices of I.C.A.R.
74. Shah, R. K. *et al* 1958 Possibilities of reclamation of the alkali soils of the little Rann of Cutch. J. Soil Water Conser., India 6, pp. 133—137.
75. Subramoney, N. 1947 Fertility investigation on the acid peats (Kari) of Travancore I, Bull. Central Res. Institute Univ. of Travancore, Trivandrum Vol. I, II, No. 1, Series A (physical sciences) pp. 1—16.
76. Talati, R. P. 1941 Damaged lands in the Deccan and their classification, Ind. J. Agri. Sci. 11, pp. 958—977.
77. Talati, R. P. 1943 Doctorate Thesis, Bombay University.
49 PC—3.

78. Talati, R. P. 1947 Field experiments on reclamation of salt land in Baramati of Bombay Deccan, Ind. J. Sci. 17, pp. 153—174.
79. Tamboli, P. M. 1958 Report of preirrigation soil survey on the Chambal commanded area in Madhya Pradesh, Agriculture Research Institute, Gwalior.
80. Taylor, G. C., Ray, A. K., 1955 Ground water geology of the pale Region Seth, D. N., Sen, B. N. Jodhpur Division, Western Rajasthan Bulletin Geological Survey of India.
81. Trivedi, A. M., and 1957 Studies of Alkali soils in North Gujarat, Shah, R. K. Journal of the Gujarat University, Vol. I, No. 2, pp. 27—36.
82. Uppal, H. L. 1955 Green manuring with special reference to *Sesbania acueata* for treatment of Alkali soils, Indian Jour. Agri. Sci. 25, pp. 211—235.
83. Uppal H. L. Aggarwal, 1961 Reclamation of saline and alkali lands, R. R. and Kibe, M. M. Farm Bulletin No. 66, Farm information Unit, Directorate of Extension, Ministry of Food and Agriculture, New Delhi.
84. Uppal, H. L. 1961 Reclaiming alkali waste lands I.C.A.R. Bulletin, No. 85.
85. Uppal, H. L. 1962 Reclamation of saline and alkali soils (paper presented at the Symposium on salinity and alkali soil problem.
86. Uppal, H. L. 1961 Sub-soil water and its relation to irrigation system Seminar on Irrigation Drainage and Water logging problems held at Bombay under the auspices of I.C.A.R.
87. Uppal, H. L. 1962 Irrigation and drainage seminar on soil Salinity and alkalinity need at IARI New Delhi.
88. Uppal, H. L. 1960 Canal linings, Irrigation and Power Research Institute, Amritsar—Published by Rajasthan Canal Board, Jaipur.
89. Uppal, H. L. Midha, D.C. April, 1962 Evolving low cost canal linings—Part I—Use of Bentonite and Lime, Indian Journal of River Valley Development, pp. 4—17.
90. Uppal, H. L. Singh, Gab Nov. 1961 Development of a tubewell for Anti-water logging, Indian Journal of Power and River Valley Development, pp. 4—17.
91. Uppal, H. L., Midha D.C. Jan. 1961 Reducing Temperature variations in the and Singh, Sohan Tile Lining, Indian Concrete Journal.
92. Watershed, W.A. 1938 Land drainage in the Deccan Canal Area, Government of Bombay, Paper No. 56.
93. U.P. Department of Ag- 1938— Report of the Usar Reclamation Committee .
riculture. 1939

- | | | | |
|------|--------------------------------------------------------------------------------|------|----------------------------------------------------------------------------------------------------------------------------------------------|
| 94. | U.S. Salinity Laboratory Staff | 1954 | Diagnosis and improvement of saline alkali soil, Agri. Hand Book No. 60, USDA |
| 95. | Waheed Khan, M. A. and Yadav, J.S.P. | 1962 | Characteristics and Afforestation Problems of Saline, Alkali, Soils, Indian Forester 188, pp. 259-271. |
| 96. | Wastelands Survey and Reclamation Committee, Ministry of Food and Agriculture. | 1960 | Report on Location and Utilisation of Wastelands in India Part I—Punjab. |
| 97. | | 1960 | Report on Location and Utilisation of Wastelands in India Part II West Bengal. |
| 98. | | 1960 | Report on Location and Utilisation of Wastelands in India Part III—Bihar. |
| 99. | | 1960 | —do— Part IV—Mysore. |
| 100. | | 1961 | Report on Location and Utilisation of Wastelands in India Part V—Andhra Pradesh. |
| 101. | | 1961 | Report on Location and Utilisation of Wastelands in India Part VI—Madhya Pradesh. |
| 102. | | 1961 | Report on Location and Utilisation of Wastelands in India Part VII—Kerala. |
| 103. | | 1961 | Report on Location and Utilisation of Wastelands in India Part VIII—Madras. |
| 104. | | 1961 | Report on Location and Utilisation of Wastelands in India Part IX—Jammu & Kashmir. |
| 105. | | 1961 | Report on Location and Utilisation of Wastelands in India Part X—Uttar Pradesh. |
| 106. | | 1962 | Report on Location and Utilisation of Wastelands in India Part XII—Orissa. |
| 107. | | 1962 | Report on Location and Utilisation of Wastelands in India Part XII—Orissa. |
| 108. | | 1962 | Report on Location and Utilisation of Wastelands in India Part XIII—Gujarat. |
| 109. | Yadav J. S. P. and Agarwal, R.R. | 1959 | Dynamics of soil changes in the Reclamation of Saline and Alkali soils of the Indian Gangetic Alluvium, Joun. Ind. Soc. Sci. 7, pp. 213-222. |
| 110. | Proceedings of the Symposium on Ground Water. | 1955 | Central Board of Geophysics. |

Notes

- | | | |
|---------------------------------------------------------------------------------------------------|-------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1. Bhal Reclamation Pilot Scheme. | | Vallabhipur, Govt. of Gujarat. |
| 2. Dhir R. D. and Krishnamurthy K. V. | 1959 | Water-logging and drainage. |
| 3. Dhir R. D. | 1962 | Anti-Water-logging Measures in India. |
| 4. Dhir, R. D. | 1962 | Problem of water-logging in the Punjab. |
| 5. Gadkary, D. A. | 1962 | Note on the work carried out in Maharashtra State in respect of survey of reclamation of waste-lands and water-logged, saline and alkali lands and dry farming and black soil regions. |
| 6. Gopalaswamy, V. A. | 1958 | Studies on the Fertility Status of Some Peaty, Marshy and Swampy Soils Thesis Assoc. I. A. R. I. Diploma New Delhi. |
| 7. Hadimani, A. S. | 1960 | Studies on Waste-lands of Delhi State, Thesis M.Sc. I.A.R.I. |
| 8. Inglis, C. C. and Gokhale, V. K. | 1928 | Report on Land Drainage, Experiments at Baranati, Government of Bombay, Technical Paper No. 24. |
| 9. Jenert, H. Greifsweld University, East Germany. | 1959 | Report on Water-logging in Punjab. |
| 10. Khan, A. D. | 1962 | Saline and Alkali Soils. |
| 11. Khan, A. D. | 1962 | Practical methods of reclamation of <i>usar</i> (Saline-alkali) soils. |
| 12. Khan, A. D. | 1962 | Progress of work of reclamation of saline and alkali lands in Uttar Pradesh. |
| 13. Proceedings of the Seminar on Irrigation and Drainage Research. | Feb. 1962 | Indian Agriculture Research Institute. |
| 14. Pandit, A. D. | 1962 | Address delivered on the 9th July 1962 at the 33rd meeting of the Advisory Board of I. C. A. R. |
| 15. Ramamoorthy, B. | 1962 | Reclamation of Saline and Saline Alkali soils. |
| 16. Reclamation of Greater Salt Lake Area. The Polder Scheme Pamphlet, Government of West Bengal. | | |
| 17. Sivaraman, M. S. | April, 1962 | Tour note on his visit to Punjab. |
| 18. Schoonover, Warren R. | 1960 | Reclamation of saline and sodic (<i>usar</i>) soils (prepared for Agricultural Engineering Symposium, Indian Institute of Technology, Kharagpur. |
| 19. Sub-surface Drainage, Research Station, Ibban-Amritsar. | 1961 | Technical Report, Irrigation and Power Research Institute, Punjab. |
| 20. Uppal, H. L. | 1961 | Salinisation of Soil by Flooding and Measures to reclaim it. Irrigation and Power Research Institute, Amritsar. |
| 21. Final Report on the scheme for Land Reclamation, Andhra Pradesh. | 1960 | I.C.A.R. Scheme. |

APPENDIX I

Study Groups which have carried out studies on different aspects of wastelands, including saline, alkali and water-logged, lands.

Saline and alkali lands.

- (a) Review of the work done in the survey of ground-water, the demarcation of areas where ground-water is sweet and where it is saline; further work necessary.
- Dr. J. S. Kanwar, Government Agricultural Chemist, Punjab—Convener.
Dr. R. R. Agarwal Director of Agriculture, Lucknow, U.P.
Shri N. C. Shah, Deputy Director of Agriculture (Engineering), Gujarat, Ahmedabad.
Shri K. M. Mehta, Agricultural Chemist Rajasthan, Udaipur.
Shri G. C. Chatterjee, Incharge, Ground Water Division, Geological Survey of India.
- (b) Extent, location, reclamation measures suggested for prevention of extension of such areas and identification of gaps.
- Dr. S. P. Raychaudhuri—Convener.
Dr. J. S. Kanwar.
Dr. A. D. Khan, Joint Director of Agriculture (Soil Conservation), U.P.
Shri D. V. Krishna Rao, Government Agricultural Chemist, Andhra Pradesh.
Shri H. T. Khemchandani, Deputy Soil Conservation Adviser, Ministry of Food & Agriculture.
Dr. B. Ramamoorthy, Physical Chemist, Indian Agricultural Research Institute, New Delhi. (Co-opted).
- (c) Study of suitable trees, grass and crops for saline and alkali lands.
- Dr. P. C. Raheja, Director, Central Arid Zone Research Institute, Jodhpur—Convener.
Dr. Mukhtar Singh, Deputy Agricultural Commissioner, Indian Council of Agricultural Research.
Shri U. S. Dalal, Deputy Director, Land Reclamation, Irrigation Research Institute, Amritsar.
Dr. A. D. Khan.
Shri Jagdish Singh, Sylviculturist, Punjab.
- (d) Study of the problems of Khar land in the coastal salines.
- Dr. S. P. Raychaudhuri—Convener.
Dr. H. G. Pandey, Agricultural Chemist, Gujarat.
Shri D. V. Ballal, Agricultural Chemist, Maharashtra.
Dr. S. K. Mukherjee, Joint Director of Agriculture, West Bengal.
Shri D. V. Krishna Rao.

Water-logged lands.

- (a) Extent of water-logged areas and their classification and rate of change. Shri R. D. Dhir—Convener.
Shri M. L. Wahi, Director, Central Design, Irrigation Branch, Chandigarh.
Chief Engineer, Delhi State.
- (b) Surface, sub-surface, including tile drainage; investigation done on depth, economics of the various methods of drainage and anti-waterlogging measures and their effectiveness; lining of canals and shallow tube-wells. Shri R. D. Dhir—Convener.
Shri M. L. Wahi, Director, Central Design & Irrigation Branch, Chandigarh
Superintending Engineer, Deccan Irrigation Circle, Poona.
Shri D. Mukherjee, Chief Engineer (Irrigation) West Bengal.
Chief Engineer (Irrigation) Orissa.
Chief Engineer (Irrigation) Bihar.
- (c) Block system of irrigation and crop planning. Dr. H. L. Uppal—Convener.
Superintending Engineer Deccan Irrigation Circle, Poona.
Shri M. M. Anand, Superintending Engineer, Western Jumna Canal, Alipore Road, Delhi.
Shri Satwant Singh, Nasirpur Farm.
Shri U. S. Madan—Convener.
Shri G. S. Dhillon, Chief Conservator of Forests, Punjab.
Sylviculturist, Forest Research Institute.
Dr. Mukhtar Singh, Deputy Agricultural Commissioner, Indian Council of Agricultural Research.
Dr. M. V. Vachhani, Crop Production Specialist, Dte. of Extension, Min. of Food & Agriculture (Deptt. of Agr.), Krishi Bhavan, New Delhi.
3. Canal irrigation viz. tube-well irrigation with reference to the study on the uniform water levy for canal and tube-well irrigation. Shri Jatinder Singh, Chief Engineer of Irrigation, Punjab—Convener.
Chief Engineer, Irrigation, U.P.
Shri Satwant Singh, Nasirpur Farm.
Shri K. L. Vij, Director (Hydro-Electric) C.W. & P.C.
4. Development of Riverain or bet lands. Shri A. S. Venugopalan—Convener.
Dr. J. S. Kanwar.
5. Drainage by inter-linking of borrow pits along railway lines, canals and roads. Dr. H. L. Uppal—Convener.
Shri B. S. Dina, Chief Engineer, Irrigation, Punjab.
6. *Wastelands*:—Consolidated report on the survey and reclamation of wastelands. Dr. S. P. Raychaudhuri—Convener.
Shri A. S. Venugopalan.
7. Review of work on soil conservation and reclamation done during the First and Second Plan periods and the Schemes for the Third Plan. Shri K. D. Sharma Research Officer, Planning Commission.

APPENDIX II

Tables of wastelands for States—District-wise

Andhra Pradesh

In the state of Andhra Pradesh, the total geographical area of 67·62 million acres is classified as under:

Table 46

Land Classification	million acres
1. Forests	14·58
2. <i>Land not available for cultivation</i>	
(a) Barren and unculturable land	6·50
(b) Land put to non-agricultural uses	3·86
3. <i>Other uncultivated land excluding fallows</i>	
(a) Culturable waste	4·58
(b) Permanent pastures and other grazing lands	3·04
(c) Land under miscellaneous tree crops and groves	0·69
4. Current fallows	4·96
5. Fallows other than current fallows	2·19
6. Net area sown	27·22
TOTAL	67·62

It will be observed that the total area under the head 'other uncultivated lands excluding fallows' is 8·31 million acres, and the area classified as "fallows other than current fallows" is 3·19 million acres. The district-wise distribution of the areas under each of these heads in Andhra Pradesh is indicated in the Table 47.

Table 47
Land utilisation statistics for Andhra Pradesh for the year 1957-58
(District-wise)

District	Total geographical area		Forest	Land not available for cultivation		Other uncultivated land excluding fallows			(in acres)		
	By professional survey	By village papers		Barren & unculturable lands	Land put to non-agricultural uses	Culturable waste	permanent pastures and other grazing lands.	Misc. tree crops and groves	Current Fallows	Fallows other than current fallows	Net Area sown
Stikakulam	2,496,954	2,491,076	433,217	494,518	79,712	203,539	93,364	25,563	99,498	153,342	908,232
Visakhapatnam	3,327,955	3,314,642	1,445,808	376,256	355,100	120,009	14,998	33,456	126,290	27,406	815,319
East Godavari	3,694,439	3,637,000	1,345,185	232,034	179,526	490,526	164,335	63,315	31,935	96,567	1,033,577
West Godavari	1,912,262	1,931,830	197,215	158,407	167,781	210,904	67,006	20,535	97,761	56,357	954,964
Krishna	2,241,178	2,236,805	221,847	310,159	106,101	119,843	53,853	36,986	85,518	28,500	1,273,898
Guntur	3,708,838	3,772,415	468,521	343,798	57,006	183,526	151,144	88,927	224,323	131,700	2,122,800
Nellore	5,090,605	4,271,087	459,589	867,788	603,189	423,657	456,437	75,918	308,622	184,40	1,492,186
Kurnool	5,937,190	5,894,616	1,701,281	299,252	259,105	406,832	19,050	25,385	201,276	153,206	2,828,720
Anantapur	4,726,247	4,728,329	476,976	411,147	275,416	459,269	29,595	44,349	216,659	299,048	2,485,870
Cuddapah	3,791,072	3,798,522	1,156,865	160,846	203,637	659,771	142,384	20,933	423,930	28,505	1,001,651
Chittoor	3,781,005	3,782,161	857,741	680,563	150,947	378,692	80,080	34,367	489,225	135,431	975,165
Hyderabad	1,252,390	1,867,129	197,238	152,851	141,543	91,036	190,484	22,470	148,288	77,020	849,190

	1	2	3	4	5	6	7	8	9	10	11	12
Nizamabad . . .	1,991,974	1,907,884	385,674	181,602	146,414	92,475	135,832	25,507	155,824	76,014	709,042	
Medak . . .	2,719,859	2,505,300	209,182	185,601	154,338	93,095	230,090	39,975	358,118	103,340	1,131,501	
Mahbubnagar . . .	4,729,882	4,560,064	737,779	269,410	177,336	91,467	177,692	19,381	647,258	63,309	2,376,532	
Naigonda . . .	3,424,915	3,443,097	249,749	235,114	166,253	88,080	321,052	26,106	503,553	127,697	1,724,193	
Warangal . . .	3,189,651	3,267,376	829,031	389,877	185,401	75,348	239,755	29,554	198,029	118,953	1,101,428	
Khammam . . .	2,944,173	2,548,766	999,462	153,539	130,418	93,445	172,684	8,328	99,608	66,402	824,880	
Katimnagar . . .	2,921,510	2,936,830	632,449	200,910	175,246	90,531	162,847	36,704	274,061	53,372	1,311,310	
Adilabad . . .	3,991,283	4,130,613	1,571,765	371,286	150,314	203,334	136,807	14,115	168,884	214,519	1,299,139	
STATE—TOTAL . . .	67,873,382	67,625,992	14,576,574	6,505,018	3,864,783	4,575,379	3,041,809	691,883	4,959,060	2,192,089	27,219,887	

Assam

According to the Assam land utilisation statistics for the year 1953-54, the State of Assam has an area of 32·94 million acres classified as under:

Table—48

Land Classification	million acres
1 Forests	12·04
2 Land not available for cultivation	
(a) Barren and unculturable land	10·70
(b) Land put to non-agricultural uses	0·55
3 Other Cultivated land excluding fallows:	
(a) Culturable waste	0·28
(b) Permanent pastures and other grazing lands	0·38
(c) Land under miscellaneous tree crops and groves	3·0
4 Current fallows	0·47
5 Fallows other than current fallows	0·41
6 Net area sown	5·11
TOTAL	32·94

It will be observed that the total area classified as "other uncultivable land excluding fallows" is 3·66 million acres whilst the area classified as "fallows other than current fallows" is 0·41 million acres. The district-wise distribution of the areas under each of the above heads in Assam is given in the table 49.

Table 49

Land utilisation statistics for Assam 1953-54

(District-wise)

District	Total geographical area		Forests	Land not available for cultivation			Other uncultivated land] excluding fallows				(in acres)		
	By professional survey	According to village papers		Land put to non-agricultural uses	Barren & unculturable land	Total	Permanent pastures and other grazing lands	Land under Mics. tree crops and groves	Cultivable waste	Total	Current fallows	Fallows other than current fallows	Net area sown
Cachar	1,719,680	1,715,200	675,299	90,230	254,208	344,438	15,000	61,000	4,860	80,860	49,750	59,350	505,503
Darrang	2,151,040	2,154,880	647,472	24,800	465,807	490,607	72,200	19,500	13,419	105,119	131,100	87,540	693,042
Garo hills	3,015,360	2,017,280	98,759	(n)	1,739,802	1,739,802	..	..	..	..	..	..	178,719
Goalpara	2,543,120	2,546,560	511,362	78,200	1,109,464	1,187,664	60,700	70,200	4,026	134,926	45,200	66,030	601,378
Kamrup	2,455,680	2,460,160	1,059,026	124,800	82,839	207,639	54,800	25,000	7,557	87,357	26,600	21,950	1,021,588
Khasi Jantia Hills	3,549,440	3,554,560	17,664	(n)	3,325,376	3,325,376	(b)	(b)	..	..	..	..	58,520
Lakhimpur	3,153,280	3,130,880	638,048	50,900	1,231,888	1,282,788	61,800	137,400	211,715	430,915	81,400	68,500	569,229
Mizo	5,205,750	5,211,520	5,074,560	(n)	46,090	46,090	..	..	..	..	..	..	90,870
Mikir & N.C. Hills	3,772,800	3,765,120	1,615,890	(n)	2,057,058	2,057,058	..	..	..	..	..	..	92,172
Naga Hills	2,725,760	2,750,080	81,062	N.A.	N.A.	N.A.	(b) 2,577,413	(b) 2,577,413	..	..	..	..	91,600
Nowgong	1,386,880	1,408,000	578,113	88,200	79,300	167,500	15,000	16,000	..	31,000	25,300	16,925	589,162
Sibsagar	2,211,840	2,224,640	796,073	93,700	309,723	403,324	100,000	76,800	13,423	190,223	116,300	92,850	625,771
STATE TOTAL	32,895,640	32,938,880	12,042,328	550,830	10,701,555	11,252,385	379,500	2,983,318	275,000	3,637,818	475,650	413,145	5,117,554

(n) Included under barren and uncultivable land.

(b) Included under 'Misc.' tree crops and groves.

Bihar

The total area of 42·82 million acres in the Bihar State has been classified as below in accordance with the land utilisation statistics for the year 1957-58:—

Table—50

Land Classification	Million Acres
1. Forests	9·67
2. Land not available for cultivation	
(a) barren and unculturable land	1·92
(b) land put to non-agricultural uses	3·51
3. Other uncultivated land excluding fallows—	
(a) culturable waste	2·28
(b) permanent pastures and other grazing lands	0·55
(c) land under miscellaneous tree-crops and groves	0·00
4. Current fallows	4·94
5. Fallows other than current fallows	2·01
6. Net area sown	17·94
Total	42·82

It would be observed that the total area classified as “other uncultivated lands excluding fallows” is 2·83 million acres, and the area classified as “fallows other than current fallows” is 2·01 million acres. The district-wise distribution of the area under each of the above heads in Bihar is given in the table 51.

Table—51

Land utilisation statistics for Bihar for the year 1957-58

(District-wise)

(In acres)

District	Total geographical area		Forest	Land not available for cultivation		Other uncultivated land excluding fallow lands			Current fallows	Fallows other than current fallows	Net area sown
	By professional survey	By village papers		Barren & unculturable lands	Land put to non-agricultural uses	Culturable waste	Permanent pastures	Misc. tree crops and grooves†			
1	2	3	4	5	6	7	8	9	10	11	12
Patna . . .	13,85,037	13,61,920	8,856	27,265	1,98,932	24,997	134	..	1,13,016	10,561	9,78,159
Gaya . . .	32,52,157	32,37,440	5,41,979	2,39,383	2,48,356	99,569	23,423	..	3,40,809	79,922	14,64,899
Shahabad . . .	23,13,778	28,10,880	6,07,784	69,847	2,53,745	35,939	2,412	..	2,28,609	24,090	15,88,454
Saran . . .	17,08,032	17,12,640	448	35,824	2,00,112	42,938	9,082	..	2,46,089	27,197	11,50,950
Champanan . . .	22,73,843	22,63,680	1,68,531	74,559	1,94,956	1,06,292	38,667	..	1,82,231	46,401	14,52,043
Muzaffarpur . . .	19,31,456	19,32,800	..	23,852	1,49,361	35,694	5,066	..	99,370	9,939	16,09,718
Darbhanga . . .	21,40,736	21,49,760	..	40,948	2,74,733	96,489	13,852	..	3,04,013	27,057	13,92,668
Monghyr . . .	25,43,949	25,16,480	1,62,341	1,92,185	3,27,964	1,23,377	14,938	..	4,15,929	83,777	11,95,969
Bhagalpur . . .	13,94,650	13,83,615	1,60,236	74,304	1,72,742	85,710	13,191	..	1,90,489	55,191	6,31,752
Saharsa . . .	13,36,410	13,24,865	606	87,273	1,65,816	1,41,533	10,858	..	2,78,409	63,194	5,77,176

	1	2	3	4	5	6	7	8	9	10	11	12
Purenea	27,24,518	26,34,240	34,306	68,351	2,75,006	96,098	68,067	..	6,04,410	1,28,840	13,59,162	
Saunthal Parganas	35,00,550	35,12,960	8,21,681	1,24,688	2,85,862	3,55,184	1,28,615	..	3,91,244	2,42,258	11,63,428	
Hazaribagh	44,86,419	44,71,040	22,19,540	2,23,501	1,71,738	2,83,646	1,10,460	..	3,96,975	3,03,359	7,61,821	
Ranchi	45,65,152	45,03,357	12,02,929	2,38,227	1,84,982	2,81,146	21,430	..	4,30,296	4,55,110	16,89,237	
Palamau	31,55,494	31,44,960	20,07,464	1,57,494	69,307	1,35,803	21,252	..	4,09,932	1,61,690	1,81,968	
Dhanbad	7,13,152	7,10,119	1,03,032	59,301	1,09,126	97,345	3,901	..	75,726	63,228	1,98,460	
Singhbhum	32,78,349	33,52,338	16,34,819	11,84,349	2,26,338	2,38,139	60,230	..	2,33,435	2,25,154	5,49,874	
STATE TOTAL	43,006,682	4,28,23,094	96,73,652	19,21,351	35,09,076	22,79,899	5,45,578	..	49,41,032	20,06,768	1,79,45,738	

† Not available.

Gujarat

According to the land utilisation statistics for the year 1956-57, the State of Gujarat has an area of 44.40 million acres classified as under:—

Table—52

Land Classification	million acres
1 Forests	2.11
2 Land not available for cultivation	
(a) barren and unculturable land	12.46
(b) land put to non-agricultural uses	0.50
3 Other uncultivated land excluding fallows—	
(a) culturable waste	1.20
(b) permanent pastures and other grazing lands	2.28
(c) land under miscellaneous tree crops and groves	1.18
4 Current fallows	1.11
Fallows other than current fallows	0.63
Net area sown	22.93
TOTAL	44.40

It would be observed that the total area classified as 'other uncultivated land excluding fallows' is 4.66 million acres and 'fallows other than current fallows' is 0.63 million acres. The district-wise distribution of the area under each of the above heads in Gujarat is indicated in the table 53.

Of the total area of 5.29 million acres under the heads 'other uncultivated land excluding fallows' and 'fallows other than current fallows', the area under 'permanent pastures and grazing lands' is 2.28 million acres, accounting for more than half the total area under the two heads referred to above. Extensive pastures exist in the Kutch district and in the areas comprising the former State of Saurashtra. The area reported under 'culturable waste'—the main head under which wastelands are included—is 1.20 million acres.

Table—153

Land utilisation statistics for Gujrat for the year 1956-57
(districtwise)

(in '00 acres)

District	Total geographical area		Forest	Land not available for cultivation		Other uncultivated land excluding fallows			Current fallows	Fallows other than current	Net area sown
	By professional survey	By village papers		Barren & unculturable land	Land put to non-agricultural uses	Culturable waste	Permanent pastures & other grazing lands	Land under Misc. tree crops and groves			
Kutch	17,042	1,08,636	1,269	80,212	..	..	..	10,822	5,352	..	10,981
Jamnagar	3,943	23,172	429	5,119	1,112	821	1,298	90	86	452	13,765
Rajkot	4,588	30,424	162	4,368	295	455	3,079	24	326	493	21,222
Surendranagar	4,230	24,883	20	5,395	189	1,443	1,021	..	633	685	15,497
Bhavnagar	4,652	26,062	82	2,258	611	766	3,150	..	635	313	18,247
Junagadh	3,966	22,985	3	1,991	38	524	3,752	69	624	1,176	14,808
Amreli	1,542	9,868	644	999	245	586	653	..	176	498	6,077
Banaskantha	4,030	25,869	2,103	2,718	780	396	2,456	376	947	376	1,717
Sabarkantha	2,845	17,400	1,803	2,912	248	521	668	1	582	283	10,282
Mehsana	43,24	25,876	159	861	437	1,693†	2,015	96	212	330	20,073
Ahmedabad	3,461	22,220	22	4,538	41	863	..	..	374	399	15,983
Kaira	2,621	16,630	210	2,167	112	148	729	..	112	109	13,043
Panchamahals	3,486	22,216	3,969	2,445	187	1,590	938	..	355	486	12,246
Baroda	2,955	18,313	1,263	1,632	26	250	1,616	126	225	124	13,051
Broach	3,115	18,914	2,176	14,028	562	309	562	2	97	207	10,971
Surat	4,932	26,325	3,251	2,935	104	1,649	873	161	206	409	16,737
Dangs	689	4,230	3,521	..	..	2†	..	..	192	..	515
STATE TOTAL	72,430	44,40,23	21,086	1,24,578	4,987	12,016	22,810	11,767	11,134	6,340	2,29,305

† This figure includes areas under culturable waste and permanent pastures and other grazing lands.

Jammu & Kashmir

According to the land utilisation statistics for the year 1958-59, the total area of the Jammu and Kashmir State may be classified as under:—

Table—54

Land Classification	Million Acres
1 Forests	1.40
2 Land not available for cultivation—	
(a) barren and unculturable land	0.83
(b) land put to non-agricultural uses	1.00
3 Other uncultivated land excluding fallows—	
(a) culturable waste	0.37
(b) permanent pastures and other grazing lands	0.35
(c) land under miscellaneous trees and groves	0.04
4 Current fallows	0.19
5 Fallows other than current fallows	0.15
6 Net area sown	1.60
TOTAL	5.93

NOTE—The above figures exclude the occupied areas of the State.

The above statement shows that the total area under the head 'other uncultivated land excluding fallows' is 0.76 million acres, and the area classified as 'fallows other than current fallows' is 0.15 million acres. The district-wise distribution of the areas under each of the above heads in Jammu and Kashmir State is given in the table 55.

Table— 55

Land utilisation statistics for Jammu and Kashmir for the year 1958-59
(District-wise)

District	Total geographical area		Land not available for cultivation		Other uncultivated land excluding fallows			Current fallows	(In acres)	
	By village papers	Forests	Land not available for cultivation		Culturable waste	Permanent pastures and other lands	Misc. tree crops and groves		Fallows other than current fallows	Net area sown
			Barren and unculturable land	Land put to non-agricultural uses						
Anantnag	5,43,722	588	71,462	38,252	11,761	61,480	13,849	21,747	14,025	3,10,558
Baramulla	5,17,898	556	173	1,17,164	42,113	64,628	2,093	24,100	3,133	2,63,938
Srinagar .	3,15,598	2,060	33,876	41,150	5,972	12,453	7,733	1,005	43,204	1,68,145
Ladakh .	1,36,577	158	57,066	13,817	11,118	..	3,807	1,022	10,837	38,762
Jammu	7,94,122	38,163	2,19,151	1,15,503	71,548	11,813	5,448	65,777	4,169	2,62,550
Udhampur	10,60,037	3,79,956	1,12,925	2,87,332	47,551	45,988	11,255	45,287	3,836	1,25,907
Kathua .	6,54,360	1,71,679	1,46,350	54,883	89,418	21,495	1,211	3,309	3,352	1,62,663
Doda .	10,43,782	5,60,027	1,46,986	1,01,950	31,259	10,257	133	8,539	52,472	1,32,159
Poonch .	8,60,621	2,42,859	45,223	2,27,773	63,820	1,22,108	..	14,548	12,177	1,32,077
STATE TOTAL	59,26,717	13,96,046	8,33,212	9,97,824	3,74,560	3,50,222	45,529	1,85,370	1,47,205	15,96,749

Note.—This statement excludes figures for the Pakistan occupied portion of the State.

Kerala

According to the land utilisation statistics, the State of Kerala has an area of 9·43 million acres classified as under:—

Table—56

Land Classification	Million Acres
1 Forests	2·46
2 Land not available for cultivation—	
(a) Barren and unculturable land	0·50
(b) Land put to non-agricultural use	0·53
3 Other uncultivated land excluding fallows—	
(a) Culturable waste	0·44
(b) Permanent pastures and other grazing lands	0·12
(c) Land under miscellaneous tree crops and groves	0·50
4 Current fallows	0·16
5 Fallows other than current fallows	0·20
6 Net area sown	4·52
TOTAL	9·43

It will be observed that the total area classified as “other uncultivated land excluding fallows” is 1·06 million acres, while the area classified as “fallows other than current fallows” is 0·2 million acres. The district-wise distribution of the areas under these two heads in Kerala is shown in the Table 57.

Table—57

Land utilisation statistics for Kerala for the year 1956-57 (District-wise)

(In acres)

District	Total geographical area		Forests	Land not available for cultivation		Other cultivated land excluding fallows			Current fallows	Fallows other than current fallows	Net area sown
	By professional survey	By village papers		Barren and unculturable land	Land put non-agricultural uses	Culturable waste	Permanent pastures and other grazing lands	Land under miscellaneous trees crops and groves			
Trivandrum . . .	5,41,632	5,33,983	1,01,703	31,057	29,245	6,772	..	1,880	5,704	8,119	3,48,503
Quilon . . .	16,53,184	15,86,496	5,69,246	54,225	59,016	4,993	9,518	26,715	28,064	11,874	8,22,845
Kottayam . . .	19,37,408	18,78,899	6,39,215	98,534	42,718	1,08,307	16,358	76,666	24,051	1,836	8,65,214
Trichur . . .	11,39,840	10,91,455	3,15,224	37,548	60,600	14,570	14,258	7,927	15,712	7,904	6,17,712
Palghat . . .	12,62,784	12,61,285	2,56,424	71,383	1,51,460	60,567	16,154	57,181	23,505	36,499	5,88,112
Kozhikode . . .	16,34,814	16,34,814	3,91,361	1,05,724	62,225	1,11,240	8,598	1,29,408	42,738	30,659	7,52,861
Cannanore . . .	14,24,960	14,24,960	1,85,250	98,835	97,800	1,30,749	55,703	2,08,595	13,960	1,04,253	5,29,815
STATE TOTAL . . .	95,94,622	94,11,892	24,58,423	4,97,308	5,03,064	4,37,198	1,20,589	5,08,372	1,54,734	2,07,144	45,25,062

202

The above figures relate to seven districts only as the districts of Alleppy and Ernakulam came into being during 1958-59.

Madhya Pradesh

In the State of Madhya Pradesh, the total geographical area of 108·36 million acres is classified as under:—

Table—58

Land Classification	Million acres
1 Forests	34·29
2 Land not available for cultivation	
(a) Barren and unculturable land	5·85
(b) Land put to non-agricultural uses	4·72
3 Other uncultivated land excluding fallows—	
(a) Culturable waste	8·44
(b) Permanent pastures and other grazing lands	8·71
(c) Land under miscellaneous tree crops and groves	0·82
4 Current fallows	1·96
5 Fallows other than current fallows	4·02
6 Net area sown	39·55
TOTAL	108·36

It will be observed that the total area under the head "other uncultivated lands excluding fallows" is 17·97 million acres, and the area classified as "fallows other than current fallows" is 4·02 million acres. The district-wise distribution of the areas under each of these heads in Madhya Pradesh is indicated in table 58.

Table—59

Land utilisation Statistics for Madhya Pradesh for the year

District	Total geographical area			Land not available for cultivation	
	By professional survey	by village papers	Forests	Barren & unculturable land	Land put to non-agricultural uses
I	2	3	4	5	6
Sagar.	25,35,046	25,34,730	7,30,856	21,644	1,02,18
Damoh	18,08,979	17,97,578	6,74,459	41,566	71,197
Jabalpur	25,07,750	25,01,252	5,38,085	62,509	1,35,525
Mandla	32,81,075	32,76,801	15,12,367	41,240	1,36,601
Hoshangabad	24,75,059	24,68,057	9,03,945	37,634	1,17,504
Narsimpur	12,66,643	12,68,064	3,08,651	16,362	56,823
East Nimar	26,44,378	26,40,536	11,47,766	36,344	1,14,754
Balaghat	22,86,989	22,49,117	10,48,850	1,02,449	1,17,985
Betul	24,85,914	24,90,337	8,40,367	14,056	1,08,354
Chindwara	29,21,914	29,27,154	10,77,578	36,733	1,23,598
Seoni	21,60,423	21,50,830	7,30,170	13,893	1,02,501
Durg	48,48,678	48,00,187	12,40,139	58,002	2,64,103
Raipur	52,56,698	54,46,489	21,98,498	49,630	2,84,000
Bilaspur	48,73,734	49,77,852	18,26,675	1,04,924	2,40,305
Surguja	55,18,733	54,81,906	28,73,885	1,51,400	1,82,268
Raigarh	32,40,947	32,03,888	11,99,207	77,294	1,32,479
Bastar	96,79,213	96,81,728	69,55,011	2,14,027	80,445
Bhind	11,02,496	11,00,415	5,076	13,931	61,749
Morena	28,72,659	28,87,389	7,89,246	4,97,493	1,62,761
Gwalior	12,81,043	12,89,645	2,71,954	2,11,847	41,815
Shivpuri	25,51,270	25,26,588	4,59,345	2,63,676	1,58,204
Guna	27,33,491	27,13,541	3,36,805	3,86,257	1,01,793
Bidisha	18,17,011	18,04,467	1,65,699	1,20,662	81,392
Rajgarh	15,25,293	15,14,081	28,327	63,930	79,092
Shajhan pur	15,28,493	15,26,365	..	2,18,546	58,420
Ujjain	15,10,605	15,01,970	10,829	72,865	55,973
Ratlam	11,04,986	12,01,926	60,798	96,013	54,735
Mandsaur	25,38,125	23,38,806	2,69,441	3,31,584	2,03,029

1959-60 (District-wise)

(In acres)

Other uncultivated land excluding fallows					
Cultivable waste	Permanent pastures and other grazing lands	Land under miscellaneous tree crops and groves	Current fallows	Fallows Other than current fallows	Net area sown
7	8	9	10	11	12
1,43,661	4,85,517	16,486	20,772	44,558	9,69,050
1,57,319	1,83,866	18,247	19,303	44,166	5,87,455
1,80,341	2,67,994	48,558	86,167	1,46,212	10,35,861
1,70,027	1,45,820	11,753	3,51,076	1,19,883	9,07,917
1,20,273	2,26,028	16,771	25,688	49,437	9,70,777
69,024	1,33,897	21,485	16,388	31,957	6,13,477
21,948	2,77,844	22,072	22,077	26,781	9,70,950
97,619	1,54,573	24,482	21,938	37,763	6,43,458
1,54,294	2,85,714	6,192	66,803	1,02,154	9,12,403
1,72,226	2,07,983	12,313	80,524	1,04,450	11,11,749
1,42,857	1,74,049	8,937	62,430	1,16,251	7,99,732
98,169	3,30,784	26,783	1,27,281	1,48,658	25,06,268
1,11,982	4,67,596	6,303	85,597	88,436	21,54,447
1,34,435	5,17,709	16,203	75,546	96,300	19,65,755
4,50,579	2,24,536	2,15,365	83,449	72,157	12,18,067
1,18,803	2,01,861	86,956	1,05,261	1,03,608	11,78,419
1,94,784	2,46,672	1,86,865	1,26,527	1,72,201	15,06,196
40,551	77,067	1,070	5,960	4,548	7,64,463
3,35,644	2,08,845	7,008	23,856	20,255	8,42,281
1,31,570	75,618	528	17,263	32,005	5,07,045
6,54,807	1,96,246	2,186	53,287	83,229	6,52,609
4,52,135	1,88,137	6,986	31,162	2,76,603	9,33,663
3,35,866	1,39,918	1,133	15,858	27,722	9,16,217
1,95,603	4,07,692	44	10,991	19,818	7,08,584
1,39,279	2,99,693	248	7,114	14,863	7,88,202
2,95,282	1,01,091	166	9,746	10,278	9,45,746
98,110	2,96,988	199	11,747	7,895	5,75,441
3,96,718	1,80,894	2,047	15,663	11,311	9,28,119

	1	2	3	4	5	6
Dewas	17,31,571	16,52,876	3,97,472	90,759	82,766	
Indore	9,46,662	8,76,413	58,997	7,847	51,057	
West Nimar	33,29,530	24,00,898	2,92,640	1,09,471	1,09,793	
Dhar	20,16,301	20,37,856	1,70,431	2,39,936	89,065	
Jhabua	16,74,144	16,78,544	2,35,093	3,27,127	83,808	
Rewa	16,05,491	15,53,668	1,09,947	1,78,957	87,812	
Satna	18,06,995	18,34,408	3,66,732	2,05,085	1,11,623	
Sidhi	25,98,675	25,27,796	11,03,314	2,46,487	92,229	
Shahdol	34,63,546	34,26,525	14,01,526	1,98,505	12,669	
Datia	5,00,762	5,02,830	61,332	19,724	36,900	
Tikamgarh	12,43,808	12,46,720	1,04,789	1,52,154	62,562	
Chhatarpur	21,63,174	21,31,407	86,694	2,57,432	1,11,093	
Panna	17,38,112	17,84,832	25,16,55	2,54,277	67,384	
Schore	23,04,243	23,08,593	5,80,989	65,668	1,06,658	
Raisen	20,93,843	20,97,700	8,66,964	13,572	76,154	
STATE—TOTAL	10,95,74,502	10,83,59,771	3,42,92,604	58,49,511	47,22,102	

In acres-

7	8	9	10	11	12
2,03,722	1,61,640	574	14,183	13,413	6,88,347
1,87,697	27,568	1,075	3,499	4,494	5,34,179
2,72,172	1,67,068	5,877	13,603	19,177	14,11,098
93,430	3,56,579	399	24,711	19,607	10,48,700
1,25,984	1,59,821	17	48,181	37,630	6,60,883
1,06,054	26,318	18,369	63,808	1,37,856	8,24,547
81,613	68,350	14,206	48,068	1,99,566	7,39,169
1,69,239	13,809	1,954	78,579	1,64,077	6,58,108
1,57,667	96,587	3,886	1,34,103	2,81,281	10,29,301
14,775	13,445	357	11,967	55,520	2,88,810
1,20,495	2,60,788	64	34,694	1,12,158	3,99,016
1,32,497	3,45,541	366	77,131	5,15,762	6,04,893
4,37,679	25,441	2,551	39,918	2,81,761	4,24,166
5,10,533	1,22,634	...	10,133	29,624	88,354
1,99,377	1,60,055	235	7,148	21,078	7,53,117
84,36,550	87,10,376	8,17,316	19,57,957	40,17,863	3,55,55,032

Maharashtra

According to the land utilisation statistics for the year 1957-58, the State of Maharashtra has an area of 76·47 million acres classified as under:—

Table 60

Land Classification	(Million Acres)
1 Forests	13·38
2 Land not available for cultivation—	
(a) Barren and unculturable land	4·61
(b) Land put to non-agricultural use	1·69
3 Other uncultivated land excluding fallows—	
(a) Culturable waste	2·30
(b) Permanent pastures and other grazing lands	0·54
(c) Land under miscellaneous tree crops and groves	3·73
4 Current fallows]	2·41
5 Fallows other than current fallows	3·52
6 Net area shown	44·29
TOTAL	76·47

It would be observed that the total area classified as 'other uncultivated land excluding fallows' is 6·57 million acres, while the area classified as "fallows other than current fallows" is 3·52 million acres. The district-wise distribution of the areas under each of the above heads in Maharashtra State is given in the table 61.

Table 61

Land utilisation statistics of Maharashtra State for the year 1956-57 (District-wise)

(in 00' acres)

District	Total geographical area		Forests	Land not available for cultivation		Other cultivated land excluding fallows			Current fallows	Fallows other than current fallows	Net area sown
	By professional survey	By village papers		Barren & unculturable land	Land put to non-agricultural uses	Culturable waste	Permanent pasture and other grazing land	Land under misc. tree crops & groves			
1	2	3	4	5	6	7	8	9	10	11	12
West Khandesh	4,821	39,798	13,906	5,150	280	836	9	1,255	656	387	17,319
Nasik	6,021	28,821	8,345	3,668	23	263	142	1,550	396	807	23,127
Thana	3,658	23,924	8,891	1,877	45	338	538	1,318	1,655	1,060	7,602
Greater Bombay	186	836	25	238	48	97	9	114	7	84	214
Kolaba	2,723	16,967	4,034	3,018	56	803	931	287	511	2,214	5,113
Ratnagiri	5,013	31,662	469	8,369	590	7,156	572	296	1,117	4,537	8,562
Ahmednagar	6,591	42,049	8,442	3,611	97	396	..	650	570	831	31,052
Poona	6,032	38,452	4,575	3,748	834	424	19	804	674	2,781	24,595
North Satara	4,041	26,956	3,667	2,347	395	188	4	636	1,807	232	16,780
South Satara	3,297	21,287	1,156	968	126	374	..	633	29	2,087	15,814
Kolhapur	3,205	20,022	3,789	1,097	507	2,031	167	1,201	487	862	9,881
Sholapur	5,811	37,031	992	1,626	145	683	83	1,310	1,643	1,596	28,953

I	2	3	4	5	6	7	8	9	10	11	12
East Khandesh.	4,575	28,763	4,004	1,861	26	226	11	2,273	175	323	19,859
Aurangabad	6,314	40,208	2,028	580	1,079	467	38	2,019	569	2,442	30,986
Parbhani	4,853	20,923	439	412	703	346	158	1,167	3,806	568	23,324
Bhir	4,261	27,599	339	341	624	475	24	1,187	3,291	1,832	19,486
Osmabad	5,532	34,662	31	368	673	357	121	867	1,962	3,938	26,248
Nanded	4,805	29,759	2,455	1,211	1,004	589	160	1,760	2,221	407	19,682
Buldhana	3,751	24,146	3,025	646	675	439	48	1,240	196	1,327	16,550
Akola	4,095	26,094	2,169	954	838	179	18	1,520	319	1,314	18,783
Amravati	4,723	30,138	8,535	441	696	437	371	1,409	254	1,449	16,577
Yeotal	5,246	33,407	7,790	1,948	956	646	636	987	459	2,057	17,928
Wardha	2,429	15,537	1,670	206	858	737	353	126	264	840	9,843
Nagpur	3,842	24,430	4,538	455	1,358	1,311	153	2,966	338	346	12,965
Chanda	9,200	59,882	35,588	614	2,472	2,271	553	5,279	265	461	12,328
Bhandara	3,582	22,831	6,476	420	1,788	685	237	3,291	298	26	9,275
STATE TOTAL	1,18,609	7,64,729	1,33,776	46,132	16,900	23,024	5,355	37,285	24,069	3,52,242	4,42,949

Madras

According to the land utilisation statistics for the year 1958-59, the total area of the Madras-State may be classified as under:—

Table 62

Land Classification	Million Acres
1 Forests	4.39
2 Land not available for cultivation—	
(a) barren and unculturable land	2.47
(b) land put to non-agricultural uses	3.10
3 Other uncultivated land excluding fallows—	.99
(b) permanent pastures and other grazing lands	0.94
(c) land under miscellaneous trees and groves	0.65
4 Current fallows	2.55
5 Fallows other than current fallows	1.64
6 Net area sown	14.29
TOTAL	32.02

The above statement shows that the total area under the head "other uncultivated land excluding fallows" is 3.58 million acres, and the area classified as "fallows other than current fallows" is 1.64 million acres. The district-wise distribution of the areas under each of the above heads in Madras State is given in the table 63.

Table 63
Land utilisation statistics for Madras for the Year 1958-59
(District-wise)

(in acres)

District	Total geographical area		Forests	Land not available for cultivation		Other uncultivated land excluding fallows			Current fallows	Fallows other than current fallows	Net area sown
	By professional survey	By village papers		Barren & unculturable land	Land put to non-agricultural uses	Culturable waste	Permanent pasture & other grazing lands	Lands under miscellaneous tree crops & groves			
I	2	3	4	5	6	7	8	9	10	11	12
Madras	31,283	32,890	..	..	32,890	..	..	..	..	..	..
Chingleput	1,961,721	1,958,852	120,834	165,264	393,114	131,352	102,682	102,292	144,321	146,703	642,290
South Arcot	2,690,496	2,968,158	158,583	398,324	233,205	144,390	29,113	111,311	143,392	134,101	1,340,739
North Arcot	2,991,098	2,979,241	775,102	182,876	322,735	139,207	52,814	32,762	143,876	114,462	1,214,407
Salem	4,520,442	4,512,923	928,852	493,110	240,082	242,249	127,603	86,307	262,136	206,926	1,925,658
Coimbatore	3,851,821	3,863,688	971,442	106,252	148,762	123,094	52,737	215,914	448,032	132,090	1,865,365
Tircuchirapalli	3,529,165	3,523,305	169,220	172,363	500,205	365,554	129,595	50,007	254,984	170,559	1,710,818
Tanjore	2,392,344	2,393,602	30,862	100,858	458,237	100,128	15,082	67,941	91,750	96,826	1,430,918
Madurai	3,142,528	3,116,045	394,145	222,734	246,173	86,959	294,425	76,425	254,795	155,216	1,384,174

	1	2	3	4	5	6	7	8	9	10	11	12
Ramanathapuram .	3,103,488	3,088,194	62,743	407,126	284,969	302,881	43,255	50,735	479,378	108,628	1,349,479	
Tirunelveli .	2,828,243	2,821,006	314,739	141,737	198,214	276,124	72,195	30,985	305,504	356,487	1,125,021	
The Nilgiris .	629,568	628,970	341,952	21,076	19,332	69,181	19,430	10,495	17,484	12,990	116,230	
Kanyakumari .	411,520	412,240	122,834	53,805	25,658	6,300	3,000	15,493	3,212	4,212	177,735	
STATE TOTAL .	32,084,717	32,022,114	4,391,308	2,467,325	3,103,576	1,987,419	941,931	654,696	2,547,855	1,639,200	14,292,834	

Mysore

According to the land utilisation statistics for the year 1957-58, the total area of the Mysore State may be classified as below:—

Table 64

Land Classification	Million Acres
1. Forests	6.64
2. Land not available or cultivation—	
(a) barren and unculturable land	2.13
(b) land put to non-agricultural uses	1.84
3. Other uncultivated land excluding fallows—	
(a) culturable waste	1.6
(b) Permanent pastures and other grazing lands	4.51
(c) land under miscellaneous tree crops and groves	0.95
4. Current fallows	2.13
5. Fallows other than current fallows	1.18
6. Net area sown	25.08
TOTAL	46.12

It would be observed that the total area classified as 'other uncultivated lands excluding fallows' is 7.07 million acres, while the area classified as "fallows other than current fallows" is 1.18 million acres. The district-wise distribution of the area under each of the above heads in Mysore State is given in the table 65.

Table 65

Land utilisation statistics for Mysore for the year 1957-58
(District-wise)

(Acres)

District	Total geographical area		Forest	Land not available for cultivation		Other uncultivated land excluding fallows			Current Fallow	Fallows other than current fallows	Net area sown
	By professional survey	By village papers		Barren & unculturable land	Land put to non-agricultural uses	Culturable waste	Permanent and other grazing lands	Land under miscellaneous tree crop and groves			
1	2	3	4	5	6	7	8	9	10	11	12
Bangalore . . .	1,971,648	1,641,180	198,697	89,318	109,024	57,154	246,368	9,058	64,048	14,251	853,262
Kolar . . .	2,040,180	1,793,701	168,762	100,336	144,077	49,982	514,362	28,867	109,777	30,544	646,994
Tumkur . . .	2,621,466	2,617,488	115,090	164,459	153,929	16,723	460,071	97,070	209,864	102,445	1,209,837
Mysore . . .	2,957,779	2,767,949	766,731	216,106	104,738	4,079	339,268	18,171	72,509	57,198	1,077,149
Mandya . . .	1,226,752	1,137,246	42,261	43,683	82,684	134,755	181,930	2,002	75,018	20,153	554,670
Hassan . . .	1,658,102	1,602,042	61,640	53,706	125,398	74,145	358,809	16,440	247,526	32,942	631,436
Shimoga . . .	2,602,343	2,546,451	366,684	128,495	224,756	119,415	625,721	219,727	1,070,740	58,974	631,939
Chikmagalur . . .	1,783,712	1,745,985	343,734	117,462	58,857	88,162	536,232	27,702	55,530	51,570	466,646
Bellary . . .	2,448,109	2,450,563	378,661	141,412	176,775	106,511	17,496	10,187	110,358	66,037	1,443,126
Chitaldurg . . .	2,678,233	2,649,009	214,307	82,760	133,934	80,828	448,278	35,587	142,627	192,313	1,318,425
Dharwar . . .	3,394,054	3,404,266	279,229	147,701	16,116	33,634	99,295	15,495	30,025	66,847	2,715,904

	1	2	3	4	5	6	7	8	9	10	11	12
Belgaum . . .	3,258,477	3,308,466	484,565	150,265	4,125	44,824	108,32	1,477	48,739	158,887	2,306,852	
Bijapur . . .	4,217,696	4,230,634	208,043	49,766	61,113	29,327	80,451	8,015	118,952	73,336	3,556,630	
Bidar . . .	1,326,208	1,335,287	13 55	41,253	42,952	53,342	71,690	9,474	124,868	77,628	900,525	
Raichur . . .	3,524,992	3,438,328	34,813	178,981	95,199	45,314	109,747	31,280	262,002	30,240	2,650,752	
Gulburga . . .	4,062,426	3,929,947	77,709	115,234	77,266	93,187	146,311	11,252	190,115	74,848	3,144,625	
South Kanara . . .	2,080,013	2,031,464	533,921	200,665	132,290	191,472	84,206	295,601	88,699	34,778	469,832	
North Kanara . . .	2,537,677	2,526,826	2,059,739	43,339	41,135	53,841	2,973	7,922	3,629	30,024	284,224	
Coorg . . .	1,018,490	1,011,685	341,982	75,131	51,214	132,223	75,854	102,939	1,336	11,621	219,385	
STATE TOTAL . . .	47,438,362	46,168,517	6,690,132	2,185,072	1,835,582	1,608,938	4,507,794	948,306	2,126,453	1,184,636	25,081,613	

Orissa

According to the land utilisation statistics for the year 1957-58, the total area of the Orissa State has been classified as below:—

Table 66

Land Classification	(Million Acres)
1. Forests	8.80
2. Land not available for cultivation—	
(a) barren and unculturable land	3.56
(b) land put to non agricultural uses	2.72
3. Other uncultivated land excluding fallows—	
(a) culturable waste	3.50
(b) permanent pastures and other grazing lands	1.82
(c) land under miscellaneous tree crops and groves	1.14
4. Current fallows	2.27
5. fallows other than current fallows	0.74
6. Net area sown	13.85
TOTAL	38.40

It would be observed that the total area classified as "other uncultivated land excluding fallows" is 6.46 million acres, and the area classified as "fallows other than current fallows" is 0.74 million acres. The district-wise distribution of the area under each of the above heads in Orissa is given in the table 67. (It may be relevant to record here that the land utilisation statistics for the State are not collected by the complete enumeration method, and as these are mere estimations, they cannot be considered reliable).

Table 67

Land utilisation statistics for Orissa during 1954-55
(District-wise)

(In acres)

District	Total geographical area		Forests	Land not available for cultivation		Other uncultivated land excluding fallows			Current fallows	Fallow s other than current fallow s	Net area sown
	By Professional survey	By village papers		Barren and unculturable land	Land put to non-agricultural uses	Culturable waste	Permanent pastures and other grazing lands	Miscellaneous tree crops and groves			
I	2	3	4	5	6	7	8	9	10	11	12
Balasore	1,596,800	1,524,006	697,682	52,678	117,709	68,961	60,105	15,630	88,639	40,037	982,565
Baudh Phulbani	2,738,560	2,740,480	216,000	100,035	143,029	395,423	35,338	1,158	33,211	9,000	807,286
olangir	2,203,523	2,183,712	345,842	147,358	27,771	430,901	286,774	17,549	30,945	45,904	850,668
Cuttack	2,711,680	2,694,400	219,968	44,095	208,227	53,317	142,255	82,014	384,248	24,476	1,535,800
Dhenkenal	2,675,840	2,704,640	1,282,707	118,043	86,546	54,973	103,468	14,787	50,000	9,000	..
Ganjam	3,089,920	3,024,013	516,857	390,000	98,675	466,000	227,002	214,703	184,076	91,000	835,700
Kalahandi	3,259,620	3,236,480	315,436	515,155	564,600	187,416	226,271	67,350	354,849	23,665	981,738
Keonjhar	2,058,120	2,058,451	691,301	46,054	219,578	179,372	156,027	53,463	46,000	16,300	650,356
Keraput	6,312,960	6,320,000	778,625	1,005,640	867,830	325,910	230,864	262,688	285,899	178,717	2,383,827

I	2	3	4	5	6	7	8	9	10	11	12
Mayurbhanj .	2,574,080	2,573,504	571,142	384,000	138,384	62,000	73,430	5,400	453,904	96,655	788,589
Puri .	2,560,640	2,537,520	757,517	148,507	153,105	165,952	127,681	100,311	32,421	31,091	1,060,940
Sambalpur .	4,332,160	4,329,293	1,118,000	194,847	91,004	952,909	65,759	308,044	171,685	613,205	1,264,440
Sundergarh .	2,451,200	2,424,320	887,680	411,246	..	160,863	84,316	..	142,916	10,000	727,299
STATE TAL	38,560,000	38,400,819	8,798,757	3,557,053	2,716,458	3,503,997	1,819,290	1,143,097	2,268,793	739,050	13,854,324

PUNJAB

According to the land utilisation statistics for the year 1957-58, the State of Punjab has an area of 30 million acres classified as under:—

Table—68

Land Classification	Million Acres
1 Forests	0·93
2 Land not available for cultivation—	
(a) Barren and unculturable land	6·52
(b) Land put to non-agricultural uses	1·25
3 Other uncultivated land excluding fallows—	
(a) Culturable waste	1·80
(b) Permanent pastures and other grazing lands	0·23
(c) Land under miscellaneous tree crops and groves	0·02
4 Current fallows	1·45
5 Fallows other than current fallows	0·01
6 Net area sown	18·07
TOTAL	30·28

It will be observed that the area classified as “other uncultivated land excluding fallows” is 2.05 million acres, while the area classified as “fallows other than current fallows” is very small, being only about 11,000 acres. The district-wise distribution of the area under each of the above heads in Punjab is indicated in the table 69.

TABLE 69

Land utilisation statistics for Punjab for the year 1957-58.
(District-wise)

(in acres)

District	Total geographical area		Forests	Land not available for cultivation		Other uncultivated land excluding fallow lands			Current fallows	Fallows other than current fallows	Net area sown
	By Professional survey	By village papers		Barren and un-culturable land	Land put to non-agricultural uses	Culturable waste	Permanent pastures and other grazing lands	Land under miscellaneous tree, crops, groves not included in area sown			
I	2	3	4	5	6	7	8	9	10	11	12
Hissar	34,50,240	34,32,204	322	57,161	90,758	2,08,477	..	..	2,59,084	..	28,16,402
Rohtak	14,90,560	14,92,631	6,221	19,618	1,09,602	97,913	24,854	261	41,530	..	11,92,632
Gurgaon	15,15,520	15,03,772	30,143	67,463	1,77,415	8,233	20,187	257	35,905	703	11,62,896
Karnal	19,66,720	19,75,033	3,908	1,57,042	80,958	2,51,678	97,214	4,494	86,493	..	12,93,246
Ambala	12,58,870	12,52,297	1,33,269	1,26,005	98,968	68,977	15,376	..	56,462	..	7,53,240
Simla	5,130	4,883	2,770	1,277	..	94	397	..	28	..	267

	1	2	3	4	5	6	7	8	9	10	11	12
angra . .	61,24,160	63,95,366	6,62,148	48,33,272	1,56,148	1,20,747	49,337	..	86,852	..	4,86,862	
Hoshiarpur .	14,80,400	14,21,975	35,813	4,67,509	90,468	24,140	21,457	12,572	46,496	..	7,23,520	
Jullundur .	8,53,760	8,46,415	208	64,065	42,820	38,596	..	..	70,539	..	6,42,789
Ludhiana .	8,46,720	8,46,415	3,334	30,446	55,608	66,472	1,733	..	49,331	..	6,39,471	
Ferozepur .	26,28,480	26,17,693	..	1,93,140	..	1,35,103	..	..	3,27,329	7,106	19,55,015
Amritsar .	12,41,600	12,55,954	943	12,187	1,57,363	1,45,284	..	..	84,852	..	8,55,325
Gurdaspur .	8,72,320	8,54,518	9,309	1,49,000	620	69,089	..	526	1,09,659	..	5,16,315	
Bhatinda .	14,44,480	15,85,258	422	69,579	..	39,585	..	..	14,739	..	14,60,933
Kapurthala .	4,03,200	4,11,550	168	2,450	54,787	45,102	..	2,788	47,607	3,760	2,54,888	
Mohindergarh	8,59,520	8,57,718	981	..	71,785	63,230	..	..	12,618	..	7,09,104
Patiala . .	16,67,200	15,80,115	33,832	1,48,818	63,954	3,24,509	..	..	46,191	..	9,62,811
Sangrur .	20,60,800	19,36,570	2,216	1,16,854	..	1,01,690	..	..	71,870	..	16,13,940
STATE TOTAL	3,01,19,680	3,02,82,919	9,26,007	85,15,906	12,51,254	18,08,919	2,31,185	20,898	14,47,585	11,569	1,80,69,596	

RAJASTHAN

According to the land utilisation statistics for the year 1957-58, the State of Rajasthan has an area of 84.28 million acres classified as under:—

Table 70

Land Classification	Million Acres
1 Forests	2.86
2 Land not available for cultivation—	
(a) Barren and uncultivable land	12.14
(b) Land put to non-agricultural uses	2.78
3 Other uncultivated land excluding fallows—	
(a) Culturable waste	18.07
(b) Permanent pastures and other grazing lands.	3.45
(c) Land under Misc. tree crops and groves	0.05
4 Current fallows	5.75
5 Fallows other than current fallows	9.29
6 Net area sown	29.91
TOTAL	84.28

It will be observed that the total area classified as "other uncultivable land excluding fallows" is 21.57 million acres whilst the area classified as "fallows other than current fallows" is 9.29 million acres. The district wise distribution of the areas under each of the above heads in Rajasthan is given in the table 71.

TABLE 71

Land utilisation statistics for Rajasthan for the year 1957-58

District	Total geographical area according to		Forests	Land not available for cultivation	
	Professional Survey	Village papers		Land put to non-agricultural uses	Barren & unculturable land
1	2	3	4	5	6
Ajmer	21,01,434	20,53,861	93,872	1,41,575	1,85,148
Alwar	20,73,997	20,66,655	2,58,939	90,132	3,64,837
Bharatpur	20,01,466	19,96,312	21,993	87,996	4,40,352
Jaipur	34,51,801	34,66,653	57,107	1,51,418	3,36,953
Jhunjhunu	14,60,742	14,58,476	1,09,357	12,743	42,108
S. Madhopur	26,04,845	25,47,152	1,46,985	96,397	6,63,293
Sikar	19,37,011	19,23,507	13,010	53,301	1,72,137
Tonk	17,63,514	17,78,351	63,426	54,653	96,447
Bikaner	67,20,589	67,20,589	20,162	1,33,900	18,119
Churu	41,03,366	41,64,991	21	2,08,103	1,230
Ganganagar	51,18,701	51,02,005	..	1,64,176	2,544
Barner	65,11,469	69,40,525	278	1,58,199	3,99,782
Jaisalmer	95,41,472	96,65,698	43,520	1,44,718	38,19,420
Jalore	31,46,534	26,08,885	17,334	75,949	2,42,996
Jodhour.	56,14,726	55,21,268	4,966	2,46,311	3,46,964
Nagaur	44,04,896	43,63,355	4,954	1,70,672	2,36,101
Pali	30,67,206	30,15,214	1,43,000	1,03,245	4,54,886
Sirohi	12,65,664	12,81,913	59,469	39,474	4,82,157
Bundi	13,81,306	13,88,995	1,82,875	61,948	4,44,878
Jhalawar	15,39,200	15,07,414	26,037	64,412	3,29,361
Kotah	30,68,237	30,44,768	85,404	1,00,811	6,90,758
Banswara	12,45,568	12,57,066	4,40,653	14,579	50,205
Bhilwara	25,81,824	25,75,747	26,045	91,288	3,94,722

(Districtwise)

(In crores)

Other uncultivate land excluding fallows			Current fallows	Fallows other than current fallows	Net area sown
Permanent pastures & other grazing land	Land under Misc. tree crops and groves	Culturable waste			
7	8	9	10	11	12
1,54,730	216	3,91,500	1,36,815	1,98,594	7,51,411
33,941	729	1,64,082	28,379	19,447	11,06,169
41,958	1,016	1,10,064	50,278	47,346	11,95,309
2,39,439	3,224	5,54,645	2,76,059	2,44,342	16,03,466
1,11,970	197	32,868	46,135	28,787	10,74,311
2,20,053	6,589	2,72,775	53,433	64,402	10,23,225
1,24,942	177	61,059	1,79,363	65,839	12,53,679
1,43,307	814	4,42,437	53,190	62,476	8,61,601
19,155	196	48,73,440	2,91,323	5,24,752	8,39,142
29,454	..	5,69,741	4,60,550	6,23,301	22,72,591
4,380	108	16,48,610	4,56,465	1,74,413	26,51,309
2,12,857	451	9,04,803	9,67,873	15,26,552	27,69,730
1,28,000	50	39,57,220	18,219	13,55,071	1,99,660
1,15,200	353	73,145	3,80,435	3,80,436	13,23,037
1,51,760	1073	1,77,312	6,77,146	15,76,783	23,38,953
1,38,130	524	36,575	7,13,448	4,85,190	25,10,761
1,47,914	5,152	1,09,819	4,17,061	5,90,801	10,43,336
63,993	151	1,08,774	95,071	1,43,509	2,89,315
7,322	1,481	1,71,715	25,818	35,506	4,57,452
1,10,116	1,390	2,47,934	116,684	62,653	6,53,827
1,08,412	3,346	6,45,719	24,987	1,00,373	12,84,958
58,390	2,392	80,449	74,724	1,44,698	3,90,976
1,97,332	427	8,15,002	71,009	4,46,683	5,32,539

1	2	3	4	5	6
Chittorgarh . . .	25,81,158	25,49,469	2,25,356	78,996	4,27,220
Dungarpur . . .	9,34,157	9,34,400	1,85,119	42,827	1,90,138
Udaipur . . .	43,54,995	43,55,214	6,33,382	1,92,357	13,03,638
STATE—TOTAL . . .	8,45,75,878	8,42,81,83	28,63,264	27,80,180	1,21,36,214

7	8	9	10	11	12
1,93,019	454	4,84,321	41,010	1,41,769	6,57,324
1,55,314	356	1,76,388	34,707	18,588	2,30,963
5,40,438	21,052	7,60,343	87,650	2,24,922	5,91,432
34,51,526	52,618	1,80,70,740	57,33,232	92,87,233	2,99,06,476

UTTAR PRADESH

According to the land utilisation statistics for the year 1957-58, the State of Uttar Pradesh has an area of 63·94 million acres classified as under:—

Table—72

Land Classification	Million Acres
1. Forests	5·78
2. Land not available for cultivation—	
(a) barren and unculturable land	2·89
(b) land put to non-agriculture uses	4·64
3. Other uncultivated land excluding fallows—	
(a) culturable waste}	4·29
(b) permanent pastures and other grazing lands	0·07
(c) land under miscellaneous tree, crops and groves	2·21
4. Current fallows	0·35
5. Fallows other than current fallows	3·63
6. Net area sown	40·08
TOTAL	63·94

It will be observed that the total area classified as “other uncultivated land excluding fallows” is 6·57 million acres and “fallows other than current fallows” is 3·63 million acres. The district-wise distribution of the area under each of the above heads in Uttar Pradesh is indicated in the attached statement.

TABLE 73

Land utilisation statistics for U.P. for 1957-58

District	Total geographical area		Forest	Land not available for cultivation	
	By professional survey	By village papers		Barren & unculturable land	Land put to non-agricultural uses
1	2	3	4	5	6
Dehradun	7,68,646	7,13,107	4,72,301	6,400	38,786
Saharanpur	13,64,371	13,58,669	1,87,885	17,914	1,37,606
Muzaffarnagar	10,76,851	10,67,040	30,669	37,495	84,072
Meerut	14,86,298	14,84,300	24,373	50,121	1,12,526
Bulandshahr	12,07,987	12,48,196	27,342	72,379	2,751
Aligarh	12,42,490	12,60,329	12,022	1,03,014	70,678
Mathura	9,38,752	9,43,975	15,856	15,987	50,457
Agra	11,90,912	12,04,511	60,395	92,918	68,812
Mainpuri	1,10,75,136	11,34,241	1,22,048	1,65,522	58,015
Etah	10,97,792	11,02,096	7,294	35,309	66,744
Bareilly	10,18,554	10,12,588	4,862	18,198	85,086
Bijnor	11,94,541	12,33,823	1,31,042	27,205	1,03,664
Budaun	12,78,726	13,06,417	18,838	31,586	80,651
Moradabad	13,64,672	14,92,014	46,122	30,365	99,710
Shahjahanpur	11,27,976	11,45,766	36,463	24,435	76,247
Pilibhit	8,64,973	10,38,086	2,77,772	10,101	62,522
Rampur	5,72,998	6,01,08	26,711	12,625	51,179
Farrukhabad	10,52,960	11,13,476	59,424	72,878	91,037
Etawah	10,67,885	11,75,998	1,47,630	1,66,093	64,978
Kanpur	15,08,499	15,49,994	47,773	1,73,477	1,00,937
Fatehpur	10,39,917	10,67,501	18,092	86,440	1,04,398
Allahabad	17,91,827	18,62,548	67,151	1,17,637	1,76,084
Jhansi	24,88,333	25,52,772	2,40,538	1,47,782	1,19,07

70

Uttar Pradesh during 1957-58
wise)

(In acres)

Other uncultivated land excluding fallows			Current fallows	Fallows other than current fallows	Net area sown
Culturable waste	Permanent pastures and other grazing lands	Misc. trees crops and groves			
7	8	9	10	11	12
8,568	1,031	37,888	27	8,663	1,39,443
40,938	197	12,243	26,576	33,128	9,02,182
49,058	329	11,346	17,630	35,531	7,90,810
71,919	715	9,412	9,563	47,677	11,58,694
74,282	398	19,125	1,301	43,021	9,87,857
37,251	947	12,452	294	45,975	9,77,696
37,669	118	10,342	159	37,124	7,76,263
54,006	281	4,498	254	43,224	8,80,123
47,677	91	13,740	237	55,639	6,71,272
531,134	661	29,965	2,225	58,467	7,70,297
29,593	233	16,925	32,655	28,459	7,96,567
46,391	926	80,266	58,808	38,476	7,52,047
46,943	394	39,669	11,221	54,379	10,22,766
52,588	1,113	15,850	35,664	50,556	11,60,095
50,079	65	34,147	16,841	67,507	8,38,862
67,764	390	89,007	19,479	38,393	4,72,658
29,706	197	4,862	8,843	32,359	4,34,306
94,077	66	35,436	1,933	56,625	7,02,000
51,015	482	13,795	409	46,455	6,85,141
62,938	13,738	57,769	1,669	53,838	10,37,855
258	38	29,504	244	64,083	6,84,444
33,323	7,600	82,010	286	1,80,073	10,98,379
9,80,426	6,613	17,487	2	3,40,418	10,00,430

I	2	3	4	5	6
Jalaun . . .	11,27,411	11,85,274	95,958	72,663	62,015
Hamirpur . . .	17,76,376	18,35,937	1,28,587	91,305	95,893
Banda . . .	18,88,224	20,06,819	1,79,184	1,50,323	85,848
Varanasi . . .	12,55,552	13,03,706	1,89,171	40,512	1,01,162
Mirzapur . . .	27,97,798	29,52,548	9,89,336	2,05,556	1,38,296
Jaunpur . . .	9,94,701	9,95,410	297	42,512	74,018
Ghazipur . . .	8,37,005	8,33,023	..	23,487	64,309
Ballia . . .	7,56,685	7,95,994	52	44,702	82,668
Gorakhpur . . .	15,66,659	16,03,140	1,54,085	7,786	1,21,282
Deoria . . .	13,35,565	13,41,708	4,444	22,690	1,00,122
Basti . . .	18,05,702	18,11,572	8,952	19,202	1,64,930
Azamgarh . . .	14,16,294	14,19,171	931	62,767	1,23,869
Nainital . . .	16,86,133	15,14,604	9,42,899	5,669	46,402
Nainital (H.P.) . . .	..	2,77,000	1,63,789	4,046	..
Almora . . .	35,20,614	34,11,638	6,90,101	..	..
Garhwal . . .	36,03,610	35,96,307	20,54,707	..	..
Tehri-Garhwal . . .	29,16,595	28,80,000	17,75,986	..	..
Lucknow . . .	6,25,517	6,24,435	12,591	60,204	51,440
Unnao . . .	11,35,302	11,73,132	42,190	1,10,512	1,00,184
Raibareli . . .	11,25,402	11,22,174	9,177	87,711	1,10,430
Sitapur . . .	14,11,642	14,41,225	21,840	15,188	1,28,896
Hardoi . . .	14,84,086	14,84,064	19,849	68,883	1,18,504
Kheri . . .	19,02,141	20,25,447	4,27,636	15,290	1,64,107
Faizabad . . .	10,94,426	10,83,677	5,272	28,106	1,24,587
Gonda . . .	18,10,918	18,81,522	1,99,333	7,775	1,48,146
Bahraich . . .	16,89,978	17,03,954	2,44,023	10,527	1,40,889
Sultanpur . . .	10,92,446	11,03,204	4,695	81,497	1,00,357
Partapgarh . . .	9,33,491	9,08,711	642	67,714	86,493
Barabanki . . .	11,03,206	11,20,289	17,190	27,831	1,27,731
STATE TOTAL	7,26,09,56	6,39,39,327	57,80,925	28,86,292	46,38,60

7	8	9	10	11	12
47,667	3,186	15,548	194	35,822	8,52,221
2,27,468	346	963	552	1,88,028	10,94,128
2,53,367	422	8,790	11	2,50,498	9,99,262
41,046	11	54,940	1,092	67,962	8,07,803
3,61,500	1,453	1,83,834	1,581	3,22,621	7,48,381
62,387	721	3 3,520	3,607	64,260	7,14,088
90,930	..	22,881	3,186	36,370	6,31,860
22,632	..	32,087	3,005	35,840	5,75,008
59,254	482	62,946	2,282	46,569	11,67,908
24,952	449	54,692	19,910	33,025	10,81,424
67,688	903	4,610	396	59,906	14,23,494
65,040	106	4,148	6,207	63,004	10,55,759
69,402	12,345	21,854	6,492	56,859	3,51,684
..	..	32,405	..	..	76,760
..	..	..	34,708	..	5,14,122
..	..	..	33,982	..	8,60,673
..	..	..	951	..	97,476
53,752	474	33,591	18	48,074	3,64,291
1,03,718	1,041	50,472	417	71,874	6,82,724
1,12,998	277	95,040	104	45,272	6,61,145
46,598	539	65,213	13,193	96,809	10,52,988
86,017	816	66,554	3,385	1,06,593	10,13,463
1,30,448	1,339	1,18,867	29,920	1,31,746	10,06,114
59,434	2,184	72,422	1,394	5,69,992	7,33,386
87,670	274	64,057	2,438	9,07,782	12,81,047
91,073	2,975	50,155	629	94,250	10,69,433
67,454	1,418	87,530	196	54,017	7,09,040
50,653	45	71,270	..	46,617	5,85,277
78,223	53	78,428	4,576	58,301	7,27,946
42,95,965	68,922	22,08,564	3,64,751	36,33,071	4,00,80,232

WEST BENGAL

The total area of the West Bengal State may be classified under five different heads as under:—

Table—74

Land Classification	Million Acres
1 Forests	2.32
2 Area not available for cultivation	2.97
3 Other uncultivated lands excluding current fallows	1.51
4 Current fallows	1.03
5 Net area sown	12.02
TOTAL:	19.85

The districtwise distribution of the area under each of the above heads in West Bengal is indicated in the table 75.

Table 75

Land utilisation statistics for West Bengal for the year 1956-57.
(District-wise)

(In acres)

District	Total geographical area		Forests	Area not available for cultivation*	Other uncultivated land excluding current fallows	Current fallows	Net area sown
	By Professional survey	By Village papers					
24-Parganas	36,30,200	36,30,200	10,53,000	6,35,000	2,50,000	67,200	16,25,000
Nadia]	9,65,800	9,65,800	..	1,38,000	80,000	56,500	6,91,300
n.Murshidabad	13,26,100	13,26,100	..	1,83,700	90,000	1,20,600	9,31,800
Burdwan	17,31,500	17,31,500	31,600	3,38,400	1,16,600	49,200	11,95,700
Birbhum	11,15,500	11,15,500	6,000	1,75,000	41,000	78,300	8,15,200
Bankura	16,94,000	16,94,000	1,95,500	1,49,500	2,37,300	2,60,500	8,51,200
Midnapur	33,62,000	33,62,000	3,81,300	3,11,700	2,46,000	1,07,800	22,15,200
Hooghly	7,75,700	7,75,700	600	1,48,400	31,900	7,800	5,87,000
Howrah	3,58,500	3,58,500	..	87,000	12,100	35,300	2,24,100
Jalpaiguri	15,19,600	15,19,600	3,61,400	2,69,000	1,85,000	50,900	6,53,300
Darjeeling	7,67,800	7,67,800	2,90,800	1,84,500	49,000	26,000	2,17,500
Malda	8,90,900	8,90,000	..	89,000	51,000	41,400	7,09,500
West Dinaipur	8,86,700	8,86,700	..	1,45,500	38,700	18,100	6,84,400
Cooch-Behar	8,46,500	8,46,500*	..	1,11,700	85,800	10,100	6,15,800
STATE TOTAL	1,98,70,800	1,98,70,800	23,20,200	29,66,400	15,14,400	10,29,700	1,20,17,000

NOTE.—The statement does not include figures in respect of the territories transferred from Bihar to West Bengal as a result of reorganisation of States.

*Include 23,100 acres for which detailed agricultural statistics are not available.

HIMACHAL PRADESH

Table—76

Classification of Area

Land classification	In acres
	1958-59 Area (in acres)
1. Total Geographical Area—	
By Professional Survey	69,90,080
By Village Papers	38,82,123
<i>Classifications:</i>	
2. Land put to non-agricultural uses	1,07,557
3. Culturable waste	1,16,089
4. Permanent pastures and other grazing lands	14,56,411
5. Land under misc. tree crops and groves not included in area sown	66,647
6. Current fallows	39,197
7. Other fallows land	10,502
8. Net area sown.	6,67,379
9. Area sown more than once	4,06,937
TOTAL CROPPED AREA	10,74,316

The above statement shows that the total area under the head 'other cultivated land excluding fallows' is 1.64 million acres, and the area classified as 'fallows other than current fallows' is 0.011 million acres. The district wise distribution of the area under each of the above heads in Himachal Pradesh is given in the table 77.

Table 77

Classification of area in each District of Himachal Pradesh Territory in 1958-59.

District	Total geographical area		CLASSIFICATION									(In acres)	
	By Professional survey	By Village papers	Forests	Barren and unculturable land	Land put to non-agricultural uses	Culturable waste	Permanent pastures and other growing lands	Land under misc. tree crops and groves not included in area sown	Current fallows	Other fallows land	Net area sown	Area sown more than once	Total cropped area
Bilaspur .	2,86,720	2,85,306	28,636	15,756	19,923	10,816	1,28,606	3	2,924	3,635	75,007	52,449	1,27,456
Chamba .	20,06,400	16,94,621	9,34,899	9,218	29,592	18,488	6,01,778	35	8,206	2,619	89,786	52,695	1,42,481
Mahasu .	30,21,440	8,67,465	1,43,426	26,169	27,787	41,618	3,97,748	402	18,168	2,488	2,09,658	1,08,677	3,18,335
Mandi .	9,74,720	4,79,539	94,765	21,589	16,128	8,297	1,38,297	..	5,545	644	1,94,274	1,21,080	3,15,354
Sirmur .	7,00,800	5,55,192	1,29,663	14,219	14,127	36,870	1,89,982	66,207	4,354	1,116	98,654	72,036	1,70,690
STATE TOTAL	69,90,080	38,82,123	13,31,390	86,951	1,07,557	1,16,089	14,56,411	66,647	39,197	10,502	6,67,379	4,06,937	10,74,316

GMGIPD—LS 1—49 PC—11-6-63—1500.

PRINTED IN INDIA BY THE GENERAL MANAGER, GOVERNMENT OF INDIA PRESS
NEW DELHI AND PUBLISHED BY THE MANAGER OF PUBLICATIONS. DELHI 1963
