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GOVERNMENT OF PAKISTAN
MINISTRY OF FOOD, AGRICULTURE AND LIVESTOCK

SOIL SURVEY OF PAKISTAN

IN COLLABORATION WITH

INTERNATIONAL IRRIGATION MANAGEMENT INSTITUTE

DETAILED SOIL SURVEY OF EIGHT WATERCOURSE COMMAND AREAS IN CHISHTIAN AND HASILPUR TEHSILS

SOIL SURVEY OF PAKISTAN
and
INTERNATIONAL IRRIGATION MANAGEMENT INSTITUTE, PAKISTAN

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FOREWORD

This is a joint report by the Soil Survey of Pakistan (SSP) and the International Irrigation Management Institute (IIMI). The staff of SSP have a long history of high quality field research on soil salinity and sodicity. In fact, it was this staff that brought to public notice the problem of secondary salinization resulting from the use of poor quality tubewell water.

The research program of IIMI is strongly focused on salinity and sodicity. The contents of this report are the result of the collaboration between SSP and IIMI. In this case, the SSP staff have played the major role.

The two organizations have also worked together on salinity studies in Rechna Doab. In addition, we continue working together in the Fordwah Eastern Sadiqia Irrigation and Drainage Project.

Both organizations have benefited very much from the financial and technical support provided by the Government of the Netherlands. This has really facilitated our working together.

Gaylord V. Skogerboe, Director
Pakistan National Program
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1. INTRODUCTION

1.1 Objectives and scope

Detailed soil investigations of eight watercourse command areas of Fordwah and Azim Distributaries were carried out by the Soil Survey of Pakistan on the request of the International Irrigation Management Institute, Pakistan (IIMI-Pakistan) Lahore. The investigations are part of the research activities of IIMI-Pakistan relating to managing irrigation systems in general and in particular to the incidence of waterlogging and salinity as related to irrigation management (Kuper and Strosser, 1992). Soil lithology and other soil characteristics like infiltration rate, hydraulic conductivity, nature of salinity and/or sodicity, soil fertility, water-table depth, etc. are prerequisites for such type of research.

Keeping in view the research programme of IIMI-Pakistan, the present investigations were carried out which included the following:

Detailed investigations of the soils of the area and their identification at soil phase level.

Preparation of detailed soil survey maps at a scale of 1:10,000 for each watercourse command and a combined report.

Characterization of each soil series with special reference to soil lithology (mechanical analysis of soil horizons), hydraulic characteristics (infiltration rate, permeability) bulk density, porosity, soil fertility (organic matter content and micro-nutrients), etc.

These investigation will help in improving the planning/execution of research projects relating to irrigation management and *to* apply the results on the related soils of the area.

1.2 Soil survey methodology

A detailed soil survey of the project area was carried out in October-November 1995 by three separate teams, each comprising of one Soil Survey Research Officer and one Assistant Soil Survey Research Officer. The methodology adopted included the following stages:

Base maps of all the eight watercourse command areas were prepared at 1:5,000 scale, separately.

Each watercourse command area was transferred on the available (1:40,000 scale) air-photos flown in 1955-56 under the Colombo Plan.

The air-photos were scanned under a mirror stereoscope to delineate physiography and associated soils of the areas on the basis of air-photo patterns and tonalities.

Field investigations were carried out using the interpretative physiography soil map and augering the soils to a depth of 150 to 200 cm, mostly in alternate fields. –Wherever necessary, the observation sites were supplemented by additional checks, to trace the exact soil boundaries. However, in barren or dunal areas, the observation density was lower.

At each auger observation site, the information recorded included: the depth and thickness of the horizons/layers; and for each horizon, the moist Munsell's colour, mottles, texture, structure, porosity, soil moisture status, consistence, calcareousness/gypsum and soil reaction. In addition, surface salt crust (locally called "papri"), depth to watertable, land use and other factors influencing soil management were also noted. Soil types and their phases were differentiated on the basis of these characteristics. In total about 1100 auger observations were made in all the eight watercourse command areas.

The information were recorded on prescribed proformae (Appendix I), using a separate sheet for each observation site. The sites were precisely located, marked, indexed and numbered on the base maps.

Twelve soil pits were exposed to a depth of 2m on representative sites of the soils recognized in the survey area, described and sampled according to the procedures laid down in the Guidelines for Soil Description (FAO, 1977).

The laboratory team performed replicated tests for infiltration (doublering infiltrometer) and permeability (auger hole and inversed auger hole methods] at the abovementioned 12 sites and collected undisturbed core samples from defined depths. In total, 213 disturbed soil samples and 73 undisturbed core samples were collected for detailed analysis in the laboratories of the Soil Survey of Pakistan at Lahore.

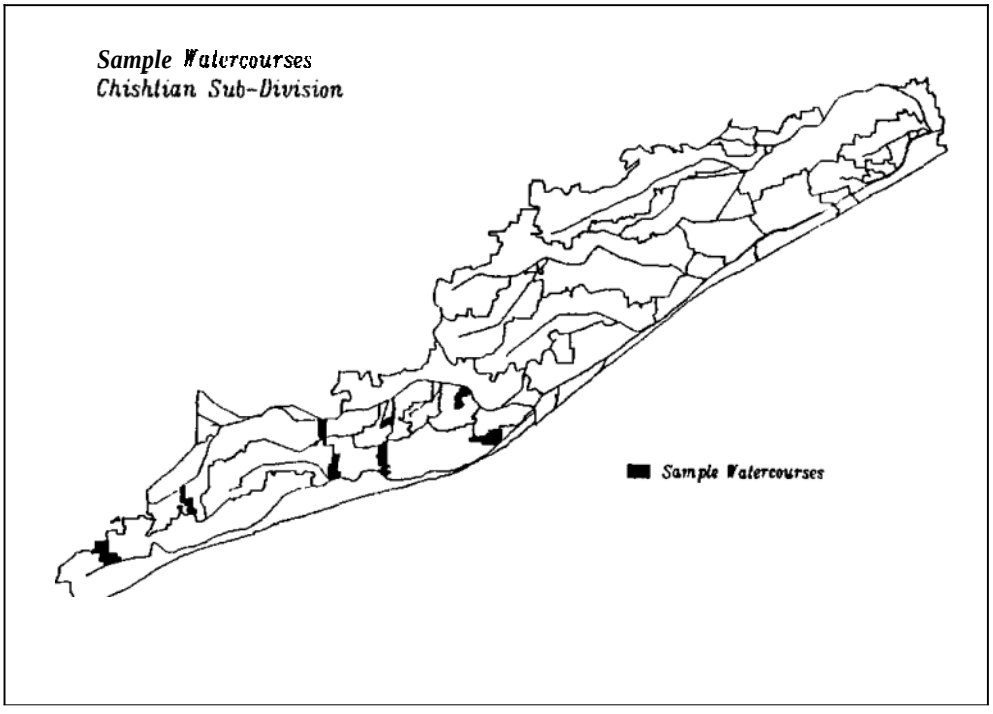
The soil boundaries drawn in the field were finalized through a deep insight of field observations recorded, supplemented by comparison with the air-photo studies.

Digitization of the soil maps at the scale of 1:10,000 of the eight watercourse command areas and word processing of the report was done by the relevant sections of IIMI-Pakistan at their Head Office, Lahore.

1.3 Location and extent

All of the eight watercourse command areas, listed below with their extent, are located between latitudes 29" 40' to 29" 50' N and longitudes 72° 25' to 72" 50' E. Four of these on the right of the Fordwah Distributary are suffixed with "R" and four on the left of the Azim with "L". Their location is shown on map provided by IIMI.

Location Map



Watercourse No.	Acres	Watercourse No.	Acres
Azim 20610 L	342	Fordwah 14320 R	497
Azim 43260 L	174	Fordwah 46725 R	414
Azim 63620 L	304	Fordwah 62050 R	336
Azim 111770 L	297	Fordwah 130100 R	653

1.4 Climate

The climate of the area is arid subtropical monsoonal. Average annual rainfall ranges between 150 to 179 mm, about two-thirds is received during monsoon (mid July to September) and the remaining in winter (December to February). Monsoon rains fall in heavy showers. The post monsoon period including winter months are extremely dry while the premonsoon period receives little rainfall.

The mean annual temperature is 26.1 °C. May and June are the hottest months with the extreme being 51.7 °C. The mean winter temperature is 14.8 "C, January being the coldest month with a mean minimum temperature of 5 °C. Potential evaporation is high at 150 mm/year. Relative humidity is low at 46%. Water balance data show a continuous water deficit throughout the year (Table 1 and Figure I).

1.5 Hydrology

The survey area is commanded by eight watercourses, four of which take off from Fordwah Distributary and the remaining from Azim Distributary. The command areas of 130100 R and 111770 L are located at the tail ends of tho two distributaries Fordwah and Azim, respectively, and the remaining upstream in the sequence. Canal water supplies generally are inadequate, worst at the tail ends. To overcome the shortage of irrigation water, tubewells are proliferating in the area. Groundwater is generally brackish, imposing soil surface salinity and damaging soil production potential. Poor quality tubewell water has damaged a considerable part of the survey area from a few millimeters to more than one meter depth of the soil.

One major canal, Fordwah, controls the hydrology of the area through a network of distributaries. Soils of the area, being mainly light textured, are prone to waterlogging through seepage from the irrigation network and injudicious use of irrigation water which has raised water tables to 90-150 cm and sometimes even to 45-90 cm depths below the ground surface.

Table 1. Climatic data.

Salient features:

Mean annual rainfall	150 to 179 rnm
Mean summer maximum temperature	40.7"C
Mean winter minimum temperature	6.2°C
Summer maximum temperature	51.7°C
Winter minimum temperature	4.4°C
Length of growing period (agricultural crops):*	
Winter days	0
Summer days	0

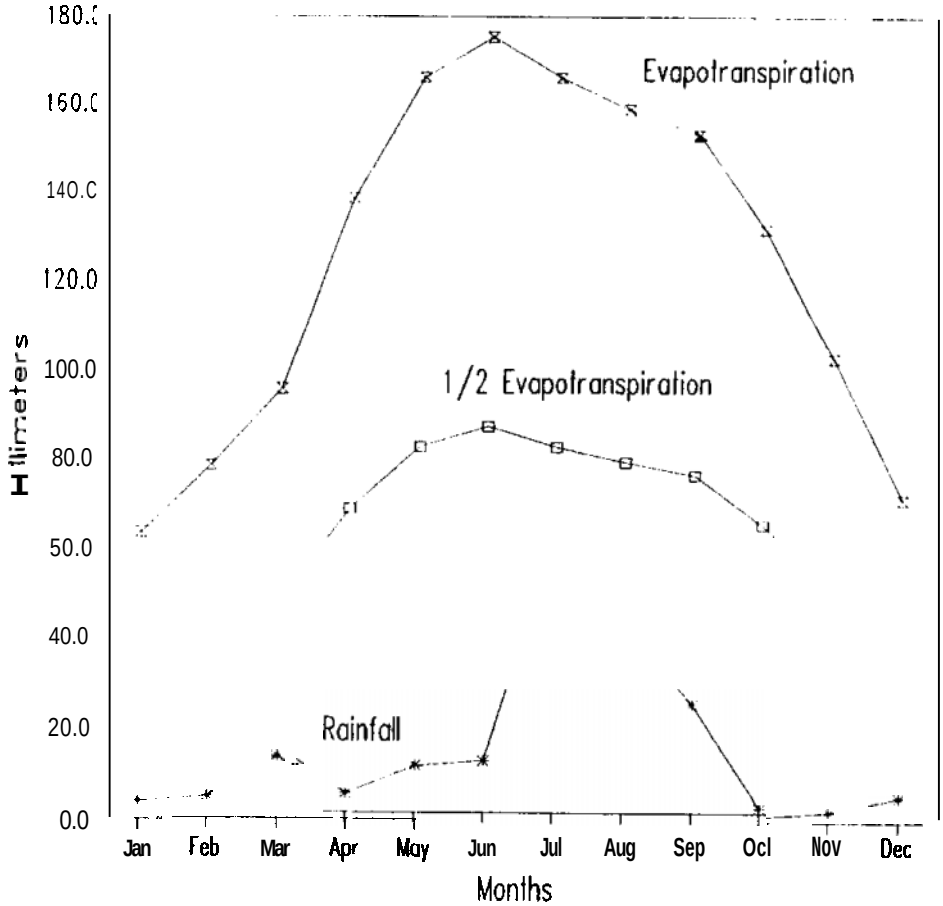
Months	Mean temperatures "C			Evapo-transpiration	1/2 Evapo-transpiration	Rainfall
	Max.	Min.	Mean	mm	mm	mm
January	21.4	5.0	13.2	63.4	31.7	4
February	25.1	7.6	16.4	78.7	39.4	5
March	26.7	13.2	20.0	96.0	48.0	14
April	37.9	19.6	28.8	138.2	69.1	4
May	43.0	26.2	34.6	166.1	83.1	10
June	43.4	29.6	36.5	175.2	87.6	11
July	40.2	28.9	34.6	166.1	83.1	59
August	38.5	27.7	33.1	158.9	79.5	41
September	38.3	25.5	31.9	153.1	76.6	23
October	36.5	18.3	27.4	131.5	65.8	1
November	30.5	12.2	21.4	102.7	51.4	2
December	23.9	5.9	14.9	71.5	35.8	5
Annual	33.8	18.3	26.1	1501.4	750.7	179

N.B. - Temperature data available for the nearest station (Fortabbas) based on 24 years data (1947-1971)

Rainfall data available for the nearest station (Chishtian) based on 20 years data (1951-1970)

* Refer Climatic Diagram (Figure 1), this corresponds with the number of days where 1/2 evapotranspiration exceeds the rainfall

Figure 1. **Climatic diagram (Fortabbas and Chishtian stations).**



Length of growing period (agricultural crops) where 1/2 evapotranspiration exceeds the rainfall:

Summer days	**0**
Winter days	**0**

1.6 Physiography and soils

The survey area comprises part of the Subrecent flood plains extending along the rivers above their active and recent flood plains in the north, which merges gradually into the sand plains of the Cholistan Desert in the south. Different physiographic units identified in the survey area are:

Level plains
Basins
Levees
Sand bars

1.6.1 Level plains

This physiographic unit is constituted by the level parts of the Subrecent flood plains. At slightly concave positions, Miani soil series occurs. A little higher to it are located Sultanpur. Bagh and then Harunabad soil series. Jhakkar soil series occupies slightly raised parts (levees) along the old abandoned channels/depressions. Typical cross sections and characteristic of these soils are shown on the soil maps of Azim 20-L, 43-L and 111-L.

1.6.2 Basins

This physiographic unit refers to the lowest parts in the landscape. Pacca and Matli soil series share this unit. The former occupying the lowest, whereas the latter slightly higher positions. Basin margins are occupied by Adilpur soil series. The Satghara soil series has been formed in the lowest parts of the basins where water stagnates seasonally. Typical cross sections and characteristic of these soil series can be seen on the soil maps of Azim 63-L and Fordwah 14-R.

1.6.3 Levees

This physiographic unit refers to low ridges parallel to a river channel course. In the survey area, levees are mainly coarse loamy in nature and locally sandy. Mainly Rasulpur and Jhang soil series share this unit. A major part of these levees has been levelled and brought under cultivation. The Rasulpur soil series occupies the lower parts whereas Jhang the upper parts of the levees. Typical cross sections and characteristics of these soils can be seen on the soil maps of Fordwah 46-R, 62-R and 130-R.

1.6.4 Sand bars

This physiographic unit is formed by deposition *of* the sandy material on the inner side of a meandering river. In the survey area, the Sodhra soil series and its phases occupy this landform. Its position and characteristics can be seen on the soil map of Azim 20-L.

2. THE SOILS

2.1 General nature

The soils of the survey area are developed in mixed calcareous river alluvium deposited during the Subrecent period. Texturally, they range from sand to silty clay and are level to nearly level except for a few stabilized low sand dunes which occupy only a little percentage in the command areas. Physically, the soils have good tilth except for a small area, which is clayey (Pacca soils) and needs mechanical cultivation.

The survey area falls adjacent to the Cholistan Desert. which has visibly affected the soils of the area. The soils, especially Rasulpur, Harunabad and Jhang series, have a sufficient admixture of the Cholistan sandy material. The silty and clayey soils (Sultanpur, Bagh, Pacca soil series, etc.) have a loamy surface due to mixing of this material transported by wind and water.

Genetically, the soils have been formed in the Subrecent alluvium period and have a structural carnbic B horizon that enhances their natural fertility, porosity, and water and nutrients holding capacities and easiness for root penetration. The soils of the area can be divided into five main textural groups as under. The extent and percentage of the individual soil series is shown in Table 2.

(a) Coarse textured soils comprise the Jhang and Sodhra soil series and occupy about 17.7 percent of the survey area. These are non-saline and non-sodic (pH 8.0-8.4) except for a small area of Sodhra series, affected by salinity/sodicity (pH 8.5 - 9.0) accompanied by high watertable (90-150 cm).

(b) Moderatelv coarse textured soils (Rasulpur soil series) covering about 41.8 percent of the survey area are non-saline, non-sodic (pH 8.0-8.4) with a small proportion deteriorated by brackish tubewell water with pH ranging from 8.5 to 8.8. Locally, these soils have a textural break in the profile ranging from coarse to medium textures at moderate depth.

(c) Medium textured soils (Bagh, Gandhra, Harunabad, Jhakkar, Nabipur and Sultanpur soil series) constitute 28.8 percent of the survey area and are mainly non-saline, non-sodic (pH 8.0 -8.4), except the Gandhra and Jhakkar soil series which are genetically saline-sodic (pH 8.5 - 9.6) but with good porosity and are easily reclaimable. Occasionally, these soils have a buried profile, usually with the same textural group.

Table 2. Extent (acres) and percentage of soil series by distributary and watercourse in Chishtian and Hasilpur tehsils.

Sr. No.	Soil Series	Distributary/Watercourse								
		Azim Distributary				Fordwah Distributary				Total
		20610-L	43260-L	63620-L	111770-L	14320-R	46725-R	62085-R	130100-R	
1	Adilpur			9.19 (0.30)	66.97 12.221					76.16 12.521
2	Bagh					17.90 10.591		8.65 (0.29)		26.55 (0.88)
3	Gandhra				6.14 10.201					6.14 10.201
4	Harunabad			24.31 10.911		142.14 (4.71)	38.56 11.281	91.12 (3.02)	29.89 (0.99)	526.02 110.811
5	Jhakkar	24.01 (0.80)	11.55 (0.38)		59.59 (1.97)					95.15 13.151
6	Jhang			3.02 (0.10)		11.60 (0.38)	47.81 (1.58)	76.65 12.611	312.46 (10.35)	453.54 115.021
7	Matli					8.19 10.271				9.19 (0.27)
8	Miani		17.53 10.591	60.26 12.011						77.79 12.591
9	Nabipur				90.27 12.061					90.27 (2.66)
10	Pacca			21.55 (0.81)						24.55 (0.81)
11	Rasulpur	57.42 11.901	8.90 (0.29)	155.73 15.15)		314.04 110.421	307.99 110.211	142.75 14.731	274.96 19.111	1201.79 (41.81)
12	Satghara	33.99 11.131								33.99 (1.13)
13	Sodhra	77.64 12.571			2.73 10.091					90.37 12.661
14	*Sultanpur*	113.45 (3.76)	126.01 14.171	13.88 (0.46)	81.02 12.701					334.36 11 1.091
15	Miscellaneous (dune land, graveyard, kiln, urban land)	35.11 11.161	10.49 (0.35)	13.47 10.451		3.01 (0.10)	20.09 10.561	14.39 10.471	36.17 (1.21)	132.70 14.401
	Total	341.62 (11.32)	174.47 15.781	3104.41 (10.09)	296.72 19.831	496.87 (16.47)	414.44 (13.73)	335.55 (111.121	653.48 (21.66)	017.56 100.001

* Figures in parenthesis refer to percent of the survey area

(d) Moderatelv fine textured soils (Adilpur and Miani soil series) are of minor extent, 5.1 percent of the survey area. Out of these, the Adilpur soil series is saline-sodic with pH ranging from 8.5 to 9.0, but with good porosity that plays a positive role for reclamation.

(e) Fine textured soils (Matli, Pacca and Satghara soil series) are of very small extent in the area (2.2 percent). Out of these, the *Matli* and *Pacca* soil series are non-saline, non-sodic (pH 8.0 - 8.4) whereas Satghara being severely saline-sodic (pH 8.8 - 10.0) and dense is uneconomic to reclaim.

The soils of the survey are, in general, brown to dark brown and dark greyish brown and moderately calcareous. The soils (mostly sandy) near the canal or elsewhere lying below the canal level, are mostly imperfectly drained (watertable at 90-150cm), locally accompanied by surface salinity.

The rest, 4.4 percent is mapped as miscellaneous land types covering stabilized low sand dunes with hummocky topography constituting urban land, lakes, graveyard and kiln.

2.2 Soil mapping units

2.2.1 Introduction

The soils in the survey area have been characterized, classified and identified as **soil** series/variants and their soil types/phases. Mapping was done at the soil phase level.

Soil series: **A** soil series is a group of soils having the same sequence and arrangement of horizons/layers with similar thickness, colour, structure, soil reaction and consistence and developed from a particular parent material. Series are given geographic names selected from the localities where they were first identified in Pakistan.

Soil variant: **A** soil variant is a taxonomic **soil** unit closely related to another taxonomic unit, a soil series, but departing from it in at least one differentiating characteristic at the series level from which it derives its name as modified by the principal distinguishing feature. Variants are in fact separate soil series but of too small an extent to justify establishment as a new series. The Rasulpur saline-sodic variant is an example.

Soil type: Within a soil series, there may be one or more soil types, depending upon textural variations of the surface horizon. Bagh loam, for example, is a soil type. The types within a series have substantially similar properties throughout the profile.

Soil ohase: The soil phase is a subdivision of a soil type differing from the type in some feature potentially significant to use and management. Some of the features used for differentiating between phases within a type are slope, soil depth, substratum, degree of wetness, reaction of the surface soil and degree of erosion. Rasulpur fine sandy loam over moderately fine at 60-90 cm is an example.

In total sixty five (65) soil mapping units at the soil phase level have been identified and mapped in all of the eight watercourse command areas. Table 3 shows the list of these mapping units with their corresponding mapping symbols and distribution (acreage and percentage) in each of the command areas. The mapping symbols have been framed using standard abbreviations, the first two letters denoting the soil series followed by the digits "1,2,4,6,7 and 10" which correspond to the soil textural class of the surface soil; sand, loamy sand, fine sandy loam/sandy loam, loam, silt loam and silty clay loam, respectively. Letters "b, a and av" indicate, where appropriate, barren, saline-sodic surface and saline-sodic variant. The digits "3" in the denominator represent the soil depth, moderately deep (60-90 cm). "W1 and W2" indicate the depth to the groundwater table at 90-150 cm and 45 - 90 cm, respectively. The letters "c, m and mf" in the denominator indicate the textural group (coarse, medium and moderately fine) of the substratum wherever differing from the soil series criteria. The letter "x" at the end of the mapping symbol indicates the inseparable complex of the two components even at the detailed soil survey level.

The soil mapping units are located on the accompanying soil maps of the eight watercourse command areas at a scale of 1:10,000 described below, following a brief introduction to the relating soil series which have been arranged alphabetically. The watercourse nos. used in the following text and the soil maps are adopted from IIMI where these are conventionally used as 20-L, 43-L, 63-L, 111-L, 14-R, 46-R, 62-R and 130-R for 20610-L 43260-L, 63620-L, 111770-L, 14320-R, 46725-R, 62050-R and 130100-R, respectively. Emphasis is laid on agricultural potential and management of each unit with a brief mention of its limitations and hazards. Specific improvements possible are given on the basis of field experience in the survey area and in similar areas elsewhere.

Table 3. Extent (acres) and percentage of soil mapping units by distributary/watercourse in Chishtian and Hasilpur tehsils.

Mapping symbols	Soil series & phases	Distributary/Watercourse							
		Arin Distributary				Fordwal Distributary			
		20610-L	43260-	63620-L	111170.	14320-R	46725-L	62085-R	130100-
	Adilpur series								
Ad6	Adilpur loam			9.19 13.021'	8.06 12.631				
Ad6 Jk6X(b)	Adilpur loam - Jhakkar loam complex, barren				56.91 (19.20)				
	Bagh series								
Bg6	Bagh loam							8.65 (2.58)	
Bg5/3CW1	Bagh loam over coarse at 60-90 cm, watertable at 90-150cm					11.59 (2.33)			
Bg4/W1	Bagh fine sandy loam, watertable at 90-150cm					8.31 (1.27)			
	Gandhra series								
Gd6	Gandhra loam				6.14 12.001				
	Harunabad series								
Hr6	Harunabad loam			24.31 17.991			15.95 (3.83)	70.29 120.951	
Hr6p	Harunabad loam with sodic crust							20.83 (6.21)	29.89 14.571
Hr6/W1	Harunabad loam, water table at 90-150 cm					10.86 12.191	22.71 5.48		
Hr4p	Harunabad fine sandy loam with sodic crust					25.35 15.101			
Hr4/W1	Harunabad fine sandy loam, watertable at 90-150cm					105.93 121.321			

' Figures in parenthesis refer to percent of the respective watercourse command area

Table 3 (continued).

Mapping symbols	Soil series & phases	Distributary/Watercourse							
			Azim Distributary			Fordwah Distributary			
		019O2-	43260-L	63620-L	111770-L	14320-R	46725-R	62085-R	130100-R
	Jhakkar series								
Jk7	Jhakkar silt loam		11.55 (6.62)	-	-		-		
Jk7/W1	Jhakkar silt loam, water table at 90-150cm	15 37 (4.50)	-	-	-		-		-
Jk6	Jhakkar loam		-	-	59.59 (22.72)		-		-
Jk4/W1	Jhakker fine sandy loam, watertable at 90-150cm	8.64 (2.53)	-	-	-		-		-
	Jhang series								
Jg4p	Jhang fine sandy loam with sodic crust		-	-	-		-		97.10 (14.86)
Jg2	Jhang loamy fine sand		-	-	-		-	68.97 (20.56)	-
Jg2-DLX	Jhang loamy sand - dune land complex		-	3.02 (0.99)	-	11.60 (2.33)	47.81 (11.49)	7.10 (2.12)	72.33 (11.07)
Jg2p	Jhang loamy fine sand with sodic crust		-	-	-		-		89.59 (13.71)
Jg2(av)	Jhang loamy fine sand, sodic variant		-	-	-		-		4.24 (0.65)
Jg2(avl-DLX	Jhang loamy fine sand, sodic variant - duneland complex							2.58 (0.76)	49.20 (7.53)
	Matli series								
Mt4	Matli fine sandy loam		-	-	-	S.07 (1.02)	-		-
Mt4p/W1	Matli fine sandy loam with sodic crust, water table at 90-150cm		-	-	-	3.11 (0.63)	-		-
	Miani series								
Mi10	Miani silty clay loam		-	5.24 (1.72)	-		-	-	-
Mi10/3mc	Miani silty clay loam over moderately coarse at 60-90cm		-	13.03 (4.28)	-		-	-	-

Tabla 3 (continued)

Mapping symbols	Soil series & phases	Distributary/Watercourse							
			Azim D	butary			ordwah I	ributary	
		20610-L	13260-L	13620-L	11770-L	14320-R	6725-R	32085-R	130100-R
Mi7	Miani silt loam		17.53 (10.05)			-			
Mi6	Miani loam			41.99 113.791		-			
	Nabipur series								
Nb6/3c	Nabipur loam over coarse at 60-90cm				35.93 111.711	-			
Nb6p	Nabipur loam with sodic crust				44.34 (14.45)	-			
	Pacca series								
Pc10	Pacca silty clay loam			24.55 18.081		-			
	Rasulpur series								
Rs6	Rasulpur loam		5.32 13.051			-		40.58 112.101	
Rs6/3m	Rasulpur loam over medium at 60-90cm		3.58 12.051			-			
Rs6p	Rasulpur loam with sodic crust					-			22.89 (3.50)
Rs6/W1	Rasulpur loam, watertable at 90-150cm					-	**29.31** 17.08)		
Rs6/3m W1	Rasulpur loam over medium at 60-90cm, watertable at 90-150cm	15.21 14.751				-			
Rs4	Rasulpur fine sandy loam	23.40 16.851		88.15 128.981		-	119.08 128.741	90.78 127.051	
Rs4/3m	Rasulpur fine sandy loam over medium at 60-90 cm					-	5.25 (1.51)		
Rs4/3mf	Rasulpur fine sandy loam over moderately fine at 60-90cm			47.39 115.571		-			
Rs4p	Rasulpur fine sandy loam with sodic crust					-			115.38 (17.66)

Table 3 (continued).

Mapping symbols	Soil series & phases	Distributary/Watercourse							
		Azim Distributary				Fordwah Distributary			
		20610-L	43260-L	63620-L	111770-L	14320-R	46725-R	82085-R	130100-R
Rs4(av)	Rasulpur fine sandy loam sodic variant	-	-	**20.19 (6.63)**	-			11.39 13.391	46.08 (7.05)
Rs4(av)-DLX	Rasulpur fine sandy loam sodic variant - dune land complex	-	-		-	7.84 **(1.58)**		-	27.61 14.231
Rs4/W1	Rasulpur fine sandy loam, watertable at 90-150cm	17.81 (5.21)	-		-	138.14 127.801	34.97 (8.44)		
Rs4/3cW1	Rasulpur fine sandy loam over coarse at 60-90 cm watertable at 90-15-cm		-		-	29.82 16.001		-	
Rs4p/W1	Rasulpur fine sandy loam with sodic crust, watertable at 90-150cm	-	-		-	41.61 **(8.37)**		-	
Rs4a/W1	Rasulpur fine sandy loam with sodic surface, watertable at 90-150cm	-	-		-	***29.20*** **(5.88)**		-	
Rs2	Rasulpur loamy fine sand	-	-		-		118.40 (28.58)	-	
Rs2-DLX	Rasulpur loamy fine sand-dune land complex	-	-		-	34.55 **(6.95)**			
Rs2p	Rasulpur loamy fine sand with sodic crust	-	-		-			-	18.67 12.551
Rs2(av)	Rasulpur loamy fine sand, sodic variant	-	-		-			-	19.88 (3.04)
Rs2(av)b	Rasulpur loamy fine sand, sodic variant, barren	-	-		-			-	26.45 **(4.05)**
Rs2/W1	Rasulpur loamy fine sand, watertable at 90-150cm	-	-		-	32.88 16.621		-	
	Satghara series								
St 7	Satghara silt loam	33.99 19.951			-			-	

Table 3 (continued).

Mapping symbol.	Soil series & phases	Distributary/Watercourse							
		Azim Distributary				Fordwah Distributary			
		20610-L	43260-L	63620-L	11770-L	14320-R	46725-R	62085-R	130100-R
	Sultanpur series								
su7	Sultanpur silt loam	83.21 (24.36)	39.46 (22.621			-	-	-	-
Su7/3c	Sultanpur silt loam over coarse at 60-90cm		4.89 (2.80)			-	-	-	-
Su7/3cW2	Sultanpur silt loam over coarse at 60-90cm, watertable at 45-90cm	6.70 (1.67)				-	-	-	-
Su6	Sultanpur loam	13.69 (4.01)	81.66 146.801	13.89 (4.56)	34.05 (11.10)	-	-	-	-
Su6/3c	Sultanpur loam over coarse at 60-90cm				3.71 1.21	-	-	-	-
Su6p	Sultanpur loam with sodic crust				43.26 114.091	-	-	-	-
Su6/W2	Sultanpur loam, watertable at 45-90cm	7.58 12.211				-	-	-	-
Su1	Sultanpur sandy overwash	3.29 (0.96)				-	-	-	-
	Sodhra series								
Sd6	Sodhra loam	3.89 (1.14)			2.: (0.89)	-	-	-	-
Sd6/W2	Sodhra loam, watertable at 45-90cm	3.52 11.031				-	-	-	-
Sd4	Sodhra fine sandy loam	13.64 13.991				-	-	-	-
Sd4(av)/W1	Sodhra fine sandy loam, sodic variant, watertable at 90-150cm	26.48 (7.75)				-	-	-	-
Sd2/W1	Sodhra loamy fine sand, watertable at 90-150cm	30.11 (8.81)				-	-	-	-

Table 3 (complete).

Mapping symbols	Soil series & phases	Distributary/Watercourse							
		Azim Distributary				Ferdwah Distributary			
		20610-L	43260-L	63620-L	111770-L	14320-R	46725-R	62085-R	130100-R
	Miscellaneous areas								
DL	Dune land			13.47 14.421					9.88 11.511
UL	Urban land	4.53 (1.33)	4.43 (2.54)			3.01 10.611	16.61 (4.01)	14.38 14.291	26.29 14.021
	Lake	30.58 18.951							
	Kiln		6.05 13.471						
	Graveyard						3.47 (0 841		
	Totals	341.62	174.47	304.41	296.72	496.87	414.44	335.55	653.48

2.2.2 Description *of* soil mapping units (soil phases)

Adilpur Series

The Adilpur series consists of brown/dark brown developed to moderate depth, moderately well drained, calcareous, strongly saline-sodic, dense, moderately fine textured (silty clay loams/heavy silt loams) soils formed in mixed river alluvium deposited in the Subrecent period. It has a structural cambic B horizon. Its substratum comprises laminated layers *of* silt loam and silty clay loam.

The series occur in an arid .subtropical continental climate and finds its position on nearly level basin margins in Subrecent flood plains.

1. Adilpur loam (Ad 61

This unit covers 8.06 acres or 2.63 percent ot the command area of Watercourse 111-L and 9.19 acres or 3.02 percent of 63-L of Azim Distributary. The soils are thinly covered by loamy rnaterial formed by an admixture of Cholistan sands and silty river alluvium on the surface.

The area is being used for cotton and wheat, mostly under canal irrigation, but crops are poor due to moderate salinity and sodicity. The irrigation with tubewell water, which is usually *of* bad quality, is adding to the salinity-sodicity problem.

To reclaim these soils, a good quality irrigation water is needed on a priority basis with the recommendations for adding gypsum, sulphuric acid, organic matter, etc. After reclaiming the surface (upto 15 cm), the area must remain under intensive cultivation with rotation of jantar and berseem for 2-3 years.

2. Adilpur loam-Jhakkar loam complex, ((barren (Ad6-JK6)X(b))

This unit falls in Azim III-L command area and occurs as inseparable soils on very gently dissected parts of Subrecent level plain covering 58.91 acres or 19.20 percent of the command area. Both of the soil components arc nearly level, beariny patchy desnio-grass and a fluffy salt layer on the surface. Texturally, Jhakkar is silt loams/very fine sandy loams and Adilpur is silty clay loams/heavy silt loams. Both are strongly saline-sodic, developed upto moderate depth and have generally loams, but occasionally a silt loam surface. A reclamation package includes land levelling, flushing the excessive soluble salts with heavy irrigation, followed by growing of jantar and berseem for 3-5 years.

About 14.3 oercent of this unit has been brought under the plough after deep truncation, leaving behind only 25-50 cm mantle of loamy material over sand. Cotton and wheat are being grown with poor yields.

Bagh Series

This soil series consists of dark greyish brown to light olive brown with common distinct/prominent greyish brown *to* light olive brown mottles in the subsoil, well drained, calcareous, medium textured (silt loams/very fine sandy loams) soils formed in mixed river alluvium deposited during the Subrecent period. It has a structural cambic B horizon developed to moderate depths. Generally, the substratum comprises layers of various textural groups ranging from silt loam to fine sand.

The series occurs in arid subtropical continental climates and occupies level to nearly level position in Subrecent level plains.

3. Baah loam (Bg 6)

This unit covers 8.65 acres or 2.58 percent of Fordwah 62-R command area. The soils have very good tilth with a thin loamy cover. This is very good agricultural land, highly suited to a wide variety of climatically suited crops and fruit orchards.

Inclusion of legumes in crop rotation, application of manure and mixing of stubbles and crop residues will help to maintain the organic matter contents and preserve the surface soil structure, and increasing its water and nutrients holding capacity. Intensive agriculture could be practiced profitably on these soils if additional irrigation water is made available. Remarkable increases in crop yields could be achieved by adopting modern management practices.

4. Baah loam over coarse at 60-90 cm, water-table at 90-150 cm (Bg6/3cw1)

This unit covers 11.59 acres or 2.33 percent area *of* Fordwah 14-R command area. The soils are level, moderately deep over sands and imperfectly drained but with good tilth. The soils are predominantly used for growing cotton, wheat and sugarcane with good yields. Locally, rice is also grown.

High watertables and the presence of sands at moderate depth are the two main hindrances for raising deep rooted crops, especially fruit orchards on these soils. Drainage can be improved by improving regional drainage systems (vertical or lateral) coupled with canal lining in their sandy portions. Growing of high delta crops like rice and sugarcane should be avoided.

After improving the drainage, all of the ecologically suited crops can be grown successfully. Adding organic matter, in any form, will enhance its water and nutrient holding capacity. Modern management practices can achieve desired results.

5. Baqh fine sandy loam. water table at 90-150 cm (Bg4/W1)

This unit covers 6.31 acres or 1.27 percent area of the Fordwah 14-R command area. The soils are deep, imperfectly drained, but with good tilth.

The drainage limitation can be overcome by adopting the recommendations and improvement measures mentioned in Unit No.4. However, its production potential is high and suitability range of crops is quite wide compared to Unit No.4.

Gandhra Series

The Gandhra series consists of brown/dark brown, well drained, calcareous, moderately saline-sodic, porous medium textured (loams/heavy sandy loams) soils formed in the mixed river alluvium deposited in the Subrecent period. It has a structural cambic B horizon, developed to moderate depth. The substratum comprises layers of various textural groups ranging from very fine sandy loam to loamy sand.

The series occurs in an arid subtropical continental climate and occupies nearly level areas in the Subrecent river plains.

6. Gandhra loam (Gd6)

This unit covers 6.14 acres or 2.00 percent of WC Azim III-L command area. The soils have a moderate salinity-sodicity problem with good tilth.

Moderate crops of cotton and wheat are grown with canal and tubewell irrigation. Tubewell water of poor quality is aggravating the salinity/sodicity problems.

To reclaim these soils, an application of gypsum with a few heavy irrigations of good quality water is needed, followed by growing of 'jantar' and 'berseem' or high delta crops like rice. After reclamation, intensive cultivation of a wide variety of crops must be continued. Use of organic manure, single super phosphate and ammonium sulphate should be preferred on these soils.

Harunabad Series

The Harunabad soil series consists of brown/dark brown to dark yellowish brown, well drained, medium textured (loams and heavy sandy loams) soils formed in Subrecent mixed river alluvium. It has a structural cambic B horizon, developed to moderate depth. Its substratum usually grades into coarse textured (light sandy loams to loamy fine sands) material.

The series occurs in an arid subtropical continental climate and occupies level to nearly level positions in the Subrecent river plains.

7. Harunabad loam (Hr6)

This unit occurs in the following three watercourse command areas.

Watercourse No.	Acreage	Percentage
Azim 63-L	24.31	7.99
Fordwah 46-R	15.85	3.83
Fordwah 62-R	70.29	20.95

The soils with a loam surface having very good tilth are flawless. At present, crops of cotton, wheat, sugarcane and fodders are being raised under canal and tubewell irrigation with good returns.

The soils are highly suited to a wide variety of farm crops and fruit orchards. Addition of iarm yard manure after every 2-3 years will improve its surface soil structure, as well as increase its water and nutrient holding capacity. Intensive agriculture can be practised on these soils if yea[-round irrigation water is available. Remarkable increases in the yield of crops can be achieved by adopting modern management practices.

8. Harunabad loam with sodic crust (Hr6p)

This unit covers 20.83 acres or 6.21 percent and 29.89 acres or 4.57 percent of Fordwah 62-R and Fordwah 130-R command areas. respectively.

The soils are similar to that of Unit No.7 except for the deteriorated surface soil to a depth of only a few millimeters caused by poor quality tubewell water.

Addition of organic matter, or a small quantity of gypsum. will ameliorate this condition, provided the farmers try to avoid further use of bad quality tubewell water for irrigation.

9. Harunabad loam, watertable at 90-150 cm(Hr6/W1)

This unit covers 10.86 acres or 2.19 percent and 22.71 acres or 5.48 percent of Fordwah 14-R and Fordwah 46-R command areas, respectively.

The soils are similar to that of Unit No.7 except being imperfectly drained but having good tilth.

At present, these soils are being used to produce good crops of cotton, wheat, sugarcane and some vegetables. The impeded drainage problem can be reversed with the following package:

Provision of regional drainage system (open drains or tubewells);

Restriction on growing high delta crops (rice, sugarcane);

Advice to the farmers not to overirrigate the soils;

Brick lining of the sandy portions of the canals; and

Growing of drought resistant crops (taramira, groundnut, grams, oilseed, etc.).

Harunabad fine sandy loam, with sodic crust (Hr4pP)

This unit covers 25.35 acres or 5.10 percent of Fordwah 14-R command area. The soils are similar to that of Unit No.8 except for a fine sandy loam surface. Remedial and improvement measures are also the same as for Unit No.8.

11. Harunabad fine sandy loam, watertable at 90-150cm(Hr4/W1)

This unit covers 105.93 acres or 21.32 percent of the Fordwah 14 R command area. The soils and improvement package are similar to those of Unit No.9 except its surface is fine sandy loam.

Jhakkar Series

The Jhakkar series consists of brown/dark brown to dark yellowish brown, calcareous, porous, saline-sodic medium textured (silt loams/very fine sandy loams) soils formed in mixed Subrecent river alluvium. It has a structural cambic B horizon developed to moderate depth. Locally, it has a buried profile with comparatively heavy textures (heavy silt loams/silty clay loams). The substratum comprises layers of varied textural classes ranging from fine sands to silty clay loams.

The series occurs in an arid subtropical continental climate and occupies slightly higher positions in Subrecent level plains.

12. Jhakkar silt loam (JK 7)

This unit covers 11.55 acres or 6.62 percent of Azini-43-L command area which is being sown to cotton, wheat and fodder. Due to its moderate salinity-sodicity hazard, the crop condition is not good. At places, these soils are irrigated with bad quality tubewell water which is adding to the problem.

To reclaim the soils, the lollowlrig package of remedial measures is recommended:

Provision of good quality irrigation water;

Application of gypsum/sulphuric acid in required doses;

Addition of organic matter;

Growing of jantar during reclamation;

Rotation of high delta crops (rice, sugarcane. berseem) with jantar; and

After reclamation, Intensive cropping should be done if sweet water is available, otherwise wheat-rice is a good rotation.

13. Jhakkar silt loam watertable at 90-150 cm (JK7/W1)

This unit covers 15.37 acres or 4.50 percent of Azim 20-L command area. It is similar in characteristics to Unit No.12, except for drainage, which is imperfect. Before the reclamation process is initiated, improvement of a regional drainage system is a must. Presence of a locked lake in this command area is adversely affecting the soils and needs some physical/biological treatment.

14. Jhakkar loam (JK 61

This unit covers 59.59 acres or 22.71 percent of Azim III-L command area. In soil characteristics and reclamation process, it is similar to Unit No.12. The soil deviates from Unit No.12 in surface texture and is comparatively more conducive for reclamation due to its better infiltration.

15. Jhakkar fine sandv loam, watertable at 90-150 cm (JK 4/W1)

This unit falls in Azim 20-L command area and covers 8.64 acres or 2.53 percent of its total extent. It is similar to Unit No.12 in soil characteristics and reclamation package. Additionally, the soil is imperfectly drained and needs an improved regional drainage system, especially an outlet to the locked lake is required. It also differs from Unit No.12 in surface texture which is fine sandy loam, reclamation of which is easier being more permeable.

Jhang Series

The Jhang series consists of brown/dark brown to dark yellowish brown, calcareous, excessively drained, coarse textured (loamy fine sand to light fine saridy loams) soils formed in mixed river alluvium with an admixture of Cholistan sands deposited during the Subrecent period. It has a structural cambic B horizon developed to moderate depth. Its substratum comprises greyish brown loamy sands and sands. The series occurs in an arid subtropical continental climate and occupies nearly level to gently undulating sandy levees.

16. Jhana fine sandv loam. with sodic crust(Jg 4p)

This unit covers 97.10 acres or 14.86 percent of Fordwah 130-R command area. The original physiography has been changed through levelling and the soil is generally sown to cotton, wheat and millets. The soils, because of its sandy nature, has less water and nutrient holding

capacity, or natural fertility, and is excessively drained; hence, the crop condition is fair to poor. Due to the shortage of canal water, the area is irrigated by tubewells that are causing salinity and sodicity problem.

To realize the optimal crop production, the following set of measures is recommended:

Use tubewell water only by mixing it with canal water;

Apply split doses of fertilizers and irrigation water;

- Add organic matter (farmyard manure/city garbage);

Avoid high delta crops (rice, sugarcane, etc);

Emphasize on drought resistant crops (grams, taramira, groundnut, etc.);

- Apply a small dose of gypsum once a year: and

- Reduce the seepage of water by lining the irrigation network.

17. Jhana loamy fine sand (Jg 2)

This unit covers 68.97 acres or 20.56 percent of Fordwah 62-R command area. At present, it is nearly level and is sown to cotton, wheat and millet, but with poor crop stands. It is like Unit No.16 in soil characteristics and needs similar agricultural practices as recommended for Unit No.16. It differs in surface texture, which is lighter.

18. Jhana loamy fine sand-dune land complex (Jg2-DLX)

The acreage and percentage of this unit at different command areas is as mentioned below:

Water course No.	Acreaae	Percentaae
Azim 63-L	3.02	0.99
Fordwah 14-R	11.60	2.33
Fordwah 46-R	47.81	11.49
Fordwah 62-R	7.10	2.12
Fordwah 130-R	72.33	11.07

About **40** percent of this unit comprises Jhang soils occupying interdunal valleys, while the rest of the 60 percent is occupied by stabilized small sand dunes; main vegetation is sarkanda and khabbal grass with some jandi covering about 25-35 percent of the surface area. The unit provides poor grazing and fuelwood.

This area is not irrigable due to its sandy nature and undulating topography. Presently, it should be left as **it** is. Controlled grazing and cutting are the **key** solutions to save the adjoining cultivated land from surface burial with wind-blown **loose** sands.

19. Jhana loamv fine sand with sodic crust (Jg2p)

This unit covers 89.59 acres or 13.71 percent ***of*** Fordwah 130-R command area. It is nearly level and mostly under tubewell irrigation, producing poor crops of cotton, guawara, and wheat. For sustainable production, recommendations mentioned in Unit No. 16 may ***be*** followed.

20. Jhang loamy fine sand, sodic variant, (Jg2(av)

This unit is of minor extent with 4.24 acres or 0.65 percent at Fordwah 130-R command area. It is nearly level, excessively drained and saline-sodic.

A few extra heavy irrigations with small doses of gypsum will normalize its condition. For further improvement, follow the suggestions given in Unit No.16.

21. Jhana loamv fine sand, sodic variant-dune land complex (Jg2(av)-DLX)

This unit covers 2.58 acres or 0.76 percent and 49.20 acres or 7.53 percent of Fordwah 62-R and Fordwah 130-R command area, respectively. About **40** percent of this unit comprises Jhang loamy fine sand sodic variant and the remaining consists of stabilized, small sand dunes. **Its** vegetation consists of lani and sarkanda covering about 15-25 percent **of** the surface area. *It* provides poor grazing and fuel wood. This soil should be left in its natural condition and used as a game reserve.

Matli Series

The Matli series consists of brown/dark brown to dark yellowish brown, developed to moderate depth, moderately well drained, calcareous, fine textured (silty clays/heavy silty clay loams) soils formed

in mixed river alluvium deposited during the Subrecent period. It has a structural cambic B horizon developed to moderate depth. The substratum comprises layers of various textural groups ranging from loamy sands to silt loams.

The series occurs in an arid subtropical continental cliniate and occupies depressional areas in Subrecent flood plains.

22. Matli fine sandy loam (Mt4)

This unit is of minor extent with 5.07 acres or 1.02 percent in Fordwah 14-R command area. The surface soil is fine sandy loam having good tilth. Good crops of sugarcane, cotton and wheat are being harvested presently under traditional management..

All of the ecologically suited crops can be grown economically, except fruit orchards, to which the clayey nature of the soils may create a hindrance to root penetration.

23. Matli fine sandy loam with sodic crust, watertable at 90-150 cm (Mt4p/W1)

This unit covers 3.11 acres or 0.63 percent of Fordwah 14-R command area. It is similar to Unit No.22, except it has a thin sodic crust on the surface because of irrigation with bad quality tubewell water and is imperfectly drained due to high watertable. Both of the these hazards are adversely affecting the production of crops. The following remedial measures are recommended:

Improvement in regional drainage system;

Addition of organic matter;

Growing of some high delta crops (rice, sugarcane, etc); and

- Mixing of adequate quantities of canal water with tubewell water for irrigation/reclamation purposes.

Miani Series

The Miani series consists of brown/dark brown to dark greyish brown with few fine faint/distinct grey mottles, moderately well drained, calcareous, moderately fine textured (silty clay loams), formed in rnixed river alluvium deposited during the Subrecent period. It has a structural

cambic **B** horizon developed to moderate depth. The substratum comprises layers of various textural groups ranging from fine sands to silt loams.

The series occurs in an arid subtropical continental climate and occupies slightly concave areas in the Subrecent level plains.

24. Miani silty clay loam (Mi10)

This unit covers 5.24 acres or 1.72 percent of Azim 63-L command area and is at a slightly lower position than the surrounding area. Collection of runoff may accumulate on these soils during the rainy seasons. Its surface texture is clayey, causing difficulty in **seed** bed preparation. At present, good crops of cotton, wheat and sugarcane are being harvested. For its improvement, the following steps may be taken:

Addition of organic matter to improve its tilth/workability;

Avoid over irrigation;

- Preference to grow high delta crops (rice); and

Emphasize on mechanical cultivation.

25. Miani silty clay loam over moderately coarse at 60-90cm (Mi10/3mc)

This unit covers 13.03 acres or 4.28 percent of Azim 63-L command area. It is similar to Unit No. 24 and requires similar improvement measures. It differs from Unit 24 **by** having a moderately coarse substratum (sandy loams) at 60 to 90 cm which is better lor the internal drainage of the soils, however, it may not be well suited for orchards because of somewhat limited water and nutrient holding capacity of deeper layers.

26. Miani silt loam (Mi 7)

This unit covers 17.53 acres or 10.05 percent of Azim 43-L command area. It is similar to Unit No.24, except it has very good tilth due to medium textured (silt loam) surface soil.

27. Miani loam (Mi 6)

This unit covers **41.99** acres or **13.79** percent of Azim 63-L command area. It is similar to Unit No.26, rather a little better, having more permeable loam surface.

Nabiour Series

The Nabipur series consists of brown to dark brown, well drained, calcareous, medium textured (loams) soils formed in mixed river alluvium deposited during the Subrecent period. It has a structural cambic B horizon developed to moderate depth. The substratum comprises various textures ranging from sand to very fine sandy loams.

The series occurs in an arid subtropical continental climate and occupies level to nearly level positions in Subrecent level plains.

28. Nabipur loam over coarse at 60-90 cm(Nb 6/3c)

This unit covers **35.93** acres or **11.71** percent of Azim 111-L command area. The soils are level, moderately deep over sands/loamy sands, with good tilth. Good crops of cotton, wheat and a variety of fodders are being harvested under traditional management.

The main hazard is the moderate depth to sands at 60-90 cm, which is a hindrance for fruit orchards only. However, other ecologically suited crops can be grown economically. Modern management will enhance the yields if good quality irrigation water is available.

29. Nabiour loam with sodic crust (Nb 6p)

This unit occurs only at Azim 111-L and covers **44.34** acres or **14.45** percent of the command area. The soils have good tilth because of the loam surface and is producing good crops of cotton and wheat.

Formation of a sodic crust on the surface of the soils as a result of irrigation with bad quality tubewell water is a warning to its further deterioration. For its improvement, the following measures may be adopted:

Avoid tubewell water irrigation, or mix it with canal water to minimize its adverse affect, or apply heavy canal water irrigation once or twice to each crop grown on such soils;

Addition of organic matter; and

Preferably use single supper phosphate fertilizer.

Remarkable increase in yields could be achieved through modern management practices coupled with the abovementioned measures.

Pacca Series

The Pacca soil series consists of dark greyish brown to very dark greyish brown, moderately well drained, calcareous, fine textured (silty clays and heavy silty clay loams) soils formed in mixed river alluvium deposited during the Subrecent period. It has a structural cambic B horizon. Occasionally, it contains a buried profile with the same textural groups. The substratum consists of layers of various textures ranging from fine sands to very fine sandy loarns and silt loam to silty clay loam.

The series occurs in an arid subtropical continental climate and occupies nearly level broad basins in the Subrecent flood plains.

32. Pacca silty clay loams (Pc 101

This unit covers 24.55 acres or 8.06 percent in Azim 63-L command area. It occupies comparatively low lying areas where the collection of runoff may adversely affect the crops during the rainy seasons. The soils are partly under cotton with moderate to poor stands. The clayey nature of the soils create a hindrance to root, water and air penetration. Surface texture, which is moderately fine (silty clay loams/clay loarns), needs special handling at a proper moisture level. For its optimal use, the following practices may be adopted:

Mechanical cultivation at proper moisture level to avoid cloding;

Addition of organic matter to improve its tilth/workability;

Avoid over irrigation;

- Preferably use high delta crops (rice, sugarcane, berseem); and

Construct an outlet to dispose of runoff quickly.

Rasulour Series

The Rasulpur series consists of brown/dark brown to dark yellowish brown, somewhat excessively drained, calcareous, moderately coarse texture (sandy loams/fine sandy loams) soils formed in an admixture of river alluvium and Cholistan sands deposited during the Subrecent period. It has a structural cambic B horizon. Sometimes, the series is underlain by medium texture material (silty loams and loams) but often its substratum consists of single grain sands and loamy sands.

The series occurs in an arid subtropical continental climate and occupies nearly level to gently undulating levees in Subrecent flood plains.

31. Rasulpur loam (Rs 6)

This unit covers 5.32 acres or 3.05 percent and 40.58 acres or 12.10 percent of the command areas of Azim 43-L and Fordwah 62-R, respectively. The soils are nearly level and due to their sandy nature lack natural fertility. At present, these soils are grown to cotton, wheat, sugarcane and various fodders. For sustained crop production, the following measures should be taken:

Balanced split doses of fertilizers with addition of green manure/farmyard manure/city garbage;

Avoid over irrigation;

Reduction of parcelling size with precision levelling;

Construction of pacca watercourses; and

Avoid high delta crops.

These soils would respond well to modern management provided the abovementioned practices are practically demonstrated to the farmers.

32. Rasulour loam over medium at 60-90 cm (Rs6/3m)

This unit covers 3.58 acres or 2.05 percent of Azim 43-L command area. It is similar to Unit No. 31 except it has medium textured material (loams, silt loams, very fine sandy loams) at moderate depth from the surface. These layers enhance its water holding capacity.

33. Rasulpur loam with sodic crust (Rs6p)

This unit covers 22.89 acres or 3.50 percent of Fordwah 130-R command area. These soils are nearly level, producing good crops of cotton, wheat and sugarcane. The hazard of sodic crust formation that seems minor today may grow bigger if appropriate measures are not undertaken. This is mainly due to the application of brackish tubewell water. For its reclamation and sustained crop production, the following measures should be adopted:

- Tubewell and canal water should be mixed for irrigation purpose;

- Avoid high delta crops (rice, sugarcane);

  Emphasize on drought resistant crops (oilseeds, grams, groundnuts. lucerne) in rotation;

  Heavy irrigation with canal water to leach the salts before sowing of the crop;

  Addition of organic matter;

- Reduction *of* parcelling size and precision levelling;

- Construction of pacca watercourses; and

  Application of split doses of fertilizers and water.

34. Rasulpur loam, watertable at 90-150 cm(Rs6/w1)

This unit covers 29.31 acres *or* 7.08 percent of Fordwah **46-R** command area. It is similar to Unit No.31, but differs in being imperfectly drained, which needs an improved regional drainage system. For amelioration, the same improvement measures as in Unit No.31 should be adopted.

35. Rasulpur loam over medium at 60 to 90 cm, watertable at 90-150 cm (Rs6/3mw1)

This unit covers 16.21 acres or 4.75 percent *of* Azim **20-L** command area. These soils are moderately deep over medium textures (loams, silt loams) and are imperfectly drained. Only drainage needs improvement on a priority basis. Other characteristics are like Unit 32 and require a similar improvement package.

36. Rasulpur fine sandy loam (Rs4)

This unit occupies the acreage and percentage at different watercourses as mentioned below:

Water course No.	Acreaae	Percentaoe
Azim **20-L**	23.40	6.85
Azim 63-L	88.15	28.96
Fordwah 46-R	119.06	28.74
Fordwah 62-R	90.78	27.05

These soils are nearly level and producing good crops of cotton, wheat, sugarcane and fodders under irrigation. Due to this sandy nature, these soils lack in natural fertility, which should **be** enhanced **by** adding fertilizers. For sustained productivity, the following interventions are recommended:

- Application of fertilizers and water in split doses;
- Addition of organic matter;

Small and precisely levelled fields; and

Construction of pacca watercourses.

37. Rasulpur fine sandy loam over medium at 60-90 cm(Rs4/3m)

This unit covers 6.25 acres or 1.51 percent of Fordwah 46-R command area. It is almost like Unit No.36, except having layers of medium textures (loarns. silt loams) at moderate depth, which are more beneficial for increasing its water and nutrient holding capacity.

38. Rasulpur fine sandy loam over moderately fine at 60-90 cm (Rs4/3mf)

This unit covers 47.39 acres or 15.57 percent of Azim 63-L command area. It is similar to Unit No.36, except it has moderately fine texture **(silty** clay loams) at moderate depth from the surface. The presence of such layers may, or may not, create a hindrance for root, air and water penetration depending upon their denseness *or* porosity and ped formation.

39. Rasulpur fine sandy loam with sodic crust (Rs4p)

This unit covers 115.38 acres or 17.66 percent of Azim command area. It is similar to Unit No.33. For its improvement, the same recommendations must be followed. This soil differs only in surface texture, which is fine sandy loams in this case.

40. Rasulpur fine sandy loams, sodic variant (Rs4(av))

This unit covers the acreage and percentage as mentioned below against the relevant watercourse command areas:

Water course No.	Acreaae	Percentaae
Azim 63-L	20.19	6.63
Fordwah 62-R	11.39	3.39
Fordwah 130-R	46.08	7.05

These soils are nearly level, deep and a major part of them is under the plough, producing poor to moderate yields of cotton and wheat. The unploughed area is irrigable subject to land levelling.

Using tubewell irrigation alone for long periods of time has adversely affected these soils to a great depth and rendered them saline-sodic. To reclaim these soils, the following measures should be undertaken:

Application of calculated quantities of gypsum and leaching;

Addition of organic matter;

Sowing of high delta crops (rice, sugarcane) after jantar during the reclamation process;

Intensive cultivation with good quality irrigation water: and

Avoid the use of brackish tubewell water alone.

41. Rasulpur fine sandy loam, sodic variant-dune land comelex (Rs4(av)-DLX)

This unit covers 7.84 acres or 1.58 percent and 27.61 acres or 4.23 percent of Fordwah 14-R and Fordwah 130-R command areas,

respectively. It has an undulating topography and contains about 40 percent **of** Rasulpur fine sandy loam sodic variant in valley positions and the remaining about 60 percent are small stabilized sand dunes. The main vegetation comprises sarkanda and lani covering about 10-25 percent of the surface area. These soils provide poor grazing and material for cottage construction.

42. Rasulpur fine sandy loams, watertable at 90-150 cm(Rs4/w1)

The areal extent, with the percentage of these soils, is mentioned below:

Water course No.	Acreage	Percentaoe
Azim **20-L**	17.81	5.21
Fordwah 14-R	138.14	27.80
Fordwah 46-R	34.97	8.44

These soils resemble Unit No.36 and need same improvement measures as for Unit No.36, except imperfect drainage, which requires improvements in the regional drainage system.

43. Rasulaur fine sandv loam over coarse at 60-90 cm, watertable at 90-150 cm (Rs4/3cw1)

This unit covers 29.82 acres or 6.00 percent of Fordwah 14-R command area. These soils are nearly level, moderately deep over coarse material (sand and loamy sands) and are imperfectly drained. The sandy strata at moderate depth makes the soils excessively drained, therefore, improvement devices mentioned for Unit No.36, should be followed and deep rooted crops, including fruit orchards, rnay be avoided. The regional drainage system should also **be** improved to lower the watertable in the area.

44. Rasulpur fine sandv loams with sodic crust, watertable at 90-1*50* cm (Rs4p/w1)

This unit covers 41.1 acres or 8.37 percent *of* Fordwah 14-R command area. These soils are similar to Unit No.36 and require the same remedial measures. The drainage may **be** improved as mentioned for Unit No.43.

45. Rasulpur fine sandy loams with sodic surface, watertable at 90-150 cm (Rs4a/w1)

This unit covers 29.20 acres or 5.88 percent of Fordwah 14-R command area. These soils are deteriorated to a depth of 10-20 cm. For its improvement, the instructions mentioned for Unit No. 40 may be followed plus the use of solely brackish tubewell water for irrigation should be avoided. Drainage can be improved as mentioned already.

46. Rasulpur loamy fine sand (Rs2)

This unit covers 118.40 acres or 28.58 percent of Fordwah 46-R command area. It occupies a higher position in the landscape adjacent to the sand dunes. These soils are nearly level and presently producing moderate crops of cotton, wheat and sugarcane under irrigation. The very sandy surface is the main limitation towards harvesting good crops, for the improvement of which the following measures may be taken:

Addition of organic matter to improve the surface structure;

- Split doses of fertilizers and irrigation water;

Small and precisely levelled fields;

Pacca watercourses;

Keep the surface moist or leave the crop residues as such in the fields to avoid wind erosion;

- Shelter belts around the sand dunes; and

Avoid high delta crops.

47. Rasulpur loamy fine sand-dune land complex (Rs2-DLX)

This unit covers 34.55 acres or 6.95 percent of Fordwah 14-R command area. Its topography is hummocky and undulating which makes it unirrigable. This soil contains about 30 to 40 percent Rasulpur loamy fine sand in a valley position, while the remaining about 60 percent comprises small stabilized sand dunes covered mainly with sarkanda and khabbal as natural vegetation which covers about 10-25 percent of the surface area. It provides poor grazing, fuelwood and material for cottage construction. Devegetation of sand dunes may be checked to save the adjacent good soils from burial by wind blown sand.

48. Rasulpur loamv fine sand with sodic crust (Rs2p)

This unit covers 16.67 acres or 2.55 percent of Fordwah 130-R command area. These soils resemble in all respects those of Unit No.46, except these have developed a thin sodic crust due to brackish tubewell water irrigation. The surface crust problem can be rectified only by stopping tubewell irrigation and by adopting the same improvement measures as recommended for Unit No.46.

49. Rasulpur loamv fine sand, sodic variant (Rs2(av))

This unit covers 19.88 acres or 3.04 percent of Fordwah 130-R command area. These soils are nearly level, somewhat excessively drained with a highly permeable surface (loamy fine sands). Reclamation interventions include the following:

Provision of good quality irrigation water;

Application of judicious doses of gypsum;

Addition of organic matter; and

Avoid irrigation with brackish tubewell water alone.

50. Rasulpur loamv fine sand, sodic variant barren (Rs2(av)b)

This unit comprises 26.45 acres or 4.05 percent of Fordwah 130-R command area. This soil is similar to Unit No.49 and requires the same improvement interventions for reclamation. **As** the area is lying barren, therefore, some extra efforts for its levelling would be needed.

51. Rasulpur loamv fine sand. watertable at 90-150 cm (Rs2/w1)

This unit covers 32.88 acres or 6.62 percent of Fordwah 14-R command area. The soils are similar to Unit No.46 and require similar improvement measures for reclamation. These soils differ from those of Unit No.46 in being imperfectly drained for which improvement of the regional drainage system is a prerequisite.

Satohara Series

The Satghara series consists of brown/dark brown to dark greyish brown, saline-sodic. dense, calcareous, fine textured (silty clays to heavy silty clay loams) soils formed in the mixed river alluvium deposited during

the Subrecent period. It has a structural cambic B horizon developed to moderate depth. The substratum comprises layers of various textures ranging from very fine sandy loams to silt loams/silty clay loams.

The series occurs in an arid subtropical continental climate and occupies nearly level basins in the Subrecent flood plains.

52. Satqhara silt loam (St7)

This unit covers 33.99 acres or 9.95 percent of Azim 20-L command area. The soils are dense and severely saline-sodic; hence, their reclamation is quite problematic and requires costly investments. A major portion of these soils are lying barren without any natural vegetation. Locally, the soils are under reclamation through planting of Australian grass and adding transported sandy material on the surface to improve its workability and permeability. For reclamation, the following recommendations are suggested:

Application of gypsum/sulphuric acid (calculated quantity);

- Mixing of sand at the surface;

Addition of organic matter in the form of green manure (jantar/city garbage);

After surface reclamation, emphasize on high delta crops for 2-3 years using, preferably, single supper phosphate and ammonium sulphate fertilizers; and

- tingifor construction of fish ponds or colonization.

Sultanpur Series

The Sultanpur series consists of brown/dark brown to yellowish brown, calcareous, medium textured (silt loams/very fine sandy loams) soils, formed in mixed river alluvium deposited during the Subrecent period. This soil has a structural (cambic) B horizon developed to moderate depth. The substratum mostly comprises layers of various textures ranging from sands to silt loams/silty clay loams.

The series occurs in an arid subtropical continental climate and occupies Subrecent level plains.

53. Sultanpur silt loam (Su7)

This unit covers 83.21 acres or 24.36 percent and 39.46 acres or 22.62 percent of Azim 20-L and Azim 43-L command areas, respectively. The soils are level with good tilth. Very good crops of sugarcane, cotton and wheat are being harvested under normal management levels.

This soil provides very good agricultural land. All of the ecologically suited crops, including fruit orchards, can be grown economically. Intensive agriculture could **be** practised profitably, if additional good quality irrigation water is made available.

Remarkable increases in crop yields could be achieved by adopting modern management practices.

54. Sultanpur silt loam over coarse at 60-90 cm (Su7/3c)

This unit covers 4.89 acres or 2.80 percent of Azim 43-L command area. The soils are level, moderately deep over sand and good crops of cotton, fodders, sugarcane and wheat are being harvested under traditional management practices.

The soils are similar to those of Unit No.53 and same management practices are needed for sustained agriculture production. ***As*** the sands occur at moderate depth, therefore, growing of fruit orchards may be avoided.

55. Sultanpur silt loam over coarse at 60-90 cm, watertable at 60-

This unit covers 5.70 acres or 1.67 percent of Azim 20-L command area. The soils are level, moderately deep over sand, watertable at 60-90 cm and poorly drained. The soils are used for moderate crops of sugarcane. The area lies in the vicinity of a lake which is responsible for high water table conditions in the soils.

56. Sultanpur loam (Su6)

This unit occurs in the command area of the following four watercourses, with the relevant acreage and percentage:

Water course No.	Acreaae	Percentaae
Azim 20-L	13.69	4.01
Azim 43-L	81.66	46.80
Azim 63-L	13.88	4.56
Azim 111-L	34.05	11.10

The soils of this unit are similar in characteristics and agricultural potential as those of Unit No.53 and differ only in surface texture (loams) with very good tilth.

57. Sultanour loam over coarse at 60-90 cm(Su6/3c)

This unit covers 3.71 acres or 1.21 percent of Azim 111-L command area. These **soils** have the same agricultural potential as those of Unit *No.*54 *and similar* improvement measures should **be** adopted.

58. Sultanpur loam with sodic crust (Su6p)

This unit covers 43.26 acres or 14.09 percent of Azim 111-L command area. The soils have a few millimeter thick salt crust resulting from brackish tubewell water irrigation. Good crops of cotton and sugarcane are grown on these soils under traditional management.

The soils are well drained and can, therefore, be reclaimed easily with a few heavy irrigations of good quality water. Addition of organic matter with single super phosphate would speed up the reclamation process. For irrigation, tubewell water should be mixed with canal water.

59. Sultanour loam, watertable at 60-90cm(Su6/w2)

This unit covers 7.56 acres or 2.21 percent of Azim 20-L command area. The area is nearly level and very near to the lake. The soils are poorly drained with a poor stand of cotton and sugarcane crops.

The drainage of this unit is directly affected by the lake water. Investigations to improve the drainage system in the area both physically and biologically are recommended before any drainage program is initiated.

60. Sultanpur with sandy overwash (Su1)

This unit covers 3.29 acres or 0.96 percent *of* Azim 20-L command area. The sandy overwash of 30-40 cm thickness has been deposited as a result *of* breaches in Azim Distributary in the past.

Before the soil is brought under the plough, the upper sandy mantle should be removed to expose the original soils.

Sodhra Series

The Sodhra series consists of very deep, brown to greyish brown to olive grey, single grain, calcareous, excessively drained coarse textured (loamy sands and sands) **soils,** formed in the mixed river alluvium deposited as sand bars during the Subrecent periods. The substratum is also sandy.

The series occurs in an arid subtropical continental climate. A major part ***of*** the sand bar has been shaped as sand dunes by wind action and the resultant topography is hummocky. A small portion is nearly level and has medium textured to moderately coarse textured (loams and fine sandy loams) surface soils. These soils are ploughed *to* produce maize, wheat and mustards.

61. Sodhra loam (Sd6)

This unit covers 3.89 acres or **1.14** percent and 2.73 acres or 0.89 percent of Azim 20-L and Azim III-L command areas, respectively. The soils are nearly level, overlain by a loamy material, and used for moderate to poor crops of cotton and wheat. These soils are inheritedly very poor in natural fertility due to their sandy nature. These soils are used for a limited range of crops under special management practices. The following practices are suggested in order to harvest a good crop.

Addition *of* organic matter in any form;

Split doses of fertilizers and irrigation water; and

Sowing of shallow rooted crops.

62. Sodhra loam, watertable at 60-90 cm (Sd6/w2)

This unit covers *a* small portion, 3.52 acres, or 1.03 percent in Azim 20-L command area. The soil is nearly level and poorly drained. At present, it supports poor crops of cotton and sugarcane.

The poor drainage condition is due lo the adjacent lake. Prior to commissioning of any drainage system in the area, comprehensive investigations are recommended.

63. Sodhra fine sandv loam (Sd4)

This unit covers 13.64 acres or 3.99 percent of Azim 20-L command area and contains nearly level, very sandy soils with moderately coarse (fine sandy loams) surface.

Recommendations for better crop yields are similar as *for* Unit No.61.

64. Sodhra fine sandv loam sodic variant. watertable at 90-150 cm (Sd4(av)/w1)

This unit covers 26.48 acres or 7.75 percent of Azim 20-L command area. About 60-70 percent of the unit comprises stabilized small sand dunes and the remaining 30-40 percent consists of interdunal hollows containing Sodhra soils. The natural vegetation consists of sarkanda, dubgrass and scattered trees of kikar and pilchi covering about 25-40 percent **of** the surface area. The area provides poor grazing and fuel wood.

65. Sodhra loamy sand. watertable at 90-15- cm (Sd2/w1)

This unit covers 30.11 acres or 8.81 percent of Azirn 20-L command area. The area comprises very sandy imperfectly drained soils with hummocky topography. About 10-25 percent of the surface area is covered with natural vegetation comprising sarkanda, dubgrass and khabal grass, which provides poor grazing.

Miscellaneous areas

The extent of miscellaneous areas in the survey area is given below:

	Dune Land (DL):	23.4 Acres
-	Urban Land (UL):	69.3 "
-	Graveyard:	3.5 "
	Kiln:	6.0 "
	Lake:	30.6 "

3. SUMMARIZED LABORATORY ANALYTICAL DATA

Relevant laboratory analytical data, for each soil series sampled in the survey area, has been given at the end of each soil profile description in Appendix II. In the following text, a detailed commentary on the characteristics and laboratory arialytical data of the soil series has been given in order to understand their trend in the survey area. Perusal of the analytical data of various soil series reveals the following facts with respect to the soil parameters as under:

3.1 Organic Matter

Organic matter (OM) content is a good indicator of soil productivity. In the survey area, OM content of surface soils is relatively higher as compared to subsoils. Considering the sufficiency classes as very low < 0.5%. low 0.5 to 0.8%. moderate 0.8 to 1.3% and high > 1.3%, the OM content of subsoils falls in the very low class for all of the soils, whereas it is generally low and moderate in surface soils, except in salt affected soils, where it is very low. The OM is low in sandy and coarse loamy (Jhang and Rasulpur) soils, moderate in medium (Sultanpur, Bagh and Harunabad] and high in fine (Pacca) textured soils.

3.2 Soil pH

Soil pH of the saturated pastes of normal samples ranges between 8.2 and 8.4, whereas it is between 8.6 and 10.6 in salt affected soils. High pH is the indication of higher exchangeable sodium percentage and residual sodium carbonates. Critical examination of ion distribution reveals that a higher pH > 9.5 in sodic variants and strongly saline-sodic soils is strongly correlated to high RSC and high $CO_3^{=}$ + HCO_3^- contents. A pH in the range of 8.6 to 9.4 in a saline-sodic soil is due to high ESP with or without high RSC. High RSC soil is the result of long continued use of high RSC tubewell water, or saturation of soil profiles due to high watertable.

3.3 Electrical Conductivity and Ion Analysis of Saturation Extract

Electrical conductivity of the saturation extract (EC_e) of Jhang, Rasulpur and Sultanpur soils is > 1 dSm^{-1} and as high as 2.95 dSm^{-1} and 3.45 dSm^{-1} in the Harunabad and Bayh soil series, which is probably the result of high watertable and use of high EC water. Similarly, higher EC of Rasulpur sodic variant is due to continuous use of high EC and RSC irrigation water and that of Sodhra sodic variant due to high watertable. EC, of salt affected soils ranges between 4 and 45 dSm^{-1}, showing a decreasing trend with depth in the soil profiles. The concentration of salts in the upper 60 cm is very high (2 to 3 fold) compared with lower depths in barren ends. Problems of salinity and sodicity

in terms of EC, pH and ESP is much lower in cultivated phases of salt affected soils.

$Ca^{++} + Mg^{++}$ are the dominant cations in the saturation extract of normal soils, whereas in saline-sodic soils the dominant cation is Na^{+}. In normal soils, the $CO_3^{=}$ anion is absent and the $SO_4^{=}$ is the dominant anion followed by Cl^{-} and HCO_3^{-} in samples with $EC_e > 2dSm^{-1}$, whereas no such trend exists in soil samples with EC, of $< 2dSm^{-1}$. In all strongly saline-sodic soils with pH 9.6 (Adilpur. Satghara, Sodhra (av)) the dominant anions are $CO_3^{=} + HCO_3^{-}$ followed by $SO_4^{=}$ and Cl^{-}. In soils with pH 8.6 to 9.0. the dominant anion is $SO_4^{=}$ followed by either Cl^{-} and $CO_3^{=} + HCO_3^{-}$ anions (Jhakkar soil series) or $CO_3^{=}$ HCO_3^{-} and Cl^{-} anions [Rasulpur sodic variant).2

3.4 Micronutrients

Considering the critical deficiency limits as less than 0.2 mg kg^{-1}, 4.5 mg kg^{-1}, 1.0 mg kg^{-1} and 0.8 mg kg^{-1} for Cu, Fe, Mn and Zn, respectively, all of the soils are invariably deficient in zinc, whereas Rasulpur, Harunabad, Bagh, Sultanpur and Jhakkar soils and Rasulpur sodic variant are also deficient in Fe. Jhang and Sodhra soil series are invariably deficient in all micronutrients, except copper. It is interesting to note that all of the soils having fine texture (Pacca, Adilpur and Satghara soil series), regardless of salinity and sodicity effected, are sufficient in all of the three remaining micronutrients. Comparing the micronutrient content of Rasulpur series with Rasulpur sodic variant and Pacca with Satghara and Adilpur series, it may be concluded that salinity and sodicity have a depressing effect on micronutrient levels and continuous use of high RSC water may depress micronutrient availability.

3.5 Bulk Density and Total Porosity

The bulk density of a soil is the mass of the soil per unit volume, while porosity is the fraction of soil volume not occupied by soil particles. The bulk density was determined by weighing oven dried undisturbed soil cores (taken in triplicate from each horizon of typical soil profile and dividing the weight of soil by volume) whereas the total porosity was calculated as under:

$$\text{Total Porosity(Volume\%)} = \left[1 - \frac{\text{Dry bulk density}}{\text{Particle density}}\right] \times 100$$

where particle density is assumed as 2.65 g cm^{-3}.

Horizonwise data of bulk density and total porosity of each soil series is given in Appendix I. These results may be used as an indicator of soil problems (i.e. compactness, root penetration, aeration and water retention/movement in the soil horizon). Soil density, soil water and soil air relationships can be read from nomograms prepared by Bodman (1942) and Taylor et, al (1966).

Perusal of data indicates that the bulk density in normal soils ranges from 1.38 to 7.66 $g\ cm^{-3}$ and 1.35 to 1.75 $g\ cm^{-3}$ in saline-sodic **soils.** Total porosity ranges from 34-49% in all of the soils, indicating that saline-sodic soils, though they are a little more compact, yet are quite porous, except Satghara soil with a bulk density of 1.59 *to* 1.71 $g\ cm^{-3}$, which is quite high, making it dense. The bulk density of the top of cultivated soils are invariably low, indicating the presence of a ploughpan in these soils (Jhang, Rasulpur, Rasulpur sodic variant, Jhakkar cultivated and Satghara soils). Higher densities of Pacca and Satghara soils (1.57 to 1.71 gcm^{-3}) indicate low aeration in these soils.

3.6 Infiltration Rates and Hydraulic Conductivity

For planning irrigation scheduling and designing drainage **systems,** a knowledge of water intake rate and transmission characteristics of soils is essential. For this purpose, the basic infiltration rate (readiness of vertical intake rate of water into a soil from the soil surface), cumulative infiltration and hydraulic conductivity of distinct horizons (with respect to transmission Characteristics) were taken in the vicinity of typical soil profiles. Infiltrations were measured using the cylinder infiltrometer method (U.S.Salinity Lab.Staff, 1954) in triplicate and observations were made at time intervals of 5, 10, 20, 30, 45, 60, 90, 120, 180 and 240 minutes. Basic infiltration rates are given at the end **of** each soil profile description and cumulative infiltration against time is reproduced in Table 4 and is also shown in the form **of** graphs.

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