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GOVERNMENT OF PAKISTAN
MINISTRY OF FOOD, AGRICULTURE AND LIVESTOCK

SOIL SURVEY OF PAKISTAN

IN COLLABORATION WITH

INTERNATIONAL IRRIGATION MANAGEMENT INSTITUTE

SEMI-DETAILED SOIL SURVEY OF CHISHTIAN IRRIGATION SUB-DIVISION

SOIL SURVEY OF PAKISTAN
and
INTERNATIONAL IRRIGATION MANAGEMENT INSTITUTE, PAKISTAN
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FOREWORD

During recent years, the Soil Survey of Pakistan (SSP) and the International Irrigation Management Institute (IIMI) have developed a strong collaborative mode of operation on salinity and sodicity research investigations.

The SSP staff have a long history of high quality field research on soil salinity. IIMI has always given SSP credit for bringing to public notice, more than thirty years ago, the problem of secondary salinization resulting from the use of poor quality tubewell water.

The contents of this report have resulted from the collaboration between SSP and IIMI. This is the second joint report on the research program in the Chishtian Irrigation Subdivision. In both cases, the SSP staff have played the major role.

The two organizations have also worked together on Salinity Management Alternatives for Rechna Doab, which was completed during 1997. We are also working together in the Fordwah Eastern Sadiqia (South) Irrigation and Drainage Project located in Southeastern Punjab. We are presently conducting salinity investigations for the total irrigated area in the Province of Sindh.

Both organizations have benefited substantially from the financial and technical support provided by the Government of The Netherlands. This has really facilitated our working together. At the same time, this has been a natural partnership. Certainly, we in IIMI have a tremendous respect for the high degree of professionalism and the extensive field experience displayed by the SSP staff, from the Director General to the field staff and to the laboratory staff.

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

1.1. OBJECTIVE AND SCOPE

This special study was carried out in Irrigation Sub-division Chishtian by the Soil Survey of Pakistan on the request of IIMI-Pakistan, Lahore. The study is in context with the IIMI's research project "Managing Irrigation for Environmentally Sustainable Agriculture in Pakistan", which aims at:

Developing "Management Strategies and Techniques" needs the knowledge of the soils of the area, salinity status, salinity built up, magnitude of irrigation water, its sources and quality, land utilization types and prevailing agronomic and irrigation practices. Thus, the scope of the study includes, beside routine semi-detailed soil surveys, the collection of additional quantitative information on the salinity, drainage and soil moisture characteristics in the area to evaluate the salinity risk due to the use of bad quality tubewell water or high watertable. For this purpose, quite a representative salinity survey of the soils occurring in varying tubewell water quality regimes was conducted and samples were analyzed for salinity/sodicity parameters in the laboratories of the Soil Survey of Pakistan. On site infiltration and permeability tests and other soil moisture characteristics investigations on undisturbed core samples were also made.

This study will serve in developing an "Interaction Model of Salinity Built-up/Reclamation" under known scenario of the factors already mentioned and suggesting an "Irrigation Management Model" to save the soils of area from any degradation. It will also serve as a base to implement the research findings by IIMI, and for soil-based agrotechnology transfer in areas of known soils.

1.2. METHODOLOGY AND MATERIAL

The basic data on soils, salinity, drainage and tubewell water quality were captured through field investigations and through soil and water analysis in the laboratory. Aerial photographs (APs) at a scale of 1:40,000, taken in 1953 and 1954 and 1:50,000 toposheets (1965-94), were used as base maps. A false coloured SPOT image (1:50,000) covering part of the area, was also used to extract information on land resources.

Photo-patterns, based tonal differences, landuses and parceling pattern etc., indicating landforms, soils and drainage, were delineated stereoscopically. Basic information about land-forms and soils was taken from the Reconnaissance Soil Survey Report of Bahawalnagar and Bahawalpur (Soil Survey Staff, 1971). The auger observations, mostly at an interval of 700 to 1000 meters and to 150 cm depth, were made along pre-selected traverses across the photo-patterns. The traverses were made mainly along distributaries and motorable roads. However, where gaps between the traverses were more than 2 to 3 km, additional observations along side-roads depending upon approach, were made to cover the gaps. Observation intensity was somewhat higher in cultivated areas as compared to barren saline-sodic areas. In total, 798 number of auger observations were taken.

Each auger observation was described by horizon/layer; and for each horizon/layer, dry and moist Munsell colours, mottles, texture, structure, consistence, calcareousness, lime nodules/concretions, salinity/sodicity and pH were noted. In addition, relief, physiographic position, profile drainage, depth to water table, salinity indications, landuse and other factors influencing soil management were also recorded. Soil series and their phases were differentiated on the basis of these characteristics.

The information was recorded on prescribed proformae using a separate sheet for each observation. The sites were precisely located on APs. All the 798 observation sites were numbered per photograph, indexed, and marked on the back side of photographs.

Keeping in view the objective of the survey, 95 sites representing twenty different soil units occurring under eight groundwater quality classes, were sampled to assess the present salinity and sodicity status of units and to predict the trend of soil salinity and sodicity under different irrigation scenarios. Critical limits of groundwater by parameters are given in Table 1.1, and the numbers of sites sampled against each water quality class and soil unit are given in Table 1.2.

Table 1.1. Critical limits of groundwater by parameters.

SAR (S)	S_1: < 6	S_2: 6-10	S_3: > 10
RSC, me l^{-1} (R)	R_1: < O	R_2: 0-1.25	R_3: > 1.25
EC, dS m^{-1} (E)	E_1: < 1.15	E_2: 1.15-1.45	E_3: > 1.45

In all, eighteen soil series were identified in the area. Descriptions and analytical data of 8 soil series was taken from the earlier reported Detailed Soil Survey of Eight Water Course Command Areas (Soil Survey Staff and IIMI, 1996) and 3 soils series were taken from the Reconnaissance Soil Survey Reports, Bahawalnagar and Cholistan (Soil Survey Staff, 1971 and 1974). For the remaining 7 soil series, bench mark soil profiles were exposed in the field to a depth of 2m. They were described and sampled according to the procedures laid down in Guidelines for Soil Description (FAO, 1977).

Table 1.2. Selected sites for salinity sampling by soil units and tubewell water quality classes.

Rasulpur	< 150	3+1*+1**	2	3	1	1*	-	1	3+1*+1**	19
	> 150	2+1+1**	1	1+1*	3	1	2	3	1+1**	18
Rasulpur, saline sodic surface	< 150	1	1	-	-	-	-	-	-	2
	> 150	1	-	-	-	-	-	-	-	1
Mariala cult.	< 150	-	-	-	-	-	-	1*	-	1
Barren	> 150	2	-	-	-	-	-	-	-	2
Harunabad	< 150	1	-	-	-	-	1	-	-	2
	> 150	1	1	1*	1	-	1	1	-	6
Awagat	< 150	-	1	-	-	-	-	-	-	1
Gandhra	> 150	-	-	1**	-	-	-	-	-	1
Sultanpur	> 150	5+1*	3	3	1	1	-	-	1	15
Sultanpur, saline sodic surface	> 150	1**	1	-	-	1	-	-	-	3
Jhakkar cult.	> 150	-	1	2	-	1	1	-	1	6
Barren	> 150	1	1	-	-	-	-	-	-	2
Miani	> 150	3	2	-	-	-	-	1	-	6
Pacca	> 150	-	-	1	-	-	1	-	1	3
Dungi cult.	> 150	-	-	1	-	-	1	-	-	2
Barren	> 150	1	1	-	-	-	-	-	-	2
Shahdra	> 150	1	-	-	-	-	-	-	-	1
	Total	28	16	14	6	5	7	7	10	93
		*$S_1R_1E_2$ **$S_1R_1E_3$	*$S_1R_2E_2$	*$S_1R_3E_2$ **$S_1R_3E_3$		*$S_2R_2E_1$		*$S_2R_2E_3$	*$S_3R_2E_3$ **$S_3R_1E_3$	

Replicated tests for infiltration (by double ring infiltrometer) and permeability (by auger-hole and inversed auger-hole methods) were carried out at 15 locations of the benchmark profile of major soils. The undisturbed samples (cores) were also collected in triplicate from each horizon of these soils for soil moisture characterization.

The boundaries of the soil mapping units were drawn on 1:40,000 APs on the basis of auger observations made across the drainage pattern using a mirror stereoscope. These boundaries were next reduced and transferred to a base map of 1:100,000 by the computer program ARC-INFO at IIMI-PAK Office, Lahore.

1.3. THE STUDY AREA

1.3.1. Location and Extent

The area covers parts of tehsils Bahawalnagar, Chishtian and Hasilpur in Bahawalnagar and Bahawalpur districts. This area is about 75 km long and 8 to 12 km wide and bounded in the north-west by the Sutlej River (excluding the riverain part) and in the south-east by the Bahawalnagar-Bahawalpur railway line. The area covers 76716 ha of Fordwah Branch command below Daulat Distributary and lies between latitudes 72°-25' and 73°-10' N and longitudes 29°-38' and 30°-1' E.

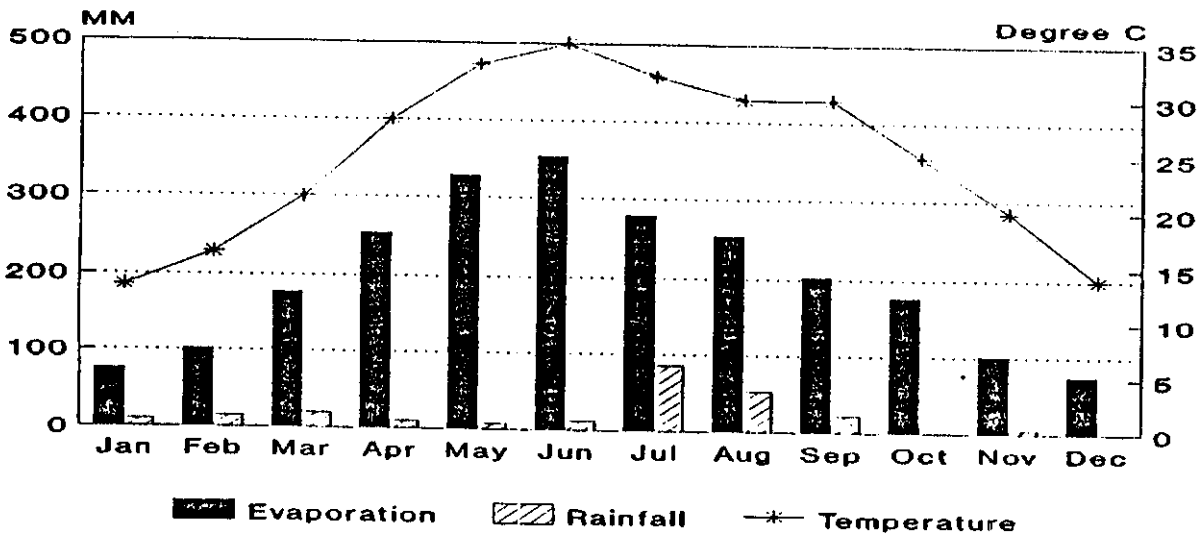
1.3.2. Climate

The climate of the area is characterized as semi-arid with an average annual rainfall of 264 mm (1975 to 1992, Pakistan Meteorological Department, Lahore), a very high rate of evapo-transpiration and high temperatures. In general, 70% of the rain occurs during July to September as high intensity showers, whereas the rest falls during the months of January to April as light showers. The evaporation rate varies between 2.5 mm/day in December and January to about 13mm/day in May and June which amounts to an annual average of 2400 mm. Moisture deficit prevails throughout the year and is the highest in the premonsoon period when hot winds blow from the adjoining desert. The hottest months are May and June when the average maximum and minimum temperatures are 46°C and 23°C, respectively, whereas the coldest month is January with maximum and minimum temperatures as 24°C and 12°C, respectively. Mean annual, mean summer and mean winter temperatures are 24.8°C, 33.5°C and 16°C, respectively. Average monthly evaporation, rainfall and temperatures are presented in Figure 1.1.

1.3.3. Soil Climate

Calculated mean annual, summer and winter soil temperatures (Wambeke, 1985) turn out to be 27.3°C, 33°C and 21.5°C, respectively, at 50 cm soil depth. Thus, the soil temperature 33°C regime of the area is Hyperthermic with mean annual soil temperature of 22°C or more and the difference of mean summer and mean winter soil temperatures as more than 5°C.

Figure 1.1. Average monthly Evaporation, Rainfall and Temperature in the Fordwah Eastern Sadiqia area.



Considering the average annual rainfall and its distribution, very high evapotranspiration rate and temperature, the soil moisture regime of the area may be interpreted as Typic Aridic, wherein there is some moisture in the control section for less than 45 consecutive days in one year. Moisture is not enough for more than one month for crop growth, thus cultivation is not possible without irrigation. However, some xerophytic plants may survive in such a natural environment.

There is, however, an extensive irrigation system irrigating the soils for the last 60 years which has created a kind of aquic condition "Episaturation", wherein the soil is saturated with water in one or more layers within 200 cm and also has one or more unsaturated layers in some parts of soil profile (high water table phases of sandy/loamy soils on the Rasulpur terrace). However, the phenomenon has not yet produced the redoximorphic features.

1.3.4. Hydrology

The survey area falls under the command of Fordwah Branch off taking from Fordwah Canal, which in turn, takes off from the left abutment of Sulemanki Headworks. Fordwah Canal is a part of the Sutlej Valley project that was completed in 1932. Chishtian Irrigation Sub-division starts from the command of Daulat Distributary of Fordwah Branch and extends down to the commands of its tail distributaries Fordwah, Mehmud and Azim. A number of other distributaries namely 3-L, Mohar, Phogan, 4-L, Khemgarh, Jagir, Shahar Farid, Masood, Soda, and 5-L also take off from Fordwah Branch and irrigate the area. Physical characteristics, such as perennial or non-perennial status, design discharge, length, CCA and number of outlets of these distributaries are given in Table 1.3.

Table 1.3. Physical characteristics of distributaries in the area.

3-L	NP*	18	13100	2970	6
Mohar	NP	38	20240	4447	12
Daulat	NP	209	115150	32690	
Phogan	NP	17.5	8750	2211	9
4-L	NP	14	17350	2053	7
Khemgarh	NP	24	15500	5053	9
Jagir	P**	23	13830	47o4	9
Shahar Farid	NP	153	74880	24892	47
Masood	P	35	52300	8099	16
Soda	NP	77	43700	10113	33
5-L	P	4	11300	884	3
Fordwah	P	153	139780	36679	87
Mehmud	P	8.25	11860	20066	7
Azim	NP	244	118000	30459	80
NP*: Non-Perennial P**: Perennial					

Before the introduction of this irrigation system, the low lying land (Subrecent and Recent flood plains of Sutlej River) was irrigated through a set of inundation canals during April to October which now have vanished. The present network irrigates Subrecent and Recent terraces as well as adjoining higher land (Rasulpur terrace in Cholistan desert). Irrigation supply in Subrecent and Recent flood plains is non-perennial, whereas in the hinterland, the supply is perennial. Ground water in the Subrecent and Recent floods is shallower and generally of good quality, whereas the general water is deeper and brackish in the old terrace. The water duty fixed for the non-perennial distributaries is much higher (0.5 l/s/ha=7.0 cfs/ 1000 acres) than that of the perennial distributaries (0.25 l/s/ha=3.6 cfs/1000 acres). Canal water supplies as fixed by the Irrigation Department are sufficient for only 80% cropping intensity (40% kharif and 40% rabi) in perennial canal command areas and 60% in

non-perennial canal command areas. However, the actual cropping intensities have gone as high as 110 to 150 percent. The irrigation requirement of the additional cropped area is supplemented by tubewells. According to a study (Kuper and Strosser, 1992) there are 5 to 15 tubewells per watercourse with an average discharge of 30 liters per second in the area. The average tubewell density is 70 tubewells per 1000 hectares, well distributed throughout the watercourse command. Maximum utilization of the tubewell water is in cotton and wheat growing periods (July to September and February to April).

Irrigation suitability of ground water is shown in Table 1.4 and its distribution is presented on a ground water quality map at the scale of 1 : 280,000 in Figure 1.2.

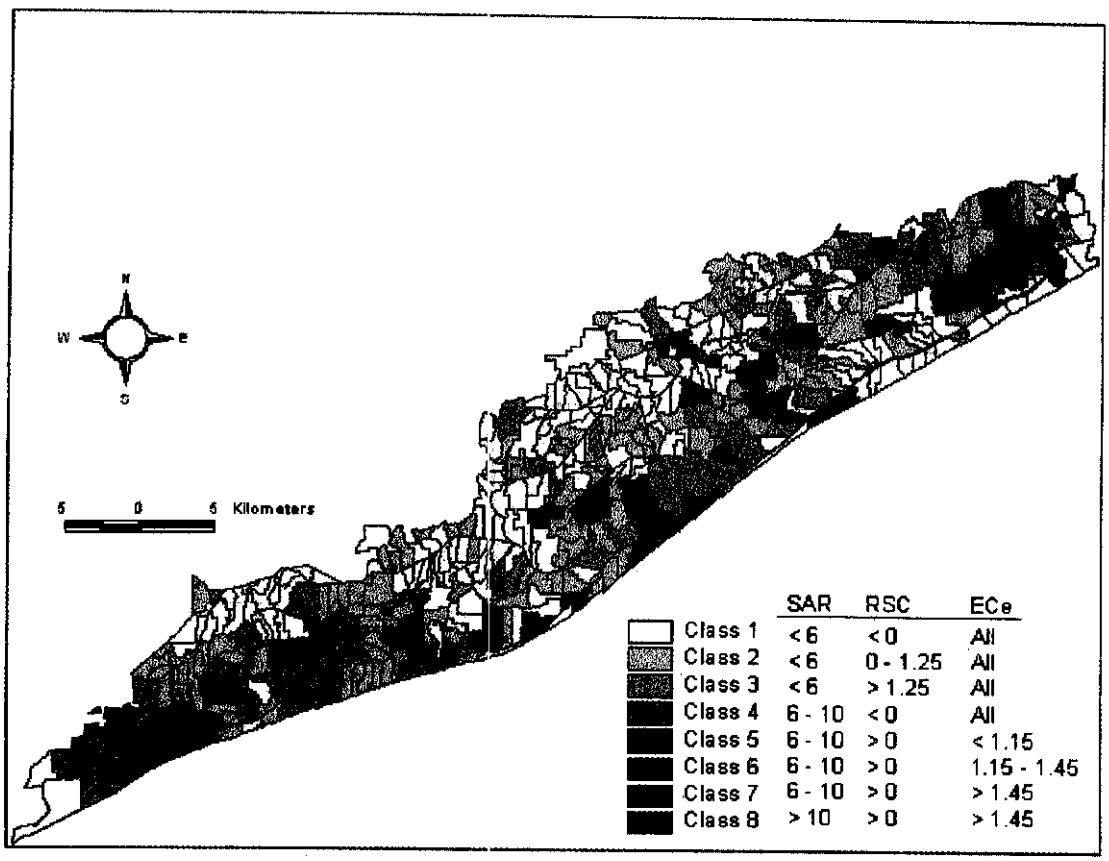


Figure 1.2. Groundwater quality from tubewell water interpolated data (1000 m).

Table 1.4. Irrigation suitability of ground water in Chishtian Irrigation Sub-division.

Class-1	< 6	< O	All classes, predominantly< 1.150	Safe	167	40.7	Safe to use for all soils and crops.	Seaming no risk
Class-2	< 6	0-1.25	-do-	Safe	83	20.2	Safe to use for all soils and crops.	Seaming no risk
Class-3	< 6	> 1.25	All classes, predominantly < 1.150 & 1.150-1.450	Marginal	75	18.3	May be used for medium salt tolerant crops; may cause problem of infiltration in clayey soils; mixing with canal water and gypsum application is advised.	No risk for sandy and loamy soils, slight surface sodicity risk (pH 8.5-8.7) in silty and clayey soils.
Class-4	6-10	< 0	All classes, predominantly > 1.450	Hazardous	7	1.7	May be used for high salt tolerant crops and sandy soils only; causes problem of surface dispersion and infiltration rate in fine and fine-silty soils; mixing with canal water and extra canal irrigation for leaching is advised.	No risk in sandy soils with flushing, moderate profile salinity/sodicity in loamy soils; mod. to higher risk of surface salinity and sodicity in silty and clayey soils.
Class-5	6-10	> 1.25	Predominantly < 1.150	Marginal	17	4.1	May be used for medium salt tolerant crops; causes problem of surface dispersion and infiltration rate in fine and fine-silty soils; mixing with canal water and gypsum application is advised	No risk of salinity, however, moderate risk of profile sodicity in sandy and loamy soils; moderate to high risk of surface sodicity in silty and clayey soils and slight risk in subsoils.
Class-6	6-10	> 1.25	Predominantly 1.150-1.450	Marginal	10	2.4	May be used for medium salt tolerant crops; causes problem of surface dispersion and infiltration rate in fine and fine-silty soils; mixing with canal water and gypsum application is advised.	Slight risk of salinity, however, moderate risk of profile sodicity in sandy and loamy soils; moderate to high risk of surface sodicity in silty and clayey soils and slight risk in subsoils.
Class-7	6-10	> 1.25	> 1.450	Hazardous	20	4.9	May be used for high salt tolerant crops; causes problem of surface dispersion and infiltration rate in fine and fine-silty soils; mixing with canal water, gypsum application and extra canal irrigation for leaching is advised.	Moderate risk in sandy and loamy soils, however, slight with flushing; high risk of salinity and sodicity in silty and clayey soils.
Class-8	>10	> 1.25	>1.450	Hazardous	31	7.6	Avoid irrigation; may be used for high salt tolerant crops and sandy soils; causes problem of surface dispersion and infiltration rate in fine and fine-silty soils, mixing with canal water, gypsum application and extra canal irrigation for leaching is essential.	-do-

- Although the classification standards of ground water quality for different soils and crops under different systems of management are different, the rating and irrigation suitability given here are in general terms. The same holds true for salinity/sodicity risk assessment.

- Perusal of water quality and soil maps reveals that a major part of the Recent and Subrecent flood plains of Sutlej River have deep ground water of good quality, is quite safe for irrigation, whereas marginal or hazardous in flood plains of Hakra (Rasulpur terrace) and Cholistan desert. It is interesting to note that saline-sodic parts of the Sutlej flood plains have the tendency of having marginal/hazardous tubewell water, maybe because of leaching effect. On the other hand, Rasulpur terrace with shallow ground water has the tendency of having safe water quality, maybe because of leakage from canals.

2. THE SOILS

2.1. PHYSIOGRAPHY AND SOILS

Based on genetic age and geomorphological characteristics of the soils, the survey area is comprised of four distinct terraces: (i) Old Wind Resorted Sandy Terrace; (ii) Subrecent (Early Holocene) River Terrace; (iii) Subrecent (Middle Holocene) River Terrace; and (iv) Recent River Terrace. These are described below.

2.1.1. Old Wind Resorted Sandy Terrace (1204 ha; 1.6%)

This terrace, which is the highest in the land scape, makes a part of the Cholistan Desert and occupies the extreme south-western corner of the area. The sand, which was originally deposited by the Hakra River in the Pleistocene Era was later on transformed into undulating sand dunes by wind action. The stabilized nearly level parts of the dunes are bright coloured loamy sands or fine sands with weak development to more than 90 cm depth (Cholistan series), whereas their leeward higher areas consist of semi-stabilized shifting fine and very fine sands. The Interdunal Flat Valleys are saline-sodic (gypsiferous) laminated silty clays/silty clay loams (Makai series), deposited by the cutting and deposition action of the Hakra River during the Subrecent era.

2.1.2. Subrecent (Early Holocene) River Terrace (32176 ha; 41.9%)

This terrace is generally 2 to 3 meters lower than the old wind resorted sandy terrace, which was deposited in the form of sandy levees and bars, part of which was later developed to sandy loams to a depth of more than 90 cm (Rasulpur series) and the part near the banks of river creeks was blown into sand dunes which were changed to loamy sands (Jhang series). The level plains within this terrace contains loams homogenized and developed to a depth of 75 to 120 cm having loam texture (Harunabad series). Locally, some old channels and depressions with impeded drainage contain mottled loams with silty clay loam surface (Awagat series). The transitional areas, with the old terrace subject to seepage from canals, resulted in high water table and consequently salinity and sodicity in these areas. Saline-sodic soils on the levees are sandy loams (Mariala Series) and those occuring in level areas are loams (Gandhra series). Long continued use of hazardous tubewell water in some areas has given rise to both surface and profile salinity and sodicity (Rasulpur saline-sodic surface and Mariala and Gandhra series).

In general, the soils of this terrace are bright coloured (brown to dark yellowish brown) and there is enough lime segregation resulting in few scattered lime concretions in sandy loam soils and occasional common fine and few medium in loam soils below 90 cm. Most of this terrace (from Daulat Distributary to Jiwan Minor) has a high watertable at 100-150 cm (imperfectly drained phase) due to seepage from irrigation channels. The problem is severer along the Fordwah Branch in the south-eastern periphery of the area, where the watertable is at 50-100 cm depth (poorly drained phase).

2.1.3. Subrecent (Middle Holocene) River Terrace (40137 ha; 52.3%)

This terrace is 1-2 meters lower than the Early Holocene terrace, covering the northern half of the area. Two physiographic units -- level plains and channel basins -- have been recognized in this terrace.

Level Plains: These comprise the former levees and their back-slopes that received silty/loamy sediments from slow moving flood water. They generally contain brighter coloured loamy and coarse silty deeply homogenized soils (Nabipur and Sultanpur series).

Channels and Basins: These occupy a relatively lower position in the landscape and are the areas of former channels and basins of Subrecent river courses which received clayey/fine silty material in basins (Pacca series), where water stagnates and fine-silty material is deposited in channels (Miani series) because water moved very slowly in these particular areas during high floods. The soils formed in these positions are, in general, grayer in colour and mottled, more distinctly in the basins. Quite a large part of the channel and basinal areas, especially the margins, had been subjected to high watertable as a result of collecting runoff and subsoil lateral seepage. Later on, the combined effect of capillary rise and high evaporation rates resulted in severely saline-sodic soils (Adilpur, Dungi and Satghara series) in these areas and also in adjoining level plains (Jhakkar series). The soils are generally porous, except Satghara, which is dense due to the clogging effect of dispersed clay.

In general, the soils in this terrace are brown/dark brown and without lime segregation in the form of mycellia or concretions.

2.1.4 Recent River Terrace (2435 ha; 3.2%)

This terrace includes level to gently undulating areas just above the seasonally flooded belt, along the Sutlej River. Due to its proximity with the river, the area is inundated during high floods. Being young, landform elements like levees, bars and back-slopes are quite evident on this terrace. The higher, undulating bar and levees contain deep sandy soils (Sodhra series) which are locally covered by silt loam or very fine sandy loam to a depth of 15 to 50 cm (Sodhra medium surface). Covered levees and bars are relatively level. One such unit occurs on the Sub-recent (Middle Holocene) terrace as slip-off-slope of an old channel which has turned into marsh land. Parts of this unit are saline-sodic, especially at the surface. Soils on the back-slopes are nearly level, stratified, showing no profile development except some homogenization in the topsoil (Shahdara series).

2.1.5. Miscellaneous Areas (764 ha, 1.0%)

Miscellaneous areas including marsh land, graveyard, open water and habitation mounds are parts of the Subrecent (Early Holocene) Terrace.

2.2. SOIL MAPPING UNITS

The main soil identification category (taxon) employed in the survey area is the soil series which have similar morphologic, physical, chemical and mineralogic characteristics within a defined range, except for differences in texture of the surface layer. All the soils of one series have a similar horizon that are similar in thickness and arrangement within a defined range and must have the same particle size class. Because of small map scale (1:100,000) and low observation intensity, it was not possible to delineate individual soil series in the area. Instead, mono map units (consociation), each consisting of predominately one soil series with one or two minor soils, have been delineated. In certain areas, where individual soils are so small and intricately associated that could not be mapped, even at a detailed scale map unit, the soil complex has been used. Each unit on the soil map is a unique natural segment of the landscape having a distinct soil and drainage status. Where possible, drainage and surface salinity - sodicity phases of the soils have also been mapped. Soil mapping units employed in the area are the consociation, (unless otherwise mentioned) and are named after the predominant soil or miscellaneous areas. In all of there are 39 soil mapping units which include 28 consociations, 7 soil complexes and 4 miscellaneous areas. A list of these soil mapping units, along with their extent, is given in Table 2.1. The distribution of the mapping units is shown on the accompanying soil map (1:100,000).

The mapping units are described in terms of their landform, extent, component soils and parameters like relief, depth, permeability, salinity-sodicity, structure and texture in Table 2.2. The degree of soil development, colour and calcareousness of soils are generally defined at the landform level as footnotes to the table. It is worth mentioning that descriptions of soil mapping units given here are mostly for the modal concept of soil series in the area. The range of soil series characteristics is given in Table 2.3.

Table 2.1. Soil mapping units and their extent.

	OLD WIND RESORTED SANDY TERRACE	1204	1.57
	Undulating		
1.	Cholistan	164	0.21
2.	Cholistan-Duneland complex	614	0.80
3.	Duneland	137	0.18
	Interdunal Valleys		
4.	Makai	289	0.38
	SUBRECENT (EARLY HOLOCENE) RIVER TERRACE	32176	41.94
	Levees and Bars		
5.	Jhang	381	0.50
6.	Jhang-Duneland complex	421	0.55
7.	Mariala, imperfectly drained	2296	2.99
8.	Rasulpur	9817	12.80
9.	Rasulpur, imperfectly drained	10489	13.67
10.	Rasulpur, poorly drained	2268	2.96
11.	Rasulpur, saline-sodic surface	833	1.09
12.	Rasulpur, saline-sodic surface, poorly drained	248	0.32
13.	Rasulpur-Duneland complex	1545	2.01
	Level Plains		
14.	Awagat, silty clay loam surface, imperfectly drained	235	0.31
15.	Awagat, silty clay loam surface, poorly drained	78	0.10
16.	Gandhra	180	0.23
17.	Harunabad	1353	1.76
18.	Harunabad, imperfectly drained	1402	1.83
19.	Harunabad, poorly drained	590	0.77
20.	Harunabad, saline-sodic surface	40	0.05

Table 2.1. (Complete)

	SUBRECENT (MIDDLE HOLOCENE) RIVER TERRACE	40137	52.32
	Level Plains		
21.	Nabipur	206	0.27
22.	Sultanpur	23213	30.26
23.	Sultanpur, saline-sodic surface	761	0.99
	Channel infills and Basins		
24.	Miani	649	0.85
25.	Miani-Pacca complex	5443	7.09
26.	Pacca	546	0.71
	Channel infills and Basin Margins		
27.	Dungi	833	1.09
28.	Jhakkar	2597	3.39
29.	Jhakkar-Adilpur complex	1803	2.35
30.	Jhakkar-Dungi complex	3041	3.96
31.	Jhakkar-Satghara complex	1045	1.36
	RECENT RIVER TERRACE	2435	3.17
	Levees and Bars		
32.	Sodhra	295	0.38
33.	Sodhra, medium surface	42	0.05
34.	Sodhra, medium surface, imperfectly drained	383	0.50
	Level Plains		
35.	Shahdra	1715	2.24
	MISCELLANEOUS AREAS	764	1.00
	Habitation mound	38	0.05
	Marsh land	327	0.43
	Grave yard	323	0.42
	Open water	76	0.01
	Grand Total:	76716	100.00

Table 2.2. Description of soil mapping units.

Old Wind Resorted Sandy Terrace[2]	1	Ch	Cholistan	164	0.21	Cholistan	90	Gently undulating stabilized slopes	V. deep	Rapid	Non-saline	V. weak sbk/ massive	Loamy sands
						Shifting sands	10	Undulating unstabilized slopes	Deep	V. rapid	Non-saline	Loose/ massive	Fine sands/loamy sands
	2	Ch-DLX	Cholistan-Dune Land complex	614	0.80	Cholistan*	60-70 (65)	Gently undulating stabilized slopes	V. deep	Rapid	Non-saline	V. weak sbk/ massive	Loamy sands
						Shifting sand	30-40 (35)	Undulating unstabilized slopes	Deep	V. rapid	Non-saline	loose/ massive	Find sands/loamy sands
				* 50% is lying barren.									
	3	DL	Dune Land*	137	0.18	Sand dunes	90	Low, undulating dunes	-	V. rapid	Non-saline	Loose	Fine sands
						Jhang	10	Nearly level ,levees and bars	Deep	V. rapid	Non-saline	Massive	Loamy sands
				* The unit is mostly barren due to moisture shortage and undulating relief.									
Subrecent, Infilled Channels	4	Mk	Makai*	289	0.38	Makai	85	Nearly level channel infills	V. deep	V. slow	Gypsiferous severely saline	Laminated	Silty clay/silty clay loams
						Cholistan	10	Gently undulating stabilized slopes	V. deep	Rapid	Non-saline	V. weak sbk/ massive	Loamy sands
						Shifting sands	5	Undulating unstabilized slopes	Deep	V. rapid	Non-saline	Loose/ massive	Fine sands/loamy sands
				*The unit is mostly lying barren due to moisture shortage and severe salinity.									
Subrecent (Early Holocene) River Terrace[3]	5	Jg	Jhang*	381	0.50	Jhang**	85	Nearly level levees and bars	Deep	Rapid	Non-saline	V. weak sbk	Loamy sands
						Rasulpur	12	Level, levees and bars	Deep	Mod. rapid	Non-saline	Weak, sbk	Sandy loams
						Sand dunes	3	Gently undulating low ridges	-	V. rapid	Non-saline	Massive	Loamy sands/fine sands
				* 40% of the unit may show strongly alkaline surface and even subsurface; ** surface texture is in general sandy loam.									

[2] Undulating sandy soils, in general, are yellowish brown to dark yellowish brown, deeply developed whereas soils in interdunal flat valleys are dark yellowish brown, young laminated, moderately calcareous.

[3] Soils in general are deep/very deep, brown to dark yellowish brown, deeply developed (75-120 cm), moderately calcareous with few to common lime nodules in subsoil.

Table 2.2. (Continued)

6	Jg-DLX	Jhang-Dumeland complex	421	0.55	Jhang	60-70 (65)	Nearly level, levees and bares	Deep	Rapid	Non-saline	V. weak, sbk	Loamy sands
					Sand dunes	30-40 (35)	Low, undulating dunes	Deep	V. rapid	Non-saline	Loose/ massive	Fine sand/loamy sands
7	Mr/W$_4$	Mariala, imperfectly drained*	2296	2.99	Mariala	85	Nearly level levees and bars	Deep	Mod. rapid	Mod. saline-sodic**	Weak, sbk	Sandy loams/fine sandy loams
					Rasulpur	15	Nearly level, levees and bars	Deep	Mod. rapid	Non-saline***	Weak, sbk	Sandy loams/fine sandy loams
			• The unit occupies tower parts in the landscape along canal/distributaries and has watertable at 50 to 100 cm depth; **part of Mariala series is non-saline strongly alkaline; *** part of soil series may have surface salinity/sodicity.									
8	Rs	Rasulpur*	9817	12.8	Rasulpur	90	Level to nearly level levees and bars	Deep	Mod. rapid	Non-saline**	Weak, sbk	Sandy loams/find sandy loams
					Harunabad	10	Level plains	Deep	Moderate	Non-saline	Weak, sbk	Loams
			* About 5% of the unit have watertable at 100 to 150 cm depth and locally have low sand dunes; ** part of the series may have strong surface alkalinity due to hazardous groundwater.									
9	Rs/W$_4$	Rasulpur, imperfectly drained*	10489	13.67	Rasulpur	90	Level to nearly level levees and bars	Deep	Mod. rapid	Non-saline**	Weak, sbk	Sandy loams/fine sandy loams
			* Rest 10% consists of Harunabad series. The unit occurs along canal/distributaries and has watertable at 50 to 100 cm depth; ** part of the series may have surface salinity/strongly alkalinity due to high watertable and hazardous tubewell water.									
10	Rs/W$_3$	Rasulpur, poorly drained*	2268	2.96	Rasulpur	90	Level to nearly level levees and bars	Deep	Mod. rapid	Non-saline**	Weak, sbk	Sandy loams/fine sandy loams
			* Rest 10% consists of Harunabad series. The unit occurs along canal/distributaries and has watertable at 50 to 100 cm depth; ** part of the series may have surface salinity/strong alkalinity due to high watertable.									
11	Rs(ss)	Rasulpur, saline-sodic surface*	833	1.09	Rasulpur, saline-sodic surface	85	Nearly level levees and bars	Deep	Mod. rapid	Saline-sodic surface (15-30 cm)**	Weak, sbk	Sandy loams/fine sandy loams
			* Rest 15% includes Rasulpur (10%) and Harunabad (5%) series; ** surface salinity and sodicity is due to low supply of irrigation water for effective leaching and partly because of marginal/hazardous tubewell water.									
12	Rs(ss) W$_3$	Rasulpur, saline-sodic surface, poorly drained*	248	0.32	Rasulpur, saline-sodic surface	90	Nearly level levees and bars	Deep	Mod. rapid	Saline-sodic surface (15-30 cm)**	Weak, sbk	Sandy loams/fine sandy loams
			* Rest 10% is Rasulpur imperfectly drained phase. The unit has watertable at 50 to 100 cm depth and about 25% of the unit is uncultivated; ** saline-sodic surface is due to high watertable.									

Table 2.2. (Continued)

13	Rs-DLX	Rasulpur-Duneland complex*	1545	2.01	Rasulpur	65	Nearly level levees and bars	Deep	Mod. rapid	Non-saline**	Weak, sbk	Sandy loams/fine sandy loams
					Sand Dunes	35	Gently undulating low ridges		Rapid	Non-saline	Massive	Loamy sands/fine sands
		* Sand dunes are barren and Rasulpur series is partly under cultivation; ** part of the series has a saline-sodic surface/profile salinity.										
14	$\frac{AW_2}{W_4}$	Awagat, silty clay loam surface, imperfectly drained*	235	0.31	Awagat, silty clay loam surface	100	Level plains	Deep	Mod. slow	Non-saline	Weak, sbk	Mottled loams with silty clay loam surface (10-20 cm)
		* The unit occupies depressional parts in the landscape and has watertable at 100 to 150 cm.										
15	$\frac{AW_2}{W_3}$	Awagat, silty clay loam surface, poorly drained*	78	0.10	Awagat, silty clay loam surface	100	Level plains	Deep	Mod. slow	Non-saline	Weak, sbk	Mottled loams with silty clay loam surface (10-20 cm)
		* The unit occupies depressional areas in the landscape and has watertable at 50 to 100 cm depth.										
16	Gd	Gandhra*	180	0.23	Gandhra	90	Level plains	Deep	Moderate	Mod. saline-sodic	Weak, sbk	Loams
		* The rest 10% is Rasulpur and Harunabad series.										
17	Hr	Harunabad	1353	1.67	Harunabad	90	Level plains	Deep	Moderate	Non-saline	Weak, sbk	Loams
					Rasulpur	10	Level levees and bars	Deep	Mod. rapid	Non-saline	Weak, sbk	Sandy loams/fine sandy loams
18	Hr/W_4	Harunabad, imperfectly drained*	1402	1.83	Harunabad	85	Level plains	Deep	Moderate	Non-saline	Weak, sbk	Loams
					Rasulpur	15	Level levees and bars	Deep	Mod. rapid	Non-saline	Weak, sbk	Sandy loams/fine sandy loams
		* The unit has watertable at 100 to 150 cm depth.										
19	Hr/W_3	Harunabad, poorly drained*	590	0.77	Harunabad	90	Level plains	Deep	Mod. slow	Non-saline	Weak, sbk	Loams
					Rasulpur	10	Level levees and bars	Deep	Mod. rapid	Non-saline	Weak, sbk	Sandy loams/fine sandy loams
		* The unit occupies depressional areas in the landscape and has watertable at 50 to 100 cm depth.										

Table 2.2. (Continued)

	20	Hr(ss)	Harunabad, saline-sodic surface	40	0.05	Harunabad, saline-sodic surface	95	Level plains	Deep	Mod. Slow	Saline-sodic surface (15-30 cm)	Weak, sbk	Loams
						Rasulpur	5	Level levees and bars	Deep	Mod. rapid	Non-saline	Weak, sbk	Sandy loams/fine sandy loams
Subrecent (Middle Holocene) Rive Terrace[4]	21	Nb	Nabipur	206	0.27	Nabipur	90	Level to nearly level plains	Deep	Moderate	Non-saline	Weak, sbk	Loams
						Sultanpur	10	Level to nearly level plains	Deep	Moderate	Non-saline	Weak, sbk	Silt loams/very fine sandy loams
	22	Su	Sultanpur	23213	30.26	Sultanpur	85	Level to nearly level plains	Deep	Moderate	Non-saline*	Weak, sbk	Silt loams/very fine sandy loams**
						Miani	10	Nearly level channel infills	Deep	Mod. slow	Non-saline	Weak, sbk	Silty clay loams
						Jhakkar	5	Nearly level levees	Deep	Moderate	Porous, mod. saline- sodic	Weak, sbk	Silt loams/very fine sandy loams
				* Locally the soil may have surface salinity/sodicity due to hazardous tubewell water and leaving the ields fallow for long time; ** major part of the unit have fine silty profile whereas it is coarse silty in north eastern corner.									
	23	Su(ss)	Sultanpur, saline-sodic surface	761	0.99	Sultanpur, saline sodic surface	90	Level to nearly level plains	Deep	Moderate	Saline-sodic surface (15-30 cm)*	Weak, sbk	Silt loams/very fine sandy loams
						Sultanpur	10	Level to nearly level plains	Deep	Moderate	Non-saline	Weak, sbk	Silt loams/very fine sandy loams
				* Locally the soil has deep profile salinity/sodicity partly reclaimed Jhakkar series.									
	24	Mi	Miani	649	0.85	Miani	90	Nearly level depressions	Deep	Mod. slow	Non-saline	Weak, sbk	Silty clay loams
						Sultanpur	10	Level to nearly level plains	Deep	Moderate	Non-saline	Weak, sbk	Silt loams/very fine sandy loams
	25	Mi-PcX	Mian-Pacca complex	5443	7.10	Miani	60	Nearly level depressions	Deep	Mod. slow	Non-saline	Weak, sbk	Silty clay loams
						Pacca	25	Nearly level concave depressions	Deep	Mod. slow	Non-saline	Weak, sbk	Silty clays/heavy silty clay loams
						Sultanpur	15	Level to nearly level plains	Deep	Moderate	Non-saline	Weak, sbk	Silt loams/very fine sandy loams

[4] Soil in general are deep, brown/dark brown, moderately calcareous, moderately deeply developed (60 – 90 cm) underlain by stratified material of varying textures.

Table 2.2. (Continued)

26	Pc	Pacca	546	0.71	Pacca	80	Nearly level concave depressions	Deep	Mod. slow	Non-saline	Weak, sbk	Silty clays/heavy silty clay loams
					Miani	10	Nearly level depressions	Deep	Mod. Slow	Non-saline	Weak, sbk	Silty clay loams
					Sultanpur	10	Level to nearly level plains	Deep	Moderate	Non-saline	Weak, sbk	Silt loams/very fine sandy loams
27	Di	Dungi*	833	1.09	Dungi	85	Nearly level concave depressions	Deep	Slow	Porous, strongly saline-sodic	Weak, sbk	Silty clays/heavy silty clay loams
					Jhakkar	15	Nearly level levees	Deep	Moderate	Porous, strongly saline-sodic	Weak, sbk	Silt loams/very fine sandy loams
		* About 35-50% of the unit is lying barren, rest is under reclamation or partly reclaimed with moderate salinity and sodicity problem.										
28	Jk	Jhakkar*	2597	3.39	Jhakkar	90	Nearly level levees	Deep	Moderate	Porous, strongly saline-sodic	Weak, sbk	Silt loams/very fine sandy loams
					Adilpur	10	Nearly level depressions	Deep	Mod. slow	Porous, strongly saline-sodic	Weak, sbk	Silty clay loams
		* About 35-50% of the unit is lying barren, rest is under reclamation or partly reclaimed with moderate salinity and sodicity problem.										
29	Jk-AdX	Jhakkar-Adilpur complex*	1803	2.35	Jhakkar	65	Nearly level levees	Deep	Moderate	Porous, strongly saline-sodic	Weak, sbk	Silt loams/very fine sandy loams
					Adilpur	30	Nearly level depressions	Deep	Mod. slow	Porous, strongly saline-sodic	Weak, sbk	Silty clay loams
					Dungi	5	Nearly level concave depressions	Deep	Slow	Porous, strongly saline-sodic	Weak, sbk	Silty clay/heavy silty clay loams
		* About 35-50% of the unit is lying barren, rest is under reclamation or partly reclaimed with moderate salinity and sodicity problem.										
30	Jk-DiX	Jhakkar-Dungi complex*	3041	3.96	Jhakkar	65	Nearly level levees	Deep	Moderate	Porous, strongly saline-sodic	Weak, sbk	Silt loams/very fine sandy loams
					Dungi	25	Nearly level concave depressions	Deep	Slow	Porous, strongly saline-sodic	Weak, sbk	Silty clays/heavy silty clay loams
					Adilpur	10	Nearly level depressions	Deep	Mod. slow	Porous, strongly saline-sodic	Weak, sbk	Silt clay loams
		* About 40-60% of the unit is lying barren, rest is under reclamation or partly reclaimed with moderate salinity and sodicity problem.										

Table 2.2. (Complete)

	31	Jk-StX	Jhakkar-Satghara complex*	1045	1.36	Jhakkar	60	Nearly level levees	Deep	Moderate	Porous, strongly saline-sodic	Weak, sbk	Silt loams/very fine sandy loams
						Satghara	40	Nearly level depressional areas	Deep	V. slow	Dense, strongly saline-sodic	Weak, sbk	Silty clays/heavy silty clay loams
			* Almost the whole unit is lying barren, locally fringes are under reclamation.										
Recent River Terrace[5]	32	Sd	Sodhra*	295	0.39	Sodhra	85	Gently undulating bars	Deep	Rapid	Non-saline	Massive/ single grain	Loamy sands/sands
						Sodhra, medium surface	15	Nearly level covered bars	Deep	Rapid	Non-saline	Massive/ single grain	Loamy sands with loams/sandy loams surface (15-30 cm)
	33	Sd(ms)	Sodhra medium surface	42	0.05	Sodhra, medium surface	90	Nearly level covered bars	Deep	Rapid	Non-saline	Massive/ single grain	Loamy sands/sands with silt loam/very fine sandy loams surface (20-40 cm)
						Shahdara	10	Nearly level plains	Deep	Moderate	Non-saline	Massive/ laminated	Silt loams/very fine sandy loams with thin bands of contrasting materials
	34	Sd(ms) W_4	Sodhra, medium surface, imperfectly drained*	383	0.50	Sodhra, medium surface	100	Nearly level covered bars	Deep	Rapid	Non-saline	Massive/ single grain	Loamy sand/sands with loams/sandy loams surface (20-45 cm)
			* the unit has watertable at 100-150 cm depth, 25% of the unit have surface salinity/sodicity and locally has profile sodicity (pH>8.5).										
	35	Sh	Shahdara	1715	2.24	Shahdara	80	Nearly level plains	Deep	Moderate	Non-saline	Massive/ laminated	Silt loams/very fine sandy loams with thin bands of contrasting material
						Sultanpur	10	Nearly level plains	Deep	Moderate	Non-saline	Weak, sbk	Silt loams/very fine sandy loams
						Sodhra, medium surface	10	Nearly level covered bars	Deep	Rapid	Non-saline	Massive/ single grain	Loamy sands/sands with silt loam,/very fine sandy loam surface (15-30 cm)
Miscellaneous Areas		ML	Marshland	327	0.43								
		GY	Graveyard	323	0.42								
		OW	Open water	76	0.10								
		HM	Habitation mound	38	0.05								

[5] Soils in general are laminated with surface homogenization only.

Table 2.3. Range of soil series characteristics.

1.	Adilpur	Topsoil	10-30	Brown to dark brown	Massive	Loam/silt loam/silty clay loam	Moderately calcareous	9.0 to 9.6	25-45 [7] (8-16) [8]
		Subsoil	60-90	Brown/dark brown	Weak coarse sub-angular blocky	silty clay loam	Moderately calcareous	8.8 to 9.6	5-25 (4-8)
		Substratum		Brown/dark brown to yellowish brown & greyish brown	Massive/dense laminated	Silt loam/silty clay loam and sand	Moderately to strongly calcareous	8.6 to 9.0	2-10 (2-4)
				➢ Faint yellowish brown/reddish brown mottles may be present in lower part of sub-soil and substratum.					
2.	Awagat	Topsoil	10-20	Dark greyish brown to brown/dark brown	Massive	Silty clay loam/loam	Moderately calcareous	8.2 to 8.4	1-4
		Subsoil	75-120	Brown/dark brown to dark yellowish brown	Very weak to weak coarse subangular blocky	Loam	Moderate to strongly calcareous	8.2 to 8.4	1-4
		Substratum		Yellowish brown to dark greyish brown	Massive	Fine sandy loam to loamy sand	Moderately calcareous	8.0 to 8.2	1-4
				➢ Common distinct yellowish brown mottles are present in profile especially at lower depths.					
3.	Cholistan	Topsoil	10-20	Yellowish brown to brown/dark brown	Massive/single grain	Fine sand/ loamy, very fine sand	Moderately calcareous	8.2 to 8.4	1-4
		Subsoil	100-140	Yellowish brown to dark yellowish brown	Massive/single grain	Loamy very fine sands/loamy sands	Moderately calcareous	8.2 to 8.4	1-4
		Substratum		Brown to yellowish brown	Single grain	Loamy sands	Moderately calcareous	8.0 to 8.2	1-4

[6] PH observed in the field by thymol blue indicator is slightly low (by 0.2 to 0.5 units) compared to the laboratory determination.

[7] Figures refer to barren areas.

[8] Figures refer to cultivated or/and under reclamation.

Table 2.3. (Continued)

4.	Dungi	Topsoil	10-15	Dark greyish brown to brown/dark brown	Massive	Silty clay loams/silt loams	Moderately calcareous	9.0 to 9.6	25-45 (8-16)
		Subsoil	75-90	Very dark greyish brown to brown/dark brown	Weak coarse and medium subangular blocky	Heavy silty clay loam	Moderate to strongly calcareous	8.6 to 9.6	5-25 (4-8)
		Substratum		Yellowish brown/greyish brown	Massive/platy	Stratified layers of silt loam to fine sands	Moderately calcareous	8.6 to 9.0	2-5 (2-4)
				➢ Common faint and distinct yellowish brown mottles are present in the profile especially at lower depth.					
5.	Gandhra	Topsoil	10-20	Dark brown to brown/dark brown	Massive	Loams/sandy loams	Moderately calcareous	8.6 to 9.0	8-16
		Subsoil	50-90	Brown/dark brown	Weak coarse and medium subanguiar blocky	Loams to light loams	Moderately calcareous	8.6 to 8.8	4-8
		Substratum	-	Brown to greyish brown	Massive & stratified	Very fine sandy loams to loamy sands	Moderately calcareous	8.2 to 8.6	2-4
6.	Harunabad	Topsoil	10-25	Dark brown to dark yellowish brown	Massive	Sandy loam/ loam	Moderately calcareous	8.2 to 8.4	1-4
		Subsoil	40-90	Brown/dark brown to dark yellowish brown	Weak coarse subangular blocky	Loam to light loam	Moderately calcareous	8.2 to 8.4	1-4
		Substratum	-	Greyish brown to yellowish brown	Very weak coarse subangular blocky	Sandy loam/ very fine sandy loam to loamy sand	Moderately to strongly calcareous; few lime nodules may be present	8.2 to 8.4	1-4
				➢ Faint yellowish brown or rust brown mottles may be present in lower part of subsoil and substratum.					
7.	Jhakkar	Topsoil	10-25	Brown to brown/dark brown	Massive	Loam/silt loam/very fine sandy loam	Moderately calcareous	9.0 to 9.6	25-45 (8-16)
		Subsoil	50-90	Brown/dark brown to dark yellowish brown	Weak coarse and medium subangular blocky	Silt loam & very fine sandy loam	Moderately to strongly calcareous	8.8 to 9.2	5-25 (4-8)
		Substratum	-	Brown/dark brown to yellowish brown and greyish brown	Massive and stratified	Silt loam/silty clay loam/ very fine sandy loam to fine sand	Moderately to strongly calcareous	8.6 to 9.0	2-4

Table 2.3. (Continued)

8.	Jhang	Topsoil	15-45	Brown to brown/dark brown	Massive	Loamy sand/ sandy loam/ loam	Moderately calcareous	8.2 to 8.4	1-4
		Subsoil	45-90	Brown/dark brown to brown & dark yellowish brown	Very weak to weak coarse subangular blocky	Loamy fine sand/loamy sand	Moderately calcareous	8.2 to 8.4	1-4
		Substratum	-	Greyish brown to brown	Massive/single grain	Loamy sand/ fine sand, occasionally fine sandy loam	Moderately calcareous	8.2 to 8.4	1-4
9.	Makai	Topsoil	10-15	Brown/dark brown to dark greyish brown	Massive/weak platy	Silty clay loam to silty clay	Moderately calcareous	8.0 to 8.4	25-45
		Subsoil	40-100	Dark yellowish brown with or without yellowish brown mottles	Weak laminated, containing few bunches of gypsum crystals	Silty clay to silty clay loam	Moderately calcareous	8.0 to .84	5-25
		Substratum	-	Dark yellowish brown, with or without yellowish and reddish brown mottles	Massive/laminated containing few bunches of gypsum crystal	Silt loam to silty clay	Moderately calcareous	8.0 to 8.4	2-10
10.	Mariala	Topsoil	10-15	Brown/dark brown to dark greyish brown	Massive	Loam/fine sandy loam	Moderately calcareous	8.6 to 9.6	8-16
		Subsoil	75-90	Brown/dark brown to dark yellowish brown	Weak coarse sub-angular blocky	Sandy loam/fine sandy loam	Moderately calcareous	8.6 to 9.0	4-8
		Substratum		Yellowish brown/greyish brown	Massive/single grain	Sandy loam to fine sand	Moderately calcareous	8.0 to 8.6	1-4
11.	Miani	Topsoil	10-15	Dark greyish brown to dark brown	Massive	Silt loam/silty clay loam	Moderately calcareous	8.2 to 8.4	1-4
		Subsoil	50-75	Brown/dark brown to dark brown	Weak coarse & medium subangular blocky	Silty clay loam/heavy silt loam	Moderately to strongly calcareous	8.2 to 8.4	1-4
		Substratum	-	Brown to yellowish brown	Massive and stratified	Silt loam/very fine sandy loam to fine sand	Moderately calcareous	8.2 to 8.4	1-4
				➢ Few fine lime nodules and common faint yellowish brown mottles may be present in subsoil and substratum.					
12.	Nabipur	Topsoil	10-25	Dark brown to brown/dark brown	Massive	Loam/sandy loam	Moderately calcareous	8.2 to 8.4	1-4

Table 2.3. (Continued)

		Subsoil	50-90	Brown/dark brown	Weak coarse & medium subangular blocky	Loam to light loam	Moderately calcareous	8.2 to 8.4	1-4
		Substratum	-	Brown to greyish brown	Massive & laminated	Very fine sandy loam to fine sand	Moderately calcareous	8.2 to 8.4	1-4
13.	Pacca	Topsoil	10-15	Very dark greyish brown to dark brown	Massive	Silt loam/silty clay loam/silty clay	Moderately calcareous	8.2 to 8.4	1-4
		Subsoil	40-75	Dark greyish brown and brown to brown/dark brown	Very weak to weak coarse & medium angular & sub-angular blocky	Silty clay/heavy silty clay loam	Moderately calcareous	8.2 to 8.4	1-4
		Substratum	-	Dark greyish brown and brown to brown/dark brown	Massive & stratified or a burried profile	Silty clay/silty clay loam and fine sandy loam to fine sand	Moderately calcareous	8.2 to 8.4	1-4
14.	Rasulpur	Topsoil	15-45	Brown/dark brown to dark greyish brown and dark yellowish brown	Massive	Loamy fine sand to fine sandy loam/ loam	Moderately calcareous	8.2 to 8.4	1-4
		Subsoil	50-120	Brown/dark brown to dark yellowish brown	Weak coarse subangular blocky	Fine sandy loam/sandy loam	Moderately calcareous	8.2 to 8.4	1-4
		Substratum	-	Greyish brown to yellowish brown	Massive/single grain	Fine sandy loam to fine sand, occasionally loam/very fine sandy loam	Moderate to strongly calcareous	8.2 to 8.4	1-4
				➢ Few faint yellowish brown mottles and lime nodules may be present in lower part of subsoil and substratum.					
15.	Satghara	Topsoil	10-15	Very dark greyish brown to dark greyish brown	Massive	Silt loam/silty clay loam	Moderately calcareous	9.0 to 10.0	25-45
		Subsoil	40-75	Dark greyish brown to brown/dark brown	Weak to moderate coarse & medium angular & subangular blocky	Silty clay/heavy silty clay loam	Moderately to strongly calcareous	9.0 to 9.6	5-25
		Substratum	-	Dark greyish brown to brown/dark brown	Massive & stratified	Silt loam/very fine sandy loam/silty clay loam	Moderately calcareous	8.5 to 9.0	2-10

Table 2.3. (Complete)

16.	Shahdra	Topsoil	10-20	Brown/dark brown to dark greyish brown	Massive	Very find sandy loam/silt loam	Moderately calcareous	8.2 to 8.4	1-4
		Subsoil		Brown/dark brown and greyish brown	Thin weak platy, may be homogenized upto 45 cm with inped lamination	Layers of silt loam/very fine sandy loam to fine sand	Moderately calcareous	8.0 to 8.4	1-4
17.	Sultanpur	Topsoil	10-25	Brown to dark greyish brown	Massive	Silt loam/very fine sandy loam/loam	Moderately calcareous	8.0 to 8.4	1-4
		Subsoil	50-90	Brown/dark brow to brown	Very weak to weak coarse subangular blocky	Silt loam/very fine sandy loam	Moderately calcareous	8.0 to 8.4	1-4
		Substratum	-	Brown to yellowish brown/greyish brown	Massive/single grain and stratified	Silt loam/very fine sandy loam to fine sand/silty clay loam	Moderately calcareous	8.0 to 8.4	1-4
				➢ Few fine faint or distinct yellowish brown mottles may be present in lower part of subsoil and substratum.					
18.	Sodhra	Topsoil	15-45	Greyish brown to brown/dark brown	Massive/single grain	Loamy sand/ fine sandy loam/loam	Moderately calcareous	8.2 to 8.4	1-4
		Subsoil	70-120	Dark greyish brown to greyish brown	Single grain/massive	Loamy sand/sand	Moderately calcareous	8.2 to 8.4	1-4

2.3. SUMMARIZED LABORATORY ANALYTICAL DATA

Interpretation of physico-chemical data of soil series (given at the end of each soil series description) is important to understand the trends of soil parameters for scientific agro-research recommendations. Perusal of the analytical data of various soil series reveals the following facts with respect to the soil parameters.

2.3.1. 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 barren salt affected soils where it is very low. The OM of surface soil is very low and low in sandy and coarse loamy (Cholistan, Jhang and Rasulpur) soils, moderate in medium and moderately fine (Sultanpur, Harunabad, Shahdara, Nabipur, Miani), and high in fine (Pacca) textured soils.

2.3.2. 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 an indication of higher exchangeable sodium percentage and residual sodium carbonates. Critical examination of ion distribution reveals that a higher pH > 9.5 in sodic and strongly saline-sodic soils is strongly correlated to high RSC (residual sodium carbonate) 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 high watertable.

2.3.3. Electrical Conductivity and Ion Analysis of Saturation Extract

Electrical conductivity of the saturation extract (EC_e) of normal soils (Jhang, Rasulpur, Sultanpur, Shahdara and Miani soil series) is generally > 1dSm^{-1} but as high as 2.95 dsm^{-1} in Harunabad series and 3.64 dSm^{-1} in Nabipur series, which is probably the result of high watertable and continuous use of high EC and RSC irrigation water. Electrical conductivity of salt affected soils ranges between 4 and 45 dSm^{-1}, having a decreasing trend with depth in the soil profiles. The concentration of salts in the upper 60 cm is very high (3 to 5 fold) compared with lower depths. This phenomenon is more pronounced in barren fields. The problem of salinity and sodicity in terms of EC_e, 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_e of < 2dSm^{-1}. In all strongly saline-sodic soils, with pH > 9.6, (Adilpur, Satghara and Mariala soil series) 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 Cl^{-} and $CO_3^{=} + HCO_3^{-}$ anions (Jhakkar soil series).

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 except Nabipur series which has shown Zn sufficiency in the surface soils, are invariably deficient in zinc, whereas Rasulpur, Harunabad, Bagh, Sultanpur and Jhakkar soils are also deficient in Fe. Jhang and Sodhra soil series are invariably deficient in all micronutrients except copper, whereas Cholistan soil series is deficient in all micronutrients except manganese. It is interesting to note that all of the soils having fine texture (Pacca, Miani, Adilpur and Satghara soil series), regardless of salinity and sodicity effects, are sufficient in all of the three remaining micronutrients. Shahdara and Nabipur soils are also sufficient in all these elements.

2.3.5. 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}.

These properties are used as an indicator of soil problems like compactness, resitance to root penetration, aeration and water retention/movement in the soil horizon (Bodman (1942) and Taylor et, al (1966)).

Perusal of data indicates that the bulk density in normal and saline-sodic soils ranges from 1.38 to 1.66 g cm^{-3} and 1.35 to 1.75 g cm^{-3}, respectively, whereas total porosity ranges from 34-49% in all of the soils. The data indicates that saline-sodic soils, though, 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 for fine textured soils making it dense. The bulk density of the top cultivated soils are invariably low, indicating the presence of a ploughpan, particularly in Jhang, Rasulpur, 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. Similarly, higher densities (1.70 to 1.77) in Nabipur indicates dispersion and clogging effect through the use of bad quality irrigation water.

2.3.6. Infiltration Rates and Hydraulic Conductivity

For the planning of irrigation scheduling and designing drainage systems, a knowledge of water intake rate and transmission characteristics of soils is essential. For this purpose, the basic intake rate (readiness of vertical intake of water through a soil profile from the soil surface), cumulative intake and hydraulic conductivity of distinct horizons (with respect to transmission characteristics) were taken in the vicinity of typical soil profiles. Intakes 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 intake rates are given at the end of each soil profile description and cumulative intakes against time is reproduced in Table 2.4 and is also shown in the form of graphs for classification of soils into intake families in Figures 2.1, 2.2 and 2.3.

Table 2.4. Cumulative intake of soils series against time.

Adilpur	0.50	0.67	0.80	0.88	0.97	1.07	1.20	1.30	1.60	1.80	0.22
Cholistan	2.05	2.75	3.93	4.83	6.08	7.37	10.63	13.47	18.67	23.80	5.13
Dungi	0.38	0.48	0.65	0.75	0.85	0.92	0.98	1.10	1.26	1.38	0.14
Harunabad	0.55	0.85	1.23	1.45	2.05	2.30	2.90	3.40	4.25	4.95	0.78
Jhakkar	0.57	0.70	0.83	0.92	1.03	1.18	1.35	1.70	1.95	2.20	0.25
Jhakkar(cult.)	0.25	0.36	0.46	0.53	0.63	0.69	0.80	0.89	0.98	1.07	0.09
Jhang	0.20	0.50	0.80	1.00	1.20	1.70	2.45	3.10	4.30	5.50	1.20
Mariala	0.42	0.52	0.70	0.78	0.88	0.97	1.08	1.17	1.36	1.53	0.18
Miani	0.25	0.38	0.50	0.57	0.63	0.67	0.72	0.75	0.81	0.87	0.06
Nabipur	1.10	1.40	1.73	1.93	2.23	2.40	2.82	3.10	3.52	3.52	0.36
Pacca	0.40	0.63	0.87	1.00	1.17	1.33	1.48	1.63	1.83	2.03	0.20
Rasulpur	0.50	0.75	1.05	1.30	1.70	2.05	2.55	3.20	4.20	5.15	1.00
Satghara	0.13	0.18	0.23	0.28	0.30	0.37	0.42	0.41	0.65	0.83	0.18
Shahdara	1.08	1.90	2.35	2.73	3.40	4.03	5.10	6.20	8.18	10.18	2.00
Sultanpur	0.40	0.60	0.90	1.10	1.20	1.30	1.45	1.60	1.90	2.20	0.30

Figure 2.1. Cumulative intake against time of normal soils.

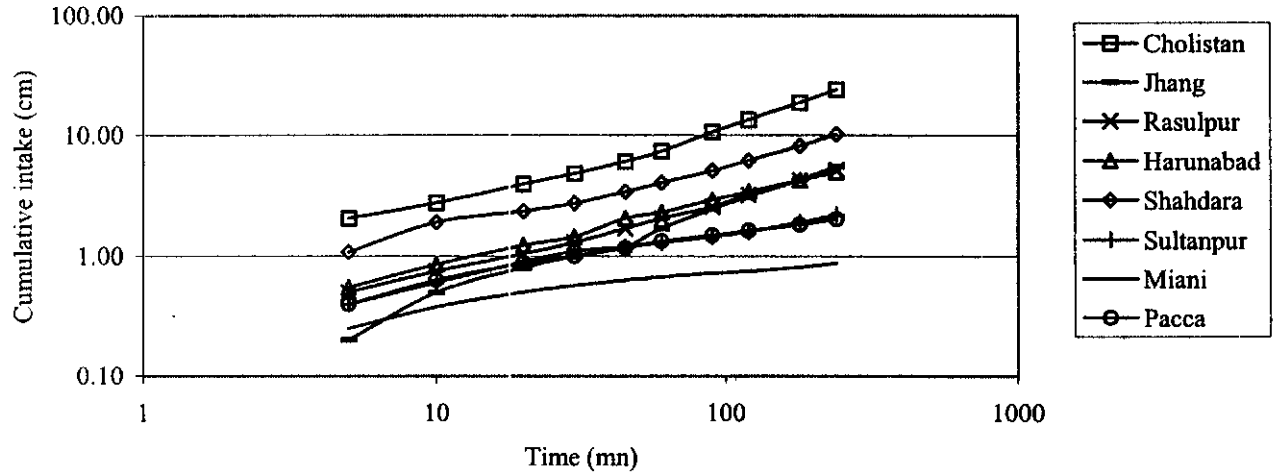


Figure 2.2. Cumulative intake against time of saline-sodic soils.

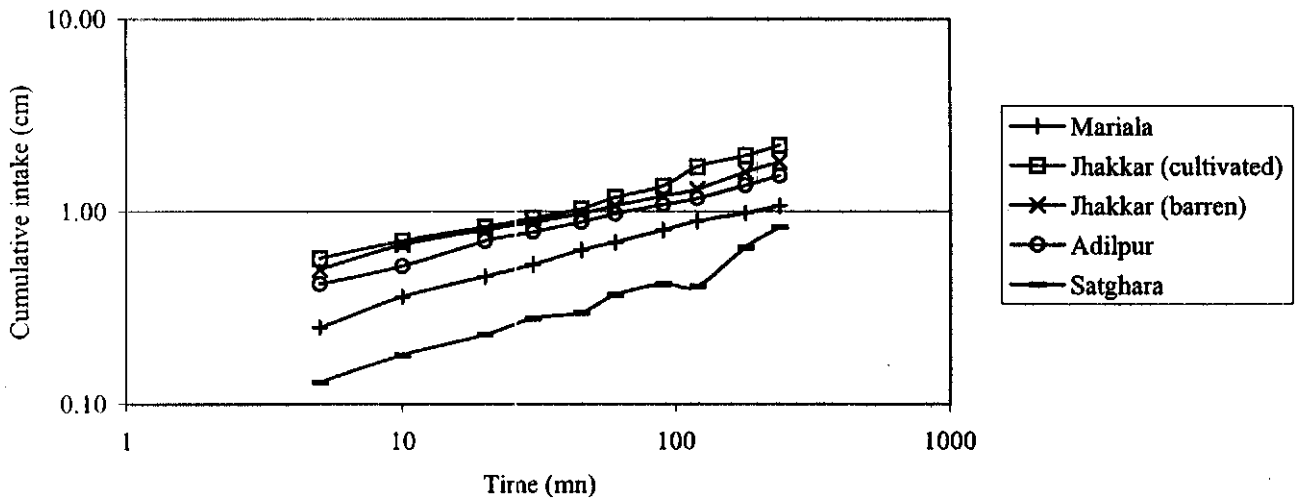
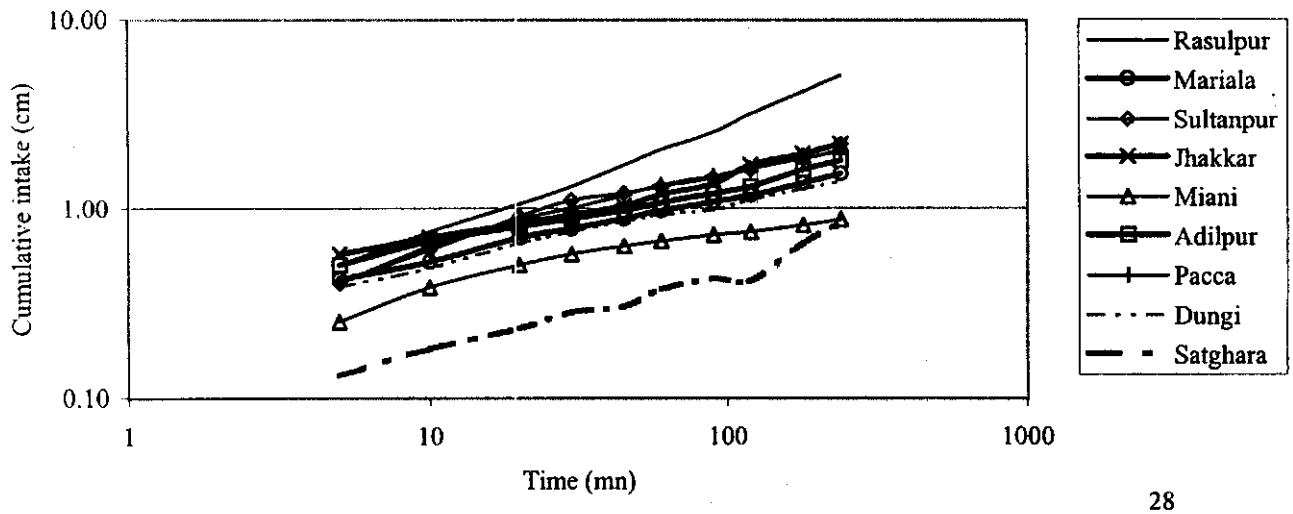


Figure 2.3. Cumulative intake against time of normal vs. saline-sodic soils.



According to FAO classification (1979), the infiltration rates of Harunabad, Jhang, Rasulpur and Shahdara fall within the optimum category for surface irrigation. However, all of these soils are unsuitable for rice cultivation because of their higher infiltration rate. Adilpur, Jhakkar, Pacca, Satghara, Miani, Mariala and Dungi soils with slow infiltration rates are marginally suitable for surface irrigation. However, these soils are suitable for rice. Slow infiltration rate is attributed partly to clayey and silty nature of soils and partly to dispersion and clogging of drainage pores in sodic soils. These soils need gypsum application, deep plowing and farm yard/green manuring for their efficient reclamation and improving their infiltration rate. Cholistan series has a high basic intake rate and is marginally suitable for surface irrigation. Green manuring and suitable irrigation management technology must be followed on this soil for achieving reasonable irrigation efficiency. The presence of a compact layer near or below the surface (plough pan) in almost all of the soils (especially Jhang, Miani, Mariala, Nabipur) may have restricted the basic intake rate.

Hydraulic conductivity was measured by the auger hole method for horizons below the watertable and by inverse auger hole method for horizons above the watertable (Van Bears 1958). Hydraulic conductivity of a horizon is a function of texture, structure, salinity/sodicity, organic matter, porosity, size of pores and bulk density. This is further influenced by moisture condition and presence of a watertable near the horizon.

Following the FAO (1963) hydraulic conductivity classification, the permeability of each soil series has been assessed and given at the end of the soil profile description. Perusal of the data shows that the permeability of Satghara soil, being dense saline-sodic, is very slow. In the case of Adilpur, it is slow and for Jhakkar (barren), Dungi, Miani and Pacca soils, it is moderately slow. The permeability of Harunabad, Sultanpur and Shahdara soils is generally moderate. However, the data indicate that it is moderately slow below 60 cm in Harunabad (may be due to subsoil saturation/relatively higher bulk density). On the other hand, it is relatively higher (moderately rapid) in Jhakkar soils with coarse substratum. The permeability of Rasulpur and Mariala series is moderately rapid to moderate, whereas it is rapid to moderately rapid for Cholistan and Jhang series.

3. SOIL DRAINAGE

3.1 GENERAL

The survey area covers 76,716 hectares (ha). About 90 percent (69,045 ha) is used for irrigated crop production. At present, about 23.45 percent (17,989 ha) of the total area has the problem of high watertable. Out of this, about 14,811 ha is imperfectly drained and 3,184 ha poorly drained and needs special attention for proper irrigation and drainage and adoption of appropriate cropping patterns. The main source of high watertable is invariably seepage from the irrigation system.

The drainage problem in the survey area is very closely related to physiography, soils and management of irrigation water. On the basis of these criteria, the drainage of the area is discussed separately on various landforms as under.

3.1.1 Drainage in Old Wind Resorted Sandy Terrace

This terrace is 2 to 3 meters higher than the adjoining subrecent (Early Holocene) terrace and mostly unirrigated. The undulating areas (SMU* No.1, 2, and 3) are sandy, whereas the level areas (SMU No.4) are clayey. A small part of the terrace has been brought under tubewell/canal irrigation for cumulation. Currently, this terrace has no problem of high watertable. However, foreseeing the reclamation (irrigation) needs of problem soils, their permeability and physiography, the area is susceptible to high watertable conditions if irrigated without providing a drainage system and adopting a proper cropping pattern.

3.1.2 Drainage in Subrecent (Early Holocene) River Terrace

This terrace is mostly under perennial canal irrigation and is being supplemented with tubewell irrigation, especially at the tails of channels where canal supplies are very acute. This terrace is dominated by sandy loam to loamy sand soils (SMU No.5 to 13), while a minor area is loamy (SMU No.14 to 20). The sandy soils have moderately rapid to rapid permeability, causing enormous seepage from canals and irrigation channels. The loamy soils, with moderately slow to moderate permeability, occupying comparatively lower parts, are prone to waterlogging. Currently, about 17,606 ha (54% of this terrace) has already been waterlogged. Around headworks and main distributaries, the watertable is at 50 to 100 cm (SMU No. 10, 12, 15 and 19) compared to farther areas where the watertable is at 100 to 150 cm (SMU No.7, 9, 14, and 18). The waterlogged phases of soils occupy a lower position compared to their normal phases in the landscape. No waterlogging in the command areas at the tail of Fordwah Branch has been noticed, which is probably because of low flowing capacities there. Seepage is more from the irrigation system rather than irrigation itself. The situation may be improved by lining of irrigation channels, growing of low delta crops, adoption of improved irrigation techniques (like long parceling pattern of small width having some slope, light but frequent irrigations) and installation of tubewells where the water quality is safe.

* SMU: Soil mapping units.

3.1.3 Drainage in Subrecent (Middle Holocene) River Terrace

This terrace is under seasonal canal and tubewell irrigation. The soils of this landform are predominantly medium textured (SMU No.21, 22, 23, and 28) followed by moderately fine (SMU No. 24, 25, 29 and 30) and fine textured (SMU No. 26 and 31) having permeability as moderate, moderately slow to slow, and slow to very slow, respectively. The sodicity problem in SMU No.27 to 31 has further lowered their permeability. There is little risk of waterlogging because of seepage from the irrigation system. Its groundwater is largely associated with the Sutlej River, which recharges it during floods. The risk of waterlogging is further reduced because of vertical drainage in the form of tubewell irrigation.

Depressional areas, particularly SMU No.25 to 27 and 29 to 31, have a problem of seasonal ponding during heavy monsoon rains or canal breaches because of local runoff and slow to very slow permeability. Prolonged ponding may result in failure/heavy damage to the cotton crop. This aspect should be given due consideration while planning the cropping pattern and reclamation technology for the area.

3.1.4 Drainage in Recent River Terrace

This terrace is just above the seasonally flooded belt adjacent to the Sutlej River. Although the area is above the general flood level, yet very high floods inundate it with sheet flooding. The soils are deep stratified sandy (SMU No.32 to 34) to medium textured underlain by sand (SMU No.35) with rapid to moderate permeability. The groundwater hydrology is associated with the Sutlej River, which recharges it during floods and acts as an open drain during dry periods. Locally, some areas along this active channel of the Sutlej River, or slip-off slope of old river channels, have high watertable at 100 to 150 cm (SMU No.34). The later unit turns into marsh land during the monsoon rainy season and/or because of a breaching the canal. The salinization process is also active in this unit and has resulted locally into strong surface salinity and sodicity.

4. SOIL SALINITY/SODICITY

4.1 GENERAL

Soil salinity refers to the amount of soluble salts in the soil, enough to affect plant growth, whereas sodicity refers to excessive sodium cations in the soil solution (Na^+ : Ca^{2+} >1) resulting in higher exchangeable Na (exchangeable sodium percentage > 15). High exchangeable sodium percentage (ESP) makes soil particles suspended and soil porosity clogged which results in deterioration of the soil physical condition and, hence, hinders plant growth. On the basis of salt contents, soils are classified as: normal, slightly saline, moderately saline and strongly saline with an electrical conductivity of the saturation extract as 0-4, 4-8, 8-15 and more than 15 dSm^{-1}, respectively. Soils are termed sodic with ESP > 15 or pH > 8.5. The sodicity problem is termed as slight with pH 8.5 to 9.0, moderate with pH 9.0 to 9.5 and strong with pH > 9.5. Soils are termed porous when the soil porosity and soil structure is not very much affected because of sodicity. However, with passing geo-times and severe sodication, soils are sometimes so degraded that no drainable porosity is left and the hydraulic conductivity has been reduced to very slow, then the soils are termed "dense". For developing any reclamation plan or research activity in a salt affected area, knowledge about salinity/sodicity, its genesis, status (extent and type) and reclamation principles is essential.

4.2. SALINITY/SODICITY STATUS

About 18.20 percent (13,966 ha) of the total area is currently salt affected. Another 38.94 percent (29,877 ha) has a risk of slight salinity and sodicity, associated with high watertable and use of brackish tubewell water. Patchy salinity, low permeability compared with the past, reduced germination and low crop yields are common features of the salinity risk prone areas. The remaining 41.85 percent (32,109 ha) constitutes normal soils with no risk of salinity or sodicity. Regarding the types of salts and their distribution in the soil profile, a critical review of laboratory data reveals that salts are evenly distributed in profiles of normal soils, whereas salt concentration decreases with depth in salt affected soils. The salt concentration is very high (3 to 6 fold) in the surface soil compared with the subsoil; this phenomenon is more pronounced in barren soils. $Ca^{2+} + Mg^{2+}$ are the dominant cations in normal soils, whereas in saline-sodic soils, the dominant cation is Na^+. In normal soils, the $CO_3^=$ anion is absent and $SO_4^=$ is the dominant anion followed by Cl^- and HCO_3^-. In strongly saline-sodic soils, with pH > 9.6, the dominant anions are $CO_3^= + HCO_3^-$ followed by $SO_4^=$ and Cl^-, whereas in slightly saline-sodic soils, the dominant anion is $SO_4^=$ followed by Cl and $CO_3^= + HCO_3^-$.

The salinity/sodicity status, genesis of salt affected soils, and their reclamation principles for the salinity/sodicity map units as shown in Table 4.1 are discussed as under. The salinity and sodicity map units are made by grouping the soil mapping units having the same severity of salinity and sodicity and needing the same reclamation measures. Physical distribution of these units is shown on an accompanying salinity and sodicity map at a scale of 1:100,000.

Table 4.1. Salinity and sodicity status of the soils of Chishtian Irrigation Sub-Division.

	Salt Affected Soil		13,966	18.20
1.	Severely saline, gypsiferous soil	4	289	0.38
2.	Porous, strongly saline-sodic soils	27,28,29,30	8274	10.79
3.	Dense, strongly saline-sodic soils	31	1045	1.36
4.	Porous, moderately saline-sodic soils	7,16	2476	3.23
5.	Slightly saline-sodic/non saline-sodic soils	11,12,20,23	1882	2.45
6.	Normal soils with risk of salinity/sodicity		29877	38.94
	a) Associated with high watertable and bad quality tubewell water	9,10,14,15, 18,19,34	15445	20.13
	b) Associated with bad quality tubewell water	1,2,3,5,6,8,13, 17	14432	18.81
7.	Normal soils with no risk of salinity and sodicity	21,22,24,25,26, 32,33,35	32109	41.85
	Misc. areas		764	1.00
		G. Total	76716	100.00

4.2.1. Severely Saline, Gypsiferous Soils (289 ha; 0.38 percent)

The unit is a part of the Old Wind Resorted Sandy terrace and occupies interdunal valleys. The salinity is of ancient nature and is the result of stagnating flood water in channel infills resulting in soil mineralization, coupled with continuous evaporation under an arid climate. The soils are mostly deep, stratified and strongly saline (EC > 16 dSm^{-1}, pH 9.0, but if reduced to 8.0, indicating a presence of gypsum) silty clays/silty clay loams with moderately slow to slow permeability. Although the unit receives seasonal canal water, the supply is very limited because of being at the tail of the distributaries and higher topography. Underground water is also hazardous. Therefore, its reclamation seems very difficult.

4.2.2. Porous Strongly Saline-Sodic Soils (8274 ha; 10.79 percent)

The unit is a part of the Subrecent (Middle Holocene) river terrace and mostly occurs at the merger of Middle and Early Holocene river terraces. The salinity and sodicity is the result of ponding and high watertable condition in these areas due to their lower physiographic positions (channel infills and depressions) coupled with mineralization and continuous evaporation under an arid climate. The soils are dominantly deep, weakly structured, strongly saline-sodic (EC: 16-50 dSm^{-1}, pH: 9.0 to 10.5, ESP: 15-85) silt loams with moderate permeability followed by silty clay loams and silty clays with moderately slow to slow permeability. Quite a large part, especially silt loam soils, is cultivated with canal or tubewell water. The soils in these areas are moderately saline-sodic (EC: 8-16 dSm^{-1}) and salts are more evenly distributed in the soil profile. In some areas, salinity is reduced to around 3 to 7 dSm^{-1} with pH 8.5 to 9.0. Reclamation of the area is feasible, if inputs like regional drainage, irrigation water (canal/tubewell) for leaching, deep chiseling, addition of organic matter for improving permeability, and gypsum application for soil amelioration are provided in the area.

4.2.3. Dense Strongly Saline-Sodic Soils (1045 ha; 1.36 percent)

This unit in terms of its physiography, genesis, salinity and sodicity status, is just like the unit described above in Section 4.2.2, except for its sodicity level and degree of soil deterioration. The unit occupies broad depressions comprising mainly deep, weakly structured, strongly saline-sodic (EC: 30-50 dS m^{-1}, pH > 9.5 and ESP: 30-80) silt loam soils with moderately slow permeability followed by dense silty clays with very slow permeability. The unit is barren. Reclamation of this unit is presently very difficult as inputs and efforts required are very high. However, reclamation principles are the same as for the unit in Section 4.2.2.

4.2.4. Porous Moderately Saline-Sodic Soils (2476 ha; 3.23 percent)

This unit is part of the Subrecent (Early Holocene) river terrace and invariably occurs along the confluence of Middle and Early Holocene river terraces. The genesis of the unit is the same as for the unit described in Section 4.4.2. The soils are deep, weakly structured, porous, moderately saline-sodic (EC: 8-16 dSm^{-1}, pH: 8.5-10.0, ESP: 15-35) sandy loams and loams, with moderate or moderately rapid permeability. The soils are mostly under cultivation. However, in some barren parts, the EC may go as high as 60 dSm^{-1}. On the other hand, some cultivated parts have been reclaimed to slightly saline-sodic (EC: around 6.0 dSm^{-1}) or non saline-sodic (EC < 4 and pH 8.5 – 9.0) soils. High watertable (100 to 150 cm) have developed in sandy loam soils which renders their reclamation difficult. Underground water of the terrace is dominantly marginal/hazardous. The area is conducive to reclamation if provided with: regional drainage/lining of irrigation channels; gypsum application for the amelioration of saline-sodic soils and hazardous water and intensive cultivation all the year round.

4.2.5. Slightly Saline-Sodic /Non Saline-Sodic Soils (1882 ha; 2.45 percent)

This unit includes reclaimed phases of saline-sodic soils (EC around 4 dSm^{-1} and pH: 8.5-9.8) and soils with surface salinity/sodicity caused by irrigation with hazardous/marginal tubewell water or the presence of a high watertable. Surface EC remains around 4-8 and pH 8.5 to 9.0. The soils are deep, well drained sandy loams or silt loams/very fine sandy loams with moderately rapid to moderate permeability. The soils are easy to reclaim if leached with good quality irrigation water, use of gypsum for the amelioration of hazardous groundwater, and with intensive cultivation.

4.2.6. Normal Soils with Risk of Slight Salinity/Sodicity (29877 ha; 38.94 percent)

The unit is a part of the Subrecent (Early Holocene) river terrace and the risk is associated with the use of bad quality tubewell water and/or high watertable. Groundwater quality of this terrace is, in general, marginal or hazardous. About 54 percent of this terrace has a watertable above 150 cm. Careful perusal of salinity survey data reveals that some sites of normal soils with or without high watertable, being irrigated with marginal or hazardous water, have either high pH (8.5 to 8.8) or higher EC (around 4 dSm-1) compared to sites being irrigated with safe tubewell water. This indicates the risk of salinity or sodicity to these areas. This risk can be overcome by: avoiding the use of bad quality tubewell water; gypsum application for water amelioration; and application of mixed tubewell and canal waters, along with lining of irrigation channels and avoiding cultivation of high delta crops.

4.2.7. Normal Soils with No Risk of Salinity/Sodicity (32109 ha; 41.84 percent)

This unit is a part of the Subrecent (Early Holocene) and recent river terraces. Tubewell water is generally safe and the area is free of high watertable. Although some sites being irrigated with hazardous tubewell water have shown slight salinity/sodicity (pH 8.5 to 8.8 and EC around 4 dSm^{-1}), the unit seemingly has no risk of salinity/sodicity at present because the groundwater quality is safe for irrigation and free of high watertable. However, as the soils of the unit are silty or clayey, they are prone to salinization/sodication if irrigated with hazardous/marginal tubewell water.

5. LAND CAPABILITY CLASSIFICATION

5.1. GENERAL

Land capability classification is a method of grouping the soils of an area to show their relative suitability for sustained production of common agricultural crops, or for grazing, or forestry.

The classification outlined below is designed to suit the agricultural conditions of Pakistan. It is similar in basic structure to the U.S.D.A. Land Capability Classification (Klingebiel and Montgomery, 1961). Soils placed in the highest class (I) have the least limitations for agricultural use and relatively little effort is required to produce high crop yields. In successively lower classes (II to IV), there are increasingly severe limitations for agricultural use and increasingly greater effort in terms of expenditure and special management is required to produce high crop yields. Soils in the lowest four classes (V to VIII) are unfit for economic arable crop production.

The classification reflects the potential of the soils for improvement. Soils in class I will respond best to good management and give the highest returns to inputs of water, quality seed and fertilizer. The lower classes have successively lower potentialities for improvement. This fact is used as the major criterion in differentiating Class III from Class IV land; in the case of Class III land, improvement to a high level of productivity, although difficult, is considered feasible and economic to the national economy; in Class IV, improvement to a high level of productivity is considered impracticable or uneconomic.

5.2. FRAMEWORK OF CLASSIFICATION

Two levels of generalization are recognized: land capability class and land capability subclass. The first and the broadest grouping, land capability class, is identified by the Roman numbers I to VIII. The prefix is used to denote that classification is for irrigated agriculture. The soils within each land class have limitations of about the same degree. Class I land (very good agricultural land) has the least limitations for crop production. Class II to IV have progressively increasing limitations. Class V to VIII are considered unfit for economic production of agricultural crops. The kinds of limitations may, however, vary within each class.

At the second level of generalization (i.e., the land capability subclass) soils having the same kind or kinds of limitations for agricultural use are grouped together. Subclasses are designed, where applicable, by small letters following the class numeral. The following subclasses have been recognized in the present survey area.

w- Soils restricted in use due to excess water because of poor drainage, or high water-table, or ponding.

s- Soils restricted in use due to limitations inherent in the soil profile such as shallow soil depth, slowly permeable layers, or low moisture-holding capacity.

a- Soils restricted in use due to salinity/sodicity.

r- Soils restricted in use due to undulating topography.

The dominant limitation determines the assignment of soils to the subclasses. If the effect of two limitations is essentially equal, the subclasses have priority according to the sequence of the list above. Limitations may have a cumulative effect (e.g. two limitations, each lowering the land capability by one class, may lower it by two classes when combined).

5.3. CLASS AND SUBCLASS DESCRIPTIONS

The class and subclass descriptions have been kept as specific as possible by restricting them to conditions encountered in the area. In the descriptions which follow, the terms traditional management means use of local seed, bullock-drawn ploughing, uncontrolled distribution of irrigation water, a low level of manuring, inadequate cultural practices, absence of drainage or flood control, etc. The term modern management implies proper water management to avoid wastage of irrigation water, use of improved steel plough (where applicable), use of good quality seed, and adequate application of fertilizers, in addition to: plant protection, adequate cultural practices, soil conservation measures, and local drainage or protection against runoff from the surrounding land where necessary.

5.3.1. Class I: Very Good Irrigated Land

Soils in this class have either no, or only a slight limitation, for crop production throughout the year and have the widest range of agricultural use. They are level to nearly level, deep and well to moderately well drained, and have good water and nutrient holding capacity with moderate to moderately slow permeability. These soils are easily worked to good physical condition, favorable for germination and growth of plants.

Under traditional management and with sufficient irrigation water, these soils can be used for crop production throughout the year and are at least moderately productive. With modern management and sufficient irrigation water, they are capable of giving very high yields of a wide range of crops throughout the year.

5.3.2. Class II: Good Irrigated Land

Soils in this class have either minor limitations for crop production throughout the year, or a narrower range of suitable crops than soils in class I. Remedial measures are mostly easy to apply.

Soils in this class have one of the following limitations: moderate depth to sand or impermeable layer; moderately rapid permeability and a low water holding capacity; slow permeability and short-periods of waterlogging; or a minor problem of workability and seed-bed preparation or minor salinity problem.

irIIw: Soils in this subclass are moderately well and seasonally imperfectly drained, and generally have medium to moderately coarse textures. They may be associated with slight profile or surface salinity and sodicity.

Under traditional management, these soils are used for crop production with irrigation, but give lower yields than the best soils due to high water-table.

With modern management, including provision of drainage and lining of irrigation channels to lower the watertable, and gypsum application as required for tubewell water amelioration, these soils can produce high yields of suitable crops.

irIIs: Soils in this subclass are either fine textured and rather slowly permeable, and/or have a fine topsoil making seedbed preparation difficult, limiting the choice of crops or requiring extra timely ploughing to maintain aeration; or are moderately coarse textured with a moderately rapid permeability and a relatively lower water and nutrient holding capacity. Some of the soils have slight surface salinity.

With sufficient irrigation water and modern management, including timely seed-bed preparation on clayey soils at proper moisture level, or more frequent and smaller applications of irrigation water on soils with a relatively low water holding capacity, they can have the same productivity and, generally, the same choice of crops as soils in class I. Management costs would however be higher. Alternatively, total productivity could be very high with crop choice, limited to rice, berseem and sugarcane on clayey soils and wheat, fodder and oilseeds on sandy loam soils.

irIIa: This subclass comprises phases of very good and good soils, which have minor problem of surface salinity/sodicity or slight profile salinity, which is associated with bad quality irrigation water or partly reclaimed saline-sodic soils. The salts could be easily leached by a few applications of extra irrigation water and slight gypsum application as required for soil and water amelioration.

Under traditional management, this land is used for general cropping under irrigation but gives lower yields.

After a few extra irrigations with good quality water and gypsum application to leach the salts, this land could be as highly productive as the very good agricultural land with modern management.

5.3.3. Class III: Moderate Irrigated Land

Soils in this class have either moderate limitations for crop production throughout the year, or severe limitations during one season, and have a very limited range of suitable crops. Part of the limitations can be removed at relatively high cost, part cannot and require special management or selection of suitable crops for attaining high productivity.

The soils in this class have either poor/seasonally poor drainage with or without some salinity; or moderate salinity/sodicity problems in soils with good porosity, with or without high water-table; or are somewhat of a sandy nature with relatively rapid permeability.

irIIIw: Soils in this subclass are poorly/seasonally poorly drained and have medium to moderately coarse textures. Part of it is associated with surface salinity and sodicity.

Traditionally these soils are mostly used for rice or fallow in summer and for wheat or a leguminous crop in winter.

With modern management, including regional drainage to lower the water-table and lining of irrigation channels, these soils can produce good yields of suitable crops throughout the year. Rice and high delta crops should not be included in crop rotation.

irIIIs: Soil in this subclass are sandy having rapid permeability, have low nutrient and water holding capacity, and low inherent fertility. Part of it is seasonally imperfectly drained and slight salinity and sodicity.

Traditionally, these soils are mostly used for wheat, guara, lentil cotton and oilseeds giving low yields.

With moderate management, including proper soil and water management technology and growing suitable crops (low delta crops, having low fertility requirements) these soils can produce high yields.

irIIIa: Soils in this subclass are general moderately saline sodic and have moderately coarse, medium, moderately fine and fine textures. The salinity/sodicity is ancient and was caused by high watertable which occurred at 1.5 to 3 meters (within the capillary range) for a long period in the geo-past. Part of moderately coarse soils have the problem of high watertable at 100-150 cm.

Under traditional management, this land is partly used for restricted irrigated cropping, but yields of most crops are moderate and some sensitive crops give poor yields, or fail. A major part of this land is lying barren and supports poor grazing.

After amelioration of salinity/sodicity by adopting reclamation technology, land leveling, deep chiseling, moderate gypsum application, heavy leaching and growing of Sudan/Australian grasses followed by a rice crop, good yields of most common crops can be obtained with modern management. The high watertable, however, would be a constant threat. To remedy this, the regional watertable can be lowered by installing tubewells and lining irrigation channels. The depressional areas, or abandoned river channels, must be connected with surface drains to dispose of the run-off quickly.

5.3.4. Class IV: Poor Irrigated Land

Soils in this class have severe limitations for crop production and may have a very narrow range of agricultural use. Improvement to a high level of productivity may or may not be technically feasible, but would entail prohibitively high expenditures for development/maintenance.

irIVs: Soils in this subclass are gently undulating and very sandy. The land is canal irrigated with limited supply, but results in a great loss of water due to very low water holding capacity/rapid permeability. These soils support poor crops under traditional management at high costs of water.

With modern and intensive management, high yields of suitable crops can be obtained. Irrigation of this land for general agricultural crops would not be economical.

5.3.5. Class VII. Land with a Poor Grazing Potential

Most of the land in this class, at present, is used for poor grazing for part of the year either due to excessive wetness, or undulating sandy soils, or severe salinity and sodicity and shortage of irrigation supply.

VIIw: This subclass consists of nearly level, very poorly drained moderately saline, sandy and loamy soils with watertable at or near the surface.

Traditionally, it supports some vegetation at its periphery and is used for poor grazing.

VIIs: This subclass comprises nearly level to undulating very sandy soils with very low water-holding capacity and very rapid permeability.

Traditionally, these soils are covered with poor scrub and are used for poor grazing and some fuel wood.

VIIa: This subclass comprises medium to moderately fine/fine textured, severely saline-sodic soils having high watertable and supports little vegetation. After reclamation through presently costly investment, these soils may have a potential for irrigated agriculture.

The land capability classification at the subclass level of soils, their phases, and miscellaneous areas, is presented in Table 5.1.

Table 5.1. Land capability classification of soils in Chishtian Irrigation Subdivision.

1.	Adilpur	irIIIa	VIIa
2.	Awagat, silty clay loam surface, poorly drained	irIIIw	--
3.	Awagat silty clay loam surface, imperfectly drained	irIIw	--
4.	Cholistan	irIVs	VIIs
5.	Duneland/shifting sand	--	VIIs
6.	Dungi	irIIIa	
7.	Ghandra	irIIIa	--
8.	Harunabad	irI	--
9.	Harunabad, saline-sodic surface	irIIa	--
10.	Harunabad, poorly drained	irIIIw	--
11.	Harunabad, imperfectly drained	irIIw	--
12.	Jhakkar	irIIIa	--
13.	Jhang	irIIIs	VIIs-
14.	Makai	irIIIa	VIIa
15.	Mariala, imperfectly drained	irIIIa	--
16.	Miani	irI	--
17.	Nabipur	irI	--
18.	Pacca	irIIs	--
19.	Rasulpur	irIIs	--
20.	Rasulpur, saline-sodic surface	irIIa	--
21.	Rasulpur, saline-sodic surface, poorly drained	irIIIw	--
22.	Rasulpur, poorly drained	irIIIw	--
23.	Rasulpur, imperfectly drained	irIIw	--
24.	Satghara	irIVa	VIIIa
25.	Shahdra	irI	--
26.	Sodhra	irIVs	VIIs
27.	Sodhra, medium surface	irIIIs	--
28.	Sodhra, medium surface, imperfectly drained	irIIIs	--
29.	Sultanpur	irI	--
30.	Sultanpur, saline-sodic surface	irIIa	--
	Miscellaneous areas		
	Graveyard		Not classified.
	Habitation mound		Not classified.
	Marsh land	--	VIIw
	Open water	--	VIIIw

Next >>

5.4. LAND CAPABILITY MAPPING UNITS

The soils of the area have been grouped into five major land capability classes and 18 land capability subclass units, which are presented in Table 5.2, along with their extent and component soil map units. Distribution of these units has been shown on the accompanying land capability map at the scale of 1:100,000.

These map units are briefly described in the subsequent section. In addition to the potential and extent, the description includes main soil characteristics of soils grouped under each unit, present land use, limitations of the units, and appropriate specific improvements.

Table 5.2. Land capability units and their extent.

1.	**Very good irrigated land**				27136	35.37
	1.1	irI.	Loamy, silty and fine silty soils with none or very slight hazard	17,21,22,24	25421	33.14
	1.2	irI-2	Silty soils, partly slightly flooded every year	35	1715	2.23
2.	**A. Good irrigated land**				29566	38.54
	2.1	IrIIw-1	Loamy soils with watertable at 100-150 cm	14,18	1637	2.13
	2.2	irIIw-2	Coarse loamy soils with watertable at 100-150 cm	9	10489	13.67
	2.3	irIIs-1	Coarse loamy soils with moderately rapid permeability	8	9817	12.80
	2.4	irIIs-2	Fine silty and clayey soils with moderately slow to slow permeability and workability problem	25,26	5989	7.81
	2.5	irIIa-1	Coarse loamy soils with surface salinity and sodicity	11	833	1.09
	2.6	irIIa-2	Loamy and silty soils with surface salinity and sodicity	20,23	801	1.04
	B. Good and moderate irrigated land with some poor grazing				1966	2.56
	2.7	irIIs-irIIIs-VIIs	Coarse loamy and sandy soils with semi-stabilized sand dunes	6,13	1966	2.56

Table 5.2. (Complete)

3.	**Moderate irrigated land**				14740	19.21
	3.1	irIIIw	Loamy soils with watertable at 50-100 cm	10,12, 15, 19	3184	4.15
	3.2	irIIIs-1	Sandy soils with rapid/moderately rapid permeability	5,33	423	0.55
	3.3	irIIIs-2	Sandy soils with rapid/moderately rapid permeability and watertable at 100-150 cm	34	383	0.50
	3.4	irIIIa-1	Saline sodic, loamy and silty soils	7,16,28	5073	6.61
	3.5	irIIIa-2	Saline sodic, silty, fine silty and clayey soils with or without slow/moderately slow permeability and workability problem	29,30,27	5677	7.4
4.	Poor irrigated land				459	0.60
	4.1	irIVs	Gently undulating sandy soils with rapid permeability	1,32	459	0.60
5.	Poor grazing land				2412	3.14
	5.1	VIIw	Sandy and loamy soils with watertable near or at the surface	Marsh land	327	0.43
	5.2	VIIs	Gently undulating sandy soils with shifting/semi-stabilized sand dunes	2,3	751	0.98
	5.3	VIIa	Severely saline-sodic dense silty and clayey soils with slow/very slow permeability	4,31	1334	1.74
	Miscellaneous Areas				437	0.57
			Open water		76	0.10
			Grave yard		323	0.42
			Habitat Mound		38	0.05
				Grand Total	76716	100.00

1. Very good irrigated land: 27136 ha, 35.37 percent

Potential: This unit has a very high potential for intensive irrigated agriculture. A few progressive farmers are getting good yields, but common farmers' production is limited due to traditional management. With regular and sufficient irrigation supplies, and a high level of management, including cultivation of improved varieties of crops adapted to climatic conditions and adequate use of fertilizers, very high returns can be obtained from this unit.

1.1 irI	25421	Level, well to moderately well drained, loamy and fine silty soils	Irrigated cropping mainly wheat, cotton, fodders sugarcane and vegetables	Nil	Intensive cropping with high inputs
1.2 irI-2	1715	Level, stratified silty soils partly slightly flooded	Wheat, cotton, fodders	Flooding, stratified substratum	Intensive cropping with high inputs, construction of protection bunds

* See also soil mapping unit 17, 21, 22, 24 and 35.

2A. Good irrigated land: 29566 ha, 38.54 percent

Potential: The unit has high potential for irrigated agriculture with a high level of management. Present production is far below the true potential of the soils due to traditional management. With modern management and high inputs, including a proper drainage system, a few extra irrigation applications, mechanical land preparation at proper moisture level, improved varieties of crops adapted to climatic conditions, application of proper and adequate fertilizers, high returns could be achieved from this unit.

2.1 irIIw-1	1637	Level, imperfectly drained (w.t. at 100-150 cm), loamy soils	Wheat, cotton, fodders, rice, sugarcane	High watertable	Provision of drainage. Intensive cropping with high inputs
2.2 irIIw-2	10489	Level, imperfectly drained (w.t. at 100-150 cm) coarse loamy (sandy loams) soils	Wheat, cotton, rice, sugarcane	High watertable, moderately rapid permeability, low nutrient and water holding capacity	Provision of drainage. Split doses of fertilizers and irrigation water. Addition of organic matter. Avoid high delta crops. Precise leveling with small fields
2.3 irIIs-1	9817	Level, somewhat excessively drained, coarse loamy (sandy loams) soils	Wheat, cotton, fodders	Moderately rapid permeability, low nutrient and water holding capacity	Split doses of fertilizers and irrigation water. Addition of organic matter. Avoid high delta crops. Precise leveling with small fields
2.4 irIIs-2	5989	Level, slightly depressional, moderately well drained, fine silty and clayey soils	Wheat, cotton, sugarcane, rice fodders	Slow permeability, difficult workability, run on sites	Mechanical land preparation. Intensive cropping with high inputs. Avoid over irrigation. Provision of drainage
2.5 irIIa-1	833	Level, saline-sodic surface, somewhat excessively drained, coarse loamy (sandy loams) soils	Wheat, cotton, fodders	Surface salinity and sodicity, moderately rapid permeability, low nutrient and water holding capacity	A few extra supplies of irrigation. Avoid brackish tubewell irrigation. Split doses of fertilizers and irrigation water. Addition of organic matter. Precise leveling with small fields
2.6 irIIa-2	2801	Level, saline-sodic surface, well-drained, loamy and silty soils	Wheat, cotton, sugarcane, fodders.	Surface salinity and sodicity	A few extra supplies of irrigation. Intensive cropping with high inputs. Avoid brackish tubewell irrigation

* See also soil mapping unit 14, 18, 9, 8, 25, 26, 11, 20, 23.

2B. Good and moderate irrigated with some poor gazing land:1966 ha, 2.56 percent

Potential: About 65% of the land comprising sandy loams soils has good to moderate potential for irrigated cultivation, whereas the rest of the area consisting of gently undulating low sand dunes and supporting little vegetation has a low potential for grazing. Uneven topography, sandy soils and limited supply of irrigation water are the main limitations. Yields can only be enhanced with land leveling and growing of suitable crops.

2.7 irIIs-irIIIs-VIIs; irIIs	1004	Nearly level, somewhat excessively drained, coarse loamy soils	Wheat, cotton, fodder	Moderately rapid permeability, low water and nutrient holding capacity, uneven topography	Split doses of fertilizer and water. Avoid high delta crops. Addition of organic matter. Precise leveling with small fields
irIIIs	273	Nearly level, excessively drained, sandy soils	Wheat, cotton, guara, pulses	Rapid permeability, very low nutrient and water holding capacity, uneven topography subject to burial by blown sand	Split doses of fertilizer and water. Precise leveling and long fields with slope. Addition of organic matter and green manuring. Cultivation of drought resistant crops
VIIs	689	Gently undulating semi-stabilized low sand dunes	Poor grazing	Undulating topography, aridity, wind erosion, very sandy soils	Should better be left in natural state. Plantation of adoptable vegetation to control wind erosion and burial of adjoining land

* See also soil mapping unit 6, and 13.

3. Moderate irrigated land: 14740 ha, 19.21 percent

Potential: This unit has a moderate potential for irrigated cultivation. Present production potential is limited either due to the sandy nature of soils, or high watertable at 50-100 cm, or moderate salinity and sodicity in the soil profiles. Provision of adequate drainage to lower the high water-table and adoption of reclamation measures like application of gypsum/sulphuric acid, or sowing of Australian grass with good quality water, are essential for reclamation and increased crop production. A major part of the saline-sodic soils under canal command areas is barren (irrigable). These soils need heavy inputs in terms of gypsum and irrigation water for their reclamation.

3.1 irIIIw	3184	Level, loamy soils with watertable at 50-100 cm. Locally surface salinity/sodicity	Wheat, jantar, rice, fodder	High watertable, surface salinity and sodicity	Provision of drainage. Lining of irrigation system. Avoid over irrigation. Cultivation of low delta crops. Leaching with gypsum.
3.2 irIIIs-1	423	Level, sandy soils, partly medium surface	Wheat, cotton, guara, oilseeds, lentil	Rapid permeability, very low nutrient and water holding capacity, low fertility	Split doses of fertilizer and irrigation water. Precise leveling and small fields with slope. Addition of organic matter and green manure. Drought resistant/low delta crops
3.3 irIIIs-2	383	Level imperfectly drained (watertable at 100-150 cm) sandy soils, medium surface	Wheat, guara, oilseeds, lentil	High watertable, rapid permeability, very low nutrient and water holding capacity, low fertility	Provision of drainage. Split doses of fertilizer and irrigation water. Precise leveling and small fields with slope. Addition of organic matter and green manure. Drought resistant/low delta crops
3.4 irIIIa-1	2296	Nearly level, porous moderately saline sodic, coarse loamy, watertable at 100-150 cm	Wheat, rice, oilseeds (raya), jantar	Moderate salinity and sodicity, high watertable	Provision of drainage. Lining of irrigation system. Precise land leveling with small fields. Application of gypsum with jantar sowing followed by wheat, oilseeds and fodders
	2777	Nearly level, moderately saline sodic loamy and silty soils	Wheat, rice, oilseed (raya), jantar	Moderate salinity and sodicity, uneven relief	Land leveling. Application of gypsum/ sulphuric acid followed by heavy leaching and cultivation of Sudan/Australian grass, followed by wheat–rice crop rotation. Application of ammonium sulphate and single super phosphate. Do not leave fallow
3.5 ir IIIa-2	3274	Nearly level, porous strongly saline-sodic silty soils	Partly lying barren and partly is cultivated to wheat, rice and jantar	Strong salinity and sodicity, uneven relief	Land leveling. Application of gypsum/ sulphuric acid followed by heavy leaching and cultivation of Sudan/Australian grass, followed by wheat–rice crop rotation. Application of ammonium sulphate and single super phosphate. Do not leave fallow
	2403	Nearly level, porous strongly saline-sodic fine silty and clayey soil	Partly lying barren and rest is cultivated to wheat rice, jantar, Sudan grass, berseem	Strong salinity and sodicity, difficult workability, slow permeability, uneven relief	Land leveling. Deep chiseling. Application of gypsum/sulphuric acid followed by heavy leaching and cultivation Sudan/ Australian grass, followed by wheat-rice-berseem crop rotation. Mechanical cultivation at proper time. Application of ammonium sulphate and single super phosphate. Do not leave fallow.

* See also soil mapping unit 10, 12, 15, 19, 5, 33, 34, 7, 16, 28, 28, 27, 29, 30.

4. Poor irrigated land: 459 ha, 0.60 percent

Potential: The unit has low potential for irrigated cultivation. Gentle slopes, uneven topography, sandy soils and limited irrigation supplies are the main limitations. With traditional management, crop yields are low. Moderate crop production can only be obtained with very high inputs and by growing drought resistant crops only.

4.1 irIVs	459	Gently undulating sandy soils	Wheat, lentil, guara, oilseeds, cotton	Very low nutrient and water holding capacity, very rapid permeability, uneven relief	Precise leveling and small fields with slope. Split doses of fertilizer and irrigation water, addition of organic matter/green manure. Emphasize on drought resistant crops like melon, guara, pulses and oilseeds

* See also soil mapping unit 1 and 32.

5. Poor grazing land: 2412 ha, 3.14 percent

Potential: At present, the unit as a whole has low potential for irrigated cultivation. However, the saline-sodic soils after reclamation can have moderate to a good potential for irrigated agriculture. High water table, severe salinity/sodicity, uneven relief and the very sandy nature of the soils are the main hazards. Because of uneven topography and limited irrigation supplies, coupled with drainage, reclamation of dense saline-sodic soils is uneconomical. The unit is mostly uncultivated and supports some vegetation used for poor grazing. These soils should be set aside till ample irrigation water and cheap amendments are available.

5.1 VIIw	327	Nearly level, moderately saline-sodic sandy and loamy soils, watertable at or near the surface	Poor grazing	Water on the surface, moderate salinity and sodicity	Provision of drainage
5.2 VIIs	751	Gently undulating, very sandy soils	Poor grazing	Very sandy soils, unfavorable relief, aridity, wind erosion	Better be left in its natural state
5.3 VII	1334	Nearly level, dense, strongly saline-sodic silty and clayey soils	Poor grazing	Severe salinity and sodicity, very slow permeability, workability, uneven relief, limited irrigation supply	Leveling and provision of good quality water.

* See also soil mapping unit M.,L; 2, 3, 4; 31.

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APPENDIX A: SOIL SERIES DESCRIPTIONS

This section includes descriptions of pedons representing the modal concept of soil series indentified and mapped in the survey area. In all, 18 soil series were identified. Descriptions of eight soil series (namely, Adilpur, Harunabad, Jhakkar, Jhang, Pacca, Rasulpur, Satghara and Sultanpur) are taken from a detailed soil survey report of eight watercourse command areas in Chishtian and Hasilpur Tehsils (SSP and IIMI, 1996); and that of three soil series (namely Gandhra, Awagat and Makai) are taken from reconnaissance soil survey reports of Bahawalnagar and Cholistan. The typical soil profiles for the remaining soil series, including Cholistan, Dungi, Makai, Mariala, Miani, Nabipur and Shahdara, were described during the present survey. The descriptions include pedo-ecological characteristics like soil parent material, physiography, slope, landuse/vegetation, climate, permeability, drainage, salinity/sodicity, watertable depth and summary of important profile characteristics followed by U.S.D.A. taxonomic classification at the soil family level. Soil moisture and temperature regimes of the area are *Typic Aridic* and *Hyperthermic,* respectively. A horizon-wise detailed standard description (FAO, 1977) of typical soil profile for each soil series is given. Physico-chemical data of soil samples collected from soil horizons of each soil series are also given.

The description of typical profiles included in this section represents only the modal concepts of soil series in the area, whereas a soil series has a certain defined range of characteristics for depth, colour, texture, structure, calcareousness, pH and salinity/sodicity, which is derived from all observations of the relevant series. This range of characteristics for all of the series is given in Table 2.3.

Soil Series	:	ADILPUR SERIES
Parent Material	:	Mixed river alluvium
Physiography	:	Subrecent level plains, depresional area
Slope	:	Level to nearly level
Land use/Vegetation	:	Scattered bushes of dab and jawan
Climate	:	Semi arid subtropical monsoonal
Permeability	:	Slow
Drainage	:	Moderately well drained
Salinity/Sodicity	:	Dense saline-sodic
Watertable Depth	:	Beyond 200 cm
Important Profile Characteristics	:	Deep, brown/dark brown, moderately calcareous, dense saline- sodic, silty clay loams with ochric epipedon and cambic subsurface horizon.
USDA Classification	:	Fine silty, mixed, hyperthermic, Sodic Haplocambids

TYPICAL PROFILE

Location: Acre No.24-193/3, W.C. No.111770-L of Azim Distributary.

Anz	0-10 cm	Brown (10YR5/3) moist and very pale brown (10YR 7/3) dry; silt loam; weak platy; sticky, plastic, friable, hard; few fine interstitial and vesicular pores; moderately calcareous; abrupt smooth boundary; pH 9.6.
BAn	10-20 cm	Brown/dark brown (10YR 4/3); silt loam; massive; sticky, plastic friable, hard; few fine interstitial pores; moderately calcareous; clear smooth boundary; pH 9.6.
Bn1	20-37 cm	Dark grayish brown (10YR 4/2) moist; silt loam^{+}; weak coarse medium angular and subangular blocky; sticky, plastic, friable, hard; few fine and very fine tubular pores; few infilled pores with eluviated material; moderate to strongly calcareous; few snail shells, clear smooth boundary; PH 9.6.
Bn2	37-65 cm	Brown/dark brown (10YR 4/3) moist; common distinct yellowish brown (10YR5/6) mottles; silt loam; weak coarse angular and subangular blocky; sticky, plastic, firm, hard; few fine and common very fine tubular pores; few infilled pores with eluviated material; moderately calcareous; clear smooth boundary; pH 9.4.
Bn3	65-96 cm	Variegated dark grayish brown (10YR4/2) and brown/dark brown (10YR4/3) moist, common distinct yellowish brown (10YR5/6) and reddish brown (5YR5/4) mottles; silt loam^{+}; sticky, plastic, firm, hard; few fine and very fine tubular pores; few infilled pores with eluviated material; moderately calcareous; clear smooth boundary; pH 9.4.
2Bn1	96-110 cm	Brown/dark brown (10YR4/3) moist, few faint yellowish brown (10YR5/4) mottles; silty clay loam; very weak coarse subangular blocky with common inped laminations; sticky, plastic, firm, hard; very few fine and very fine tubular pores; few infilled root channels with humified material; strongly calcareous; clear smooth boundary; pH 9.2.
2Bn2	110-160 cm	Brown/dark brown (10YR4/3) moist, few faint yellowish brown (10YR5/6) mottles; silty clay loam; very weak coarse subangular blocky with common inped laminations; sticky, plastic, firm, hard; very few fine and very fine tubular pores; common infilled root channels with humified material; moderately calcareous, clear smooth boundary; pH 8.8.
2 C	160^{+} cm	Brown (10YR5/3) moist; silt loam; massive; sticky, plastic, friable, hard; no pores; moderately calcareous; pH 8.6.

Basic Infiltration Rate	:		0.22 cm hr^{-1}	Very slow
Hydraulic Conductivities				
(Inverse Auger Hole Method)	:	20-60 cm	0.41 cm hr^{-1}	Slow
		77-100 cm	0.14 "	"
		139-170 cm	0.19 "	"

ANALYTICAL DATA

Lab. No.	Hori-zon	Depth, cm	Mechanical analysis				Bulk density, g cm^{-3}	Pore density, (vol%)	$CaCO_3$ %	Org. matter, %	pH sat. paste	Ec_e, dSm^{-1}
			Sand %	Silt %	Clay %	Text. class						
19287	Anz	0-10	26	56	18	SiL	1.72	35	11.0	0.1	10.4	42.10
288	BAn	10-20	13	60	27	SiL	1.54	42	13.0	0.1	10.6	14.65
289	Bn_1	20-37	17	53	30	SiCL	1.42	47	10.5	0.2	10.5	5.62
290	Bn_2	37-65	16	55	29	SiCL	1.50	43	14.0	0.1	10.5	1.09
291	Bn_3	65-96	17	50	33	SiCL	1.51	43	16.0	0.1	10.5	1.04
292	$2Bn_1$	96-110	20	42	38	SiCL	1.55	41	16.0	0.1	10.5	1.00
293	$2Bn_2$	110-160	15	59	26	SiL	1.55	41	11.0	0.3	10.4	2.28
294	2c	160- +	19	55	26	Sil	1.53	42	15.0	0.3	9.8	1.71

Depth, cm	Soluble saturation extractions, meq l^{-1}						SAR	ESP	Micronutrient, mg kg^{-1}			
	CO_3	HCO_3	Cl	SO_4	Ca+Mg	Na			Cu	Fe	Mn	Zn
0-10	162.4	30.8	67.5	160.3	6.0	415.0	254.6	81.0	0.50	6.75	1.30	0.35
10-20	51.2	8.0	17.5	69.6	6.8	139.7	75.9	54.8	0.60	10.50	1.35	0.25
20-37	14.0	5.0	9.8	27.4	3.2	53.0	42.0	38.0	0.85	6.50	1.50	0.35
37-65	1.2	5.0	2.6	2.1	2.4	8.5	7.8	9.8	0.45	2.80	1.30	0.20
65-96	0.4	5.8	2.0	2.2	2.4	8.0	7.3	9.6	0.25	2.30	1.45	0.15
96-110	0.3	5.0	2.1	2.6	2.0	8.0	8.0	10.0	0.70	6.70	1.20	0.20
110-160	8.0	6.6	2.4	5.8	3.6	19.2	14.3	16.0	0.30	1.90	1.70	0.15
160- +	4.0	5.0	2.7	5.4	1.2	15.9	20.6	22.0	0.30	2.40	1.85	0.20

Soil Series	:	AWAGAT SERIES
Parent Material	:	Mixed river alluvium
Physiography	:	Subrecent level plains
Slope	:	Level to nearly level
Land use/Vegetation	:	Wheat, cotton, oilseeds and fodders
Climate	:	Semi arid, subtropical monsoonal
Permeability	:	Moderate
Drainage	:	Imperfectly drained
Salinity/Sodicity	:	Nil
Watertable Depth	:	Saturation at 100 cm
Important Profile Characteristics	:	Deep, brown/dark brown to dark yellowish brown, mottled, moderately calcareous, loams with an ochric epipedon and cambic subsurface horizon.
USDA Classification	:	Fine loamy, mixed, hyperthermic, Aquic Haplocambids

TYPICAL PROFILE*

Location: About 0.5 mile south (180° MB) of the milestone No.122 $\frac{1}{2}$ on Bahawalnagar - Head Sulemanki Road, opposite to Chabiana railway station.

Ap	0-13 cm	Brown/dark brown (10YR 4/3) moist and pale brown (10YR 6/3) dry; loam; massive; slightly sticky, slightly plastic, friable, hard, few medium and fine interstitial pores; moderately calcareous; few medium and common fine roots; gradual smooth bounday; pH 8.0.
AB	13-23 cm	Brown/dark brown (10YR 4/3) moist and pale brown (10YR 6/3) dry; loam; weak coarse subangular blocky; slightly sticky, slightly plastic, friable, hard; few medium interstitial and few fine tubular pores; moderately calcareous; few fine roots; clear smooth boundary; pH 8.3.
BA	23-30 cm	Brown/dark brown (10YR 4/3) moist and pale brown (10YR 6/3) dry; loam approaching fine sandy loam; very weak coarse subangular blocky; slightly sticky, slightly plastic, very friable, slightly hard; common fine and very fine tubular pores; moderately calcareous; few very fine roots; clear smooth boundary; pH 8.4.
BW_1	30-76 cm	Dark yellowish brown (10YR 4/4) moist and light yellowish brown (10YR 6/4) dry; common medium faint and distinct yellowish brown mottles; loam; weak coarse subangular blocky; slightly sticky, slightly plastic, friable, hard; few medium common fine and very fine tubular pores; moderately calcareous; few worn costs; few very fine roots; gradual smooth boundary; pH 8.2.
BW_2	6-92 cm	Dark yellowish brown (10YR 4/4) moist and light yellowish brown (10YR 6/4) dry; common medium and distinct yellowish brown mottles; loam; weak coarse subangular blocky; slightly sticky, slightly plastic, friable, hard; common fine and very fine tubular pores; few fine lime specks and kanker, moderately calcareous and strongly in patches; few very fine roots; gradual smooth boundary; pH 8.2.
BCK	92-132 + cm	Yellowish brown (10YR 5/4) moist and light yellowish brown (10YR 6/4) dry; few fine faint mottles; clay loam; massive; sticky, plastic, friable, hard; common fine and very fine tubular pores; common to many fine kanker and lime specks, strongly calcareous; saturated; few very fine roots; pH 8.4.

* Taken from Reconnaissance Soil Survey Report, Bahawalnagar (1971); laboratory data is not present in the report. In the survey area Awagat, silty clay loam surface phase is present.

Soil Series	:	CHOLISTAN SERIES
Parent Material	:	Old wind resorted, river alluvium
Physiography	:	Stabilized undulating sand dunes
Slope	:	Nearly level to undulating, humocky
Land use/Vegetation	:	Bajra and wheat
Climate	:	Semi arid subtropical monsoonal
Permeability	:	Very rapid
Drainage	:	Excessively drained
Salinity/Sodicity	:	Nil, but surface crust is severely sodic (pH 9.2) due to hazardous tubewell water
Watertable Depth	:	Beyond 150 cm
Important Profile Characteristics	:	Deep, dark yellowish brown to yellowish brown, moderately calcareous, loamy very find sand with an ochric epipedon and with deep cambic subsurface horizon.
USDA Classification	:	Mixed, hyperthermic, Typic Torripsamments

TYPICAL PROFILE

Location: About 100 meters in the east of Dera Malik Ghulam Hussain and on the left side of Fordwah Distributary (FD-132L).

Ap	0-14cm	Yellowish brown (10YR 5/4) moist; loamy very fine sand; massive to single grain; non sticky, non plastic, very friable, soft; few fine and very fine interstitial pores; common fine and very fine roots; moderately calcareous; defused smooth boundary; pH 8.6.
Bw_1	14-41 cm	Yellowish brown (10YR 5/4)) moist; very fine sand; massive to single grain; non sticky, non plastic, very friable, soft; few fine and very fine tubular pores; few fine and very fine roots; moderately calcareous; clear smooth boundary; pH 8.4.
Bw_2b	41-59 cm	Brown/dark brown (10YR 4/3) moist; loamy sand; massive to single grain; non sticky, non plastic, very friable, soft; few very fine tubular pores; few very fine roots; moderately calcareous; clear smooth boundary; pH 8.2.
Bw_3	59-109 cm	Yellowish brown (10YR 5/4) moist; loamy very fine sand; massive to single grain; non sticky, non plastic, very friable, soft; few very fine tubular pores; few very fine roots; moderately calcareous; clear smooth boundary; pH 8.2.
Bw_4	109-150 + cm	Brown (10YR 5/3) moist; loamy fine sand; massive to single grain; non sticky, non plastic, very friable loose; few fine and very fine tubular pores; moderately calcareous; pH 8.0.

Basic Infiltration Rate	:		5.13 cm hr^{-1}	Moderately rapid
Hydraulic Conductivities (Inverse Auger Hole Method)	:	50-90 cm	52.35 cm hr^{-1}	Very rapid

ANALYTICAL DATA

Lab. No.	Hori-zon	Depth, cm	Mechanical analysis				Bulk density, g cm^{-3}	Pore density, (vol%)	$CaCO_3$ %	Org. matter, %	pH sat. paste	Ec_e, dSm^{-1}
			Sand %	Silt %	Clay %	Text. class						
19379	Ap	0-14	84	7	9	LS	-	-	2.0	0.3	8.8	1.95
380	Bw_1	14-41	89	9	2	S	1.57	41	1.5	0.2	8.5	1.38
381	Bw_2b	41-59	71	21	8	SL/LS	1.59	40	3.0	0.1	8.4	1.89
382	BW_3	59-109	86	51	9	LS	1.50	43	4.5	0.1	8.3	1.61
383	BW_4	109-150	69	22	9	SL	1.59	41	4.5	0.0	8.2	2.02

Depth, cm	Soluble saturation extractions, meq l^{-1}						SAR	ESP	Micronutrient, mg kg^{-1}			
	CO_3	HCO_3	Cl	SO_4	Ca+Mg	Na			Cu	Fe	Mn	Zn
0-14	0.8	5.4	3.2	10.2	2.4	17.0	15.5	18.0	0.15	2.00	2.10	0.20
14-41	1.2	7.4	3.2	2.0	2.4	11.4	10.2	12.0	0.20	1.30	2.10	0.25
41-59	0.4	3.2	4.7	8.6	5.2	13.7	8.5	10.	0.15	2.30	2.35	2.20
59-109	0.4	4.2	4.2	7.3	2.4	13.4	12.3	14.0	0.25	2.20	2.50	2.20
109-150	0.4	1.2	6.2	12.6	5.0	16.2	11.5	12.0	0.30	1.70	3.05	0.10

Soil Series	:	DUNGI SERIES
Parent Material	:	Mixed river alluvium
Physiography	:	Fringes of the basins/channels
Land use/vegetation	:	Raya, sudan grass, alfalfa and rice
Slope	:	Nearly level
Climate	:	Semi arid, sub tropical monsoonal
Permeability	:	Moderately slow
Drainage	:	Moderately well/seasonally imperfectly drained
Salinity/Sodicity	:	Porous saline-sodic
Watertable Depth	:	Beyond 150 cm
Important Profile Characteristics	:	Deep, dark/very dark greyish brown to brown/dark brown, mottled, moderately calcareous, porous saline-sodic, silty clays/heavy silty clay loams with ochric epipedon and deep cambic subsurface horizon.
USDA Classification	:	Fine*, mixed, hyperthermic, Sodic Haplocambids

TYPICAL PROFILE

Location — About 1 Km in the north east of the crossing of Chishtian - Mehta Jhado Road and Shahr Farid Distributary.

Ap	0-11 cm	Dark greyish brown (10 YR 4/2) moist ad light brownish grey (10 R 6/2) dry, silt loam; massive; sticky, plastic, firm, hard; few fine interstitial and tubular pores; few fine and very fine roots; moderately calcareous; clear smooth boundary; pH 8.8.
Bw1	11-48cm	Very dark greyish brown (10 YR 3/2) moist; few faint yellowish brown mottles; silty clay loam; weak coarse and medium subangular blocky; very sticky, very plastic, firm, very hard; few fine and common very fine tubular pores; few fine and common very fine roots; a crotoviana; moderately calcareous; clear smooth boundary; pH 8.8.
Bw2	48-86 cm	Brown/dark brown (10YR 4/3) moist; common faint yellowish brown mottles; silty clay loam; massive to weak coarse subangular blocky; sticky, plastic, firm, hard; few fine and common very fine tubular pores; few very fine roots; moderately calcareous; clear smooth boundary; pH 8.8.
Bw3	86-107 cm	Very dark greyish (10YR 3/2) moist, common faint yellowish brown mottles; silty clay; weak coarse and medium subangular blocky; very sticky, very plastic, firm, very hard; few fine and very fine tubular pores; few very fine and medium decayed roots; few snail shells; moderately to strongly calcareous; gradual smooth boundary; pH 8.8.
BW_1b	86-107 cm	Very dark greyish brown (10YR 3/2) moist, common faint yellowish brown motles; silty clay; weak coarse and medium subangular blocky; very sticky, very plastic, firm, very hard; few fine and very fine tubular pores; few very fine and medium decayed roots; few snail shells, moderately to strongly calcareous; gradual mooth bounday; pH 8.8.
C	107-150 + cm	Yellowish brown (10 YR 5/4) moist; common faint and distinct yellowish brown mottles; silt loam; massive; sticky, plastic, firm, hard; few fine and very fine tubular pores; moderately to strongly calcareous; pH 8.4.

* Fine silty particle size class also exist.

Basic Infiltration Rate	:		0.14 cm hr^{-1}	Very slow
Hydraulic Conductivities (Inverse Auger Hole Method)	:	52-98 cm	0.79 cm hr^{-1}	Moderately slow
		102-145 cm	1.45 "	Moderately slow

ANALYTICAL DATA

Lab No.	Hori-zon	Depth, cm	Mechanical Analysis				Bulk Density	Pore Density	$CaCO_3$, %	Org. Matter %	pH Sat. paste	Ece* dSm^{-1}
			Sand, %	Silt, %	Clay, %	Text, class						
1940 2	Ap	0-4	24	59	17	Sil	-	-	10.5	1.02	8.4	3.77
403	Bw_1	11-43	14	53	33	SiCl	1.44	46	11.0	0.81	8.7	6.13
404	Bw_2	48-86	8	58	34	SiCl	1.53	42	8.5	0.47	8.7	5.08
405	Bw_3b	86-107	15	43	42	SiC	1.54	42	10.0	0.47	8.8	1.35
406	C	107-150+	17	66	17	SiL	1.51	43	9.5	0.34	8.8	0.97

Depth, cm	Soluble saturation extractions, meq l^{-1}						SAR	ESP	Micronutrient Analysis, mg kg^{-1}			
	CO_3	HEO_3	Cl	SO_4	Ca+Mg	Na			Cu	Fe	Mn	Zn
0-18	A	3.6	9.9	24.2	4.0	33.7	23.8	25.0	-	-	-	-
18-48	0.4	8.2	13.1	39.6	13.0	48.3	-	-	-	-	-	-
48-86	0.4	7.6	9.6	33.2	9.4	41.4	-	-	-	-	-	-
86-107	0.4	2.8	3.2	7.1	3.2	10.3	8.17	10.0	-	-	-	-
107-150	0.4	2.8	2.3	4.2	3.2	6.5	5.15		-	-	-	-

* Profile is reclaimed phase of Dungi series.

Soil Series	:	GANDHRA SERIES
Parent Material	:	Mixed river alluvium
Physiography	:	Subrecent level plains
Slope	:	Level to nearly level
Land use/Vegetation	:	Wheat, oilseeds and cotton
Climate	:	Semi arid subtropical, monsoonal
Permeability	:	Moderate
Drainage	:	Well drained
Salinity/Sodicity	:	Porous saline sodic
Watertable Depth	:	Beyond 200 cm
Important Profile Characteristics	:	Deep, brown/dark brown, moderately calcareous, porous saline-sodic loams with ochric epipedon and cambic subsurface horizon
USDA Classification	:	Coarse loamy, mixed, hypderthermic, Sodic Haplocambids

TYPICAL PROFILE*

Location: About 1500 feet south-south east (190° MB) from the centre of the bridge on Fordwah Canal in front of Madrasa Railway Station.

Ap	0-20 cm	Brown/dark brown (10YR 4/3) moist and pale brown (10YR 6/3) dry; loam; massive; slightly sticky, slightly plastic, friable, hard; few very fine tubular pores; moderately calcareous, few fine lime specks; few medium, fine and common very fine roots; clear smooth boundary; pH 8.8.
BW_1	20-86 cm	Brown/dark brown (10YR 4/3/4) moist and pale brown (10YR 6/3) dry; loam; weak coarse subangular blocky; slightly sticky, slightly plastic friable, hard; common fine and very fine tubular pores; moderately calcareous, few to cmmon fine lime specks; few sand pockets; few fine and common very fine roots; clear smooth boundary; pH 8.7.
BCK	86-145 cm	Brown/dark brown (10YR 4/3.4) moist; and pale brown (10YR 6/3) dry; loam; very weak coarse subangular blocky; slightly sticky, slightly plastic, friable, hard, common fine and very fine tubular pores; strongly calcareous, common very fine hard and soft lime kanker, common lime specks; common sand pockets; few fine and very fine roots; clear smooth boundary; pH 8.5.
C	145-152 cm	Dark greyish brown (2.5Y 4/2.4) moist; loam; massive; slightly sticky, slightly plastic, friable, hard; few medium common fine and very fine tubular pores; moderatley calcareous, few fine lime kanker; no roots; pH 8.5.

* Taken from Reconnaissance Soil Survey Report Bahawalnagar (1971); laboratory data is not present in report.

Soil Series	:	HARUNABAD SERIES
Parent Material	:	Mixed river alluvium
Physiography	:	Subrecent level plains
Slope	:	Level to nearly level
Land use/Vegetation	:	Cotton, sugarcane, wheat and fodders
Climate	:	Semi arid subtropical monsoonal
Permeability	:	Moderate/moderately slow, may be because of high watertable
Drainage	:	Imperfectly drained
Salinity/Sodicity	:	Nil
Watertable Depth	:	Perched saturation at 140 cm
Important Profile Characteristics	:	Deep, brown/dark brown to dark yellowish brown, moderately calcareous, loam/light loam with an ochric epipedon and a cambic subsurface horizon.
USDA Classification	:	Coarse loamy, mixed, hyperthermic, Typic Haplocambids*

TYPICAL PROFILE

Location: Acre No.21-549/1, W.C. No.14320-R of Fordwah Distributary.

Ap	0-15 cm	Brown/dark brown (10YR4/3) moist; fine sandy loam; massive; slightly sticky, slightly plastic, very friable, slightly hard; common fine and medium interstitial pores; few earth worm castes, common fine and very fine roots; moderately calcareous;clear smooth boundary; pH 8.4.
BA	15-26 cm	Dark grayish brown (10YR4/2) moist; fine sandy loam; massive; slightly sticky, slightly plastic, very friable, slightly hard; few fine interstitial and few medium fine and very fine tubular pores; few earthworm casts; common fine and very fine roots; clear smooth boundary; pH 8.2.
Bw_1	26-78 cm	Brown/dark brown (7.5YR 4/4) moist; loam; weak coarse subangular blocky; slightly sticky, slightly plastic, very friable, slightly hard; many fine and very fine tubular pores; few earth worm casts; common fine and very fine roots; moderately calcareous; gradual smooth boundary; pH 8.0.
Bw_2	78-110 cm	Brown/dark brown (7.5YR4/4) moist; loam; very weak coarse subangular blocky; slightly sticky, slightly plastic, very friable, slightly hard, many fine and very fine tubular pores; few fine and common very fine roots; moderately calcareous; gradual smooth boundary; pH 8.2.
C	110-145+ cm	Brown/dark brown (10YR4/3) and dark yellowish brown (10YR4/4) moist; common faint rust brown (5YR5/4) mottles; sandy loam with pockets of medium gray (10YR 6/1) sand; massive; slightly sticky, slightly plastic, very friable, slightly hard; common fine very fine tubular pores; few very fine roots; moderately calcareous; pH 8.0

* Poorly drained phase is Aquic Haplocambids.

Basic Infiltration Rate	:		0.78 cm hr^{-1}	Slow
Hydraulic Conductivities				
(Inverse Auger Hole Method)	:	22-50 cm	6.44 cm hr^{-1}	Moderately rapid
		66-100 cm	0.56 "	Moderately slow*
		137-214 cm	0.98 "	" *

* may be due to perched watertable conditions and wetness of the profile at these depths.

ANALYTICAL DATA

Lab. No.	Hori-zon	Depth, cm	Mechanical analysis				Bulk density, g cm^{-3}	Pore density, (vol%)	$CaCO_3$ %	Org. matter, %	pH sat. paste	Ec_e, dSm^{-1}
			Sand %	Silt %	Clay %	Text. class						
19329	Ap	0-15	62	27	11	FSL	1.45	45	6.5	1.1	8.2	1.23
330	BA	15-26	66	25	9	FSL	1.57	41	6.5	0.5	8.3	1.05
331	Bw_1	26-78	50	35	15	L	1.59	40	7.0	0.2	8.1	2.95
332	Bw_2	78-110	48	35	17	L	1.60	40	8.5	0.1	8.2	2.58
333	C	110-145	58	25	17	FSL	1.66	37	7.0	0.1	8.2	2.21

Depth, cm	Soluble saturation extractions, meq l^{-1}						SAR	ESP	Micronutrient, mg kg^{-1}			
	CO_3	HCO_3	Cl	SO_4	Ca+Mg	Na			Cu	Fe	Mn	Zn
0-15	A	4.8	3.2	4.3	5.2	7.1	4.0	6.0	0.45	1.80	1.90	0.25
15-26	A	3.6	2.6	4.3	8.4	2.1	1.0	1.0	0.40	2.00	1.50	0.25
26-78	A	2.2	6.7	20.6	10.8	18.7	8.1	10.0	0.30	1.90	1.60	0.25
78-110	A	2.4	6.1	17.3	12.4	13.4	5.4	7.8	0.30	2.40	2.00	0.35
110-145	A	2.4	5.4	14.3	10.0	12.1	5.4	7.8	0.30	1.90	1.80	0.20

Soil Series/Phase	:	JHAKKAR SERIES (Cultivated)
Parent Material	:	Mixed river alluvium
Physiography	:	Subrecent level plains, slightly raised parts
Slope	:	Level to nearly level
Land use/Vegetation	:	Cotton, rice, wheat and fodders
Climate	:	Semi arid, subtropical monsoonal
Permeability	:	Slow
Drainage	:	Well drained
Salinity/Sodicity	:	Porous saline-sodic
Watertable Depth	:	Beyond 200 cm
Important Profile Characteristics	:	Deep, brown/dark brown to dark yellowish brown, moderately calcareous, porous saline-sodic, epipedon and cambic subsurface horizon
USDA Classification	:	Fine silty mixed, hyperthermic, Sodic Haplocambids

TYPICAL PROFILE

Location: Acre No.17-173/15, W.C. No.111770-L of Azim Distributary.

Apn	0-17 cm	Brown/dark brown (10YR 4/3) moist and pale brown (10YR6/3) dry; loam; massive, puddled; slightly sticky, slightly plastic, firm, very hard; common fine vesicular and interstitial pores; few fine roots; moderately calcareous; clear smooth boundary; pH 8.8.
BAn	17-24 cm	Brown/dark brown (10YR 4/3) moist; loam; massive; slightly sticky, slightly plastic, firm, hard; few very fine tubular pores; few fine roots; moderately calcareous; clear smooth boundary; pH 8.8.
Bn_1	24-39 cm	Brown/dark brown (10YR 4/3) moist, common faint yellowish brown (10YR 5/6) mottles; silt loam$^+$; weak coarse angular and subangular blocky; sticky, plastic, firm, hard; common fine and very fine tubular pores; few fine lime nodules; few very fine roots; strongly calcareous; clear smooth boundary; pH 8.8.
Bn_2	39-46 cm	Dark grayish brown (10YR4/2) moist; silt loam$^+$; weak coarse angular and subangular blocky, sticky, plastic, friable, hard; common fine and very fine tubular pores; few very fine roots; moderately calcareous; clear smooth boundary; pH 8.8.
Bn_3	46-96 cm	Brown/dark brown (10YR 4/3) moist; few faint rust brown (5YR5/6) and yellowish brown (10YR5/6) mottles; silt loam; very weak coarse subangular blocky; slightly sticky, slightly plastic, friable, hard; common fine and very fine tubular pores; few infilled pores with eluviated material; moderately calcareous; clear smooth boundary; pH 8.6.
C1	96-109 cm	Grayish brown (10YR 5/2) moist; loamy fine sand; massive; non-sticky, non-plastic, loose; few fine roots; moderately calcareous; clear smooth boundary; pH 8.6.
C2	109-117 cm	Grayish brown (2.5Y5/2) moist; sand; single grain; non-sticky, non-plastic, loose; moderately calcareous; clear smooth boundary; pH 8.4.

C3 117-130 cm Dark grayish brown (2.5Y4/2) moist; loamy very fine sand; massive; non-sticky, non-plastic, loose; moderately calcareous; clear smooth boundary; pH 8.2.

C4 130-180+ cm Grayish brown (2.5Y5/2) moist; sand; single grain; non-sticky; non-plastic, loose; moderately calcareous; pH 8.2.

Basic Infiltration Rate	:		0.09 cm hr^{-1}	Very slow
Hydraulic Conductivities				
(Inverse Auger Hole Method)	:	20-40 cm	0.14 cm hr^{-1}	Slow
		66-90 cm	11.48 "	Moderately rapid
		111-140 cm	9.64 "	"
		165.195 cm	12.16 "	"

ANALYTICAL DATA

Lab. No.	Hori-zon	Depth, cm	Mechanical analysis				Bulk density, g cm^{-3}	Pore density, (vol%)	$CaCO_3$ %	Org. matter, %	pH sat. paste	Ec_e, dSm^{-1}
			Sand %	Silt %	Clay %	Text. class						
19302	Apn	0-17	36	46	18	L	1.53	42	11.5	0.4	9.4	6.02
302	BAn	17-24	36	46	18	L	1.73	34	11.5	0.4	9.4	6.02
303	Bn_1	24-39	21	60	19	SiL	1.58	40	14.0	0.2	9.3	4.14
304	Bn_2	39-46	23	52	25	SiL	1.49	44	17.0	0.2	9.6	3.40
305	Bn_3	46-96	27	51	22	SiL	1.46	45	15.0	0.1	9.8	3.28
306*	C*	96-180	91	9	0	LS/S	1.40	47	9.0	0.0	9.4	4.35

Depth, cm	Soluble saturation extractions, meq l^{-1}						SAR	ESP	Micronutrient, mg kg^{-1}			
	CO_3	HCO_3	Cl	SO_4	Ca+Mg	Na			Cu	Fe	Mn	Zn
0-17	0.8	5.0	10.3	44.1	8.0	52.2	26.1	28.0	0.50	2.00	1.10	0.35
17-24	0.8	5.0	10.3	44.1	8.0	52.2	26.1	28.0	0.50	2.00	1.10	0.35
24-39	0.8	4.6	8.6	27.4	5.6	35.8	21.4	23.0	0.90	9.00	4.60	0.30
39-46	2.4	5.0	5.5	21.1	5 6	28.4	16.9	18.0	0.65	2.75	0.90	0.15
46-96	0.8	2.8	5.6	23.6	3 6	29.2	21.8	23.0	0.60	2.75	1.35	0.25
96-180	0.4	2.2	8.4	32.5	5.2	38.3	23.7	24.0	0.25	1.60	1.00	0.15

* C covers C_1, C_2, C_3 and C_4.

Soil Series/Phase	:	JHAKKAR SERIES (BARREN)
Parent Material	:	Mixed river alluvium
Physiography	:	Subrecent level plains, slightly raised parts
Slope	:	Nearly level to very gently undulating
Land use/Vegetation	:	Scattered bushes of dab and jawan
Climate	:	Semi arid subtropical monsoonal
Permeability	:	Moderately slow
Drainage	:	Moderately well drained
Salinity/Sodicity	:	Porous saline-sodic
Watertable Depth	:	Beyond 200 cm
Important Profile Characteristics	:	Deep, brown/dark brown to dark yellowish brown, moderately calcareous, porous saline-sodic, silt loam and very fine sandy loam with an ochric epipedon and cambic subsurface horizon.
USDA Classification	:	Coarse silty, mixed, hyperthermic, Sodic Haplocambids

TYPICAL PROFILE

Location: Acre No.17-193/3, W.C. No.111770-L of Azim Distributary.

Anz	0-11 cm	Brown (10YR5/3) moist and pale brown (10YR 6/3) dry; very fine sandy loam; massive partly thin play; slightly sticky, slightly plastic, friable, slightly hard; common fine and very fine vericular pores; few common to fine roots; moderately calcareous; clear smooth boundary; Ph 8.8.
Abn	11-20 cm	Brown (10YR 5/3) moist; very fine sandy loam; very weak medium subangular blocky; slightly sticky, slightly plastic, friable, slightly hard; few medium, common fine and very fine tubular pores; few very fine roots; moderately calcareous; clear smooth boundary; pH 8.8.
Bn1	20-40 cm	Dark yellowish brown (10YR 4/4) moist; silt loam; weak coarse and medium subangular blocky; slightly sticky, slightly plastic, friable, hard; common fine and many very fine tubular pores; few very fine roots; moderately calcareous; clear smooth boundary; pH 8.8.
Bn2	40-60 cm	Yellowish brown (10YR5/4) moist; very fine sandy loam; weak medium and coarse subangular blocky; slightly sticky, slightly plastic, friable, hard; many fine interstitial, few fine and common very fine tubular pores; few very fine roots; moderately calcareous; clear smooth boundary; pH 8.6.
Bn3	60-82 cm	Brown (10YR5/3) moist; very fine sandy loam/silt loam; weak medium and coarse subangular blocky; slightly sticky, slightly plastic, friable, slightly hard; common fine and many very fine tubular pores; few very fine roots; moderately calcareous; clear smooth boundary; pH 9.4.
BCn	82-110 cm	Brown/dark brown (10YR 4/3) moist; few faint yellowish brown (10YR5/6) mottles; silt loam; massive and partly thin platy; sticky, plastic, firm, hard; common very fine tubular

pores; common infilled root channels with humified material; few snail shells; few very fine roots; moderately calcareous; clear smooth boundary; pH 9.2.

2bn 110-155 cm Dark yellowish brown (10YR 4/4) moist; silty clay loam; very weak coarse and medium subangular blocky with inped laminations; very sticky, very plastic, firm, very hard; few very fine tubular pores; common infilled root channels with humified material; few thin broken clay films on ped faces; few very fine roots; moderately calcareous; pH 9.2.

Basic Infiltration Rate	:		0.25 cm hr^{-1}	Slow
Hydraulic Conductivities				
(Inverse Auger Hole Method)	:	28-70 cm	1.12 cm hr^{-1}	Moderately slow
		73-105 cm	0.58 "	"
		123-155 cm	0.60 "	"

ANALYTICAL DATA

Lab. No.	Hori-zon	Depth, cm	Mechanical analysis				Bulk density, g cm^{-3}	Pore density, (vol%)	$CaCO_3$ %	Org. matter, %	pH sat. paste	Ec_e, dSm^{-1}
			Sand %	Silt %	Clay %	Text. class						
19295	Anz	0-11	25	54	21	SiL	1.37	50	10.0	0.5	8.8	45.20
296	ABn	11-20	27	58	15	SiL	1.35	49	9.0	0.2	8.9	18.81
297	Bn_1	20-40	30	59	11	SoL	1.64	38	9.0	0.2	8.8	16.16
298	Bn_2	40-60	27	61	12	SiL	1.43	46	7.0	0.2	9.1	14.25
299	Bn_3	60-82	36	51	13	SiL	1.53	42	9.0	0.2	10.1	9.13
300	BCn	82-110	26	51	23	SiL	1.53	42	14.0	0.1	10.0	8.51
301	2Bn	110-155	16	63	21	SiL	1.75	34	16.0	0.1	10.8	6.06

Depth, cm	Soluble saturation extractions, meq l^{-1}						SAR	ESP	Micronutrient, mg kg^{-1}			
	CO_3	HCO_3	Cl	SO_4	Ca+Mg	Na			Cu	Fe	Mn	Zn
0-11	1.2	3.6	119.0	328.2	40.0	448.0	100.2	59.0	0.65	1.70	1.45	0.30
11-20	0.4	3.8	46.8	137.1	32.0	156.1	39.0	37.0	0.70	3.60	2.50	0.40
20-40	0.2	6.6	26.0	128.8	25.2	136.4	38.3	36.0	0.50	1.70	1.80	0.30
40-60	0.4	2.0	15.5	124.6	27.2	115.3	31.3	31.0	0.45	1.80	2.25	0.25
60-82	7.2	6.0	12.2	65.9	4.4	86.9	58.7	46.0	0.55	3.0	1.90	0.25
82-110	22.8	7.8	11.4	43.1	2.4	82.7	75.5	54.0	0.55	5.0	2.60	0.35
110-155	16.8	5.4	7.5	30.9	3.6	57.0	42.5	37.0	0.35	4.0	2.75	0.25

Soil Series	:	JHANG SERIES
Parent Material	:	Mixed river alluvium, partly wind resorted
Physiography	:	Subrecent levees, levelled
Slope	:	Level to nearly level
Land use/Vegetation	:	Cotton, wheat, pulses and grain
Climate	:	Semi arid subtropical monsoonal
Permeability	:	Moderately rapid
Drainage	:	Somewhat excessively drained
Salinity/Sodicity	:	Nil
Watertable Depth	:	Beyond 200 cm
Important Profile Characteristics	:	Deep, grayish brown to brown/dark brown, moderately calcareous, loamy fine sands/loamy sands with an ochric epipedon and with or without a shallow cambic subsurface horizon.
USDA Classification	:	Coarse loamy/sandy, mixed, hyperthermic, Typic Haplocambids

TYPICAL PROFILE

Location: Acre No.16-97/10, W.C. No.130100-R of Fordwah Distributary.

Ap	0-20 cm	Brown/dark brown (10YR 4/3) moist and pale brown (10YR 6/3) dry; massive; fine sandy loam; slightly sticky, very slightly plastic, very friable, soft; few fine interstitial and tubular pores; very few medium, common fine and many very fine roots; moderately calcareous; clear smooth boundary; pH 8.4.
Bw_1	20-44 cm	Brown/dark brown (10YR 4/3) moist; fine sandy loam; very weak coarse subangular blocky; slightly sticky, slightly plastic, very friable, soft; common fine and very fine tubular pores; few fine and common very fine roots; moderately calcareous; gradual smooth boundary; pH 8.4.
Bw_2	44-80 cm	Brown (10YR 5/3) moist; loamy fine sand; massive; non-sticky, non-plastic, very friable, loose; few fine and very fine tubular pores; moderately calcareous; few very fine roots; gradual smooth boundary; pH 8.4.
C	80-180 cm	Grayish brown (2.5Y5/2) moist; loamy sand; massive; non-sticky, non-plastic, loose; moderately calcareous; pH 8.4.

Basic Infiltration Rate	:		1.20 cm hr^{-1}	Moderately slow
Hydraulic Conductivities				
(Inverse Auger Hole Method)	:	9-30 cm	9.00 cm hr^{-1}	Moderately rapid
		33-60 cm	6.57 "	"
		112-148 cm	6.87 "	"

ANALYTICAL DATA

Lab. No.	Hori-zon	Depth, cm	Mechanical analysis				Bulk density, g cm^{-3}	Pore density, (vol%)	$CaCO_3$ %	Org. matter, %	pH sat. paste	Ec_e, dSm^{-1}
			Sand %	Silt %	Clay %	Text. class						
19318	Ap	0-20	61	29	10	FSL	1.43	46	8.0	0.8	8.3	0.56
319	Bw_1	20-44	74	16	10	FSL	1.56	41	10.5	0.4	5.4	0.72
320	Bw_2	44-80	78	15	7	LFS	1.52	43	12.5	0.3	8.2	0.82
321	C	80-180	78	13	9	LFS	1.50	43	13.0	0.2	8.5	0.37

Depth, cm	Soluble saturation extractions, meq l^{-1}						SAR	ESP	Micronutrient, mg kg^{-1}			
	CO_3	HCO_3	Cl	SO_4	Ca+Mg	Na			Cu	Fe	Mn	Zn
0-20	A	2.2	1.7	1.7	4.4	1.2	0.81	-	0.35	2.10	2.05	0.35
20-44	A	1.6	1.7	3.9	4.0	3.2	2.26	2.9	0.30	1.25	0.80	0.35
44-80	A	3.0	2.2	3.0	8.0	0.2	0.10	-	0.30	1.75	0.75	0.35
80-180	A	1.4	0.8	1.5	2.8	0.9	0.76	-	0.25	1.75	0.75	0.30

Soil Series	:	MAKAI SERIES
Parent Material	:	Mixed river alluvium
Physiography:	:	Subrecent interdunal valley flats
Landuse/vegetation	:	Mainly barren, sparce cover of lana, lani and pilchi
Climate	:	Semi-arid, subtropical monsoonal
Salinity/sodicity	:	Severely saline, gypsiferous
Watertable depth	:	Beyond 200 cm
Important Profile Characteristics	:	Deep, brown/dark brown, moderately calcareous, gypsiferous strongly saline, weak thin platy with no subsurface horizon. A buried profile encounters usually below 90 cm depth
USDA Classification	:	Fine, mixed, hyperthermic, Typic Salorthids

TYPICAL PROFILE

Location — About 50 meters west (magnetic bearing 275o) of R.D. No.5 on Makai Minor, passing by Khanpur Village which is about 26 Km south east of Ghotki Town.

A1	0-10 cm	Brown/dark brown (10YR 4/3) moist and light brownish grey (10YR 6/2) dry; loam; weak granular; slightly sticky, slightly plastic, friable, hard; few very fine interstitial pores; many very fine soft salt specks (probably of gypsum); moderately calcareous; clear smooth boundary; pH 8.0.
IIC1	10-18 cm	Dark greyish brown (10YR 4/2) moist and light brownish grey (10YR 6/2) dry; silty clay; weak medium and coarse subangular blocky breaking into weak thin platy and weak granular; very sticky, very plastic, firm, very hard; few very fine tubular pores; many fine gypsum crystals on ped faces and between the plates; moderately calcareous; clear wavy boundary; pH 8.2.
IIC2	18-30 cm	Brown/dark brown (10YR) moist and pale brown (10YR 6/3) dry, few fine distinct yellowish brown (10YR 5/6) mottles; silty clay; weak thin platy and massive; very sticky, very plastic, firm, very hard; few fine and very fine tubular pores; common bunches of gypsum crystals and specks; moderately calcareous; earth worm activity present; clear smooth boundary; pH 8.4.
IIC3	30-48 cm	Brown/dark brown (10YR 4/3) moist and pale brown (10YR 6/3) dry; few fine and medium distinct reddish brown (5YR 4/4) and few fine distinct yellowish brown (10YR 5/8) mottles; silty clay; weak thin platy; very sticky, very plastic, very firm, very hard; few medium and very fine tubular pores; few bunches of gypsum crystals; moderately calcareous; earth worm activity present; abrupt smooth boundary; pH 8.3.
IIC4	48-53 cm	Brown (7.5YR 5/2) moist and pinkish grey (7.5YR 6/2) dry; few fine distinct reddish brown (5 YR 4/4) and yellowish brown (10YR 5/8) mottles; clay; very weak thin platy; very sticky, very plastic, very firm, extremely hard; few fine and very fine tubular pores; few gypsum crystals; moderately calcareous; earth worm activity present abrupt smooth boundary; pH 8.2.

IIC5	53-58cm	Brown (10YR 5/3) moist and pale brown (10YR 6/3) dry, few fine distinct reddish brown (5YR 4/4) and yellowish brown (10YR 5/8) mottles; silty clay loam; with few laminations of greyish brown (10YR 5/2) silt loam; weak thin play sticky, plastic, firm, hard; few fine and very fine tubular pores; few gypsum crystals; moderately calcareous; earth worm activity present; clear smooth boundary; pH 8.2.
IIC6	58-104 cm	Brown/dark brown (10YR 4/3) and brown (7.5 YR 5/2) moist and pale brown (10YR 6/3) and pinkish grey (7.5YR) dry, (alternative layers), few fine distinct reddish brown (5YR 4/4) and yellowish brown (10YR 5/8) mottles; silty clay and clay (alternative layers); very weak thin platy and massive; very sticky, very plastic, very firm, very hard; few fine and very fine tubular pores; few gypsum crystals; moderately calcareous, earth work activity present; abrupt smooth boundary; pH 8.2.
IIIA1b	104-114 cm	Very dark greyish brown (10YR 3.4/2) moist and greyish brown (10YR 5/2) dry; few faint dark yellowish brown (10 YR 5/4) mottles; silty clay loam; massive; sticky, plastic, friable, hard; few medium and common fine tubular pores; few fine gypsum crystals; moderately calcareous; few charcoal pieces, few pockets of very fine sandy loam; few very fine roots; clear broken boundary; pH 8.2.
IIIB21b	114-132 cm	Dark greyish brown (10YR 4/2) moist and light brownish grey (10YR 6/2) dry, few medium faint brown (10YR 5/3) mottles; silt loam with few laminations of very fine sandy loam; weak coarse subangular blocky (70%) and massive (30%); slightly sticky, slightly plastic, friable, slightly hard; common medium and fine gypsum crystals; moderately calcareous; few earth work-casts; no roots; clear broken boundary; pH 8.2.
IVB22b	132-152 cm	Dark greyish brown (10YR 4/2.4) moist and light brownish grey (10YR 6/2) dry, few faint yellowish brown (10YR 5/8) mottles; silty clay; weak coarse subangular blocky; very sticky, very plastic, very firm, very hard; few medium fine and very fine tubular pores; fine gypsum crystals; moderately calcareous; no roots; clear broken boundary; pH 8.2.

N.B. Surface is covered by 1 cm thick hard salt crust, the pH of which is 8.8 at the first instance, the color of the indictor then changes to reddish yellow after 1 to 2 minutes.

Soil Series	:	MIANI SERIES
Parent Material	:	Mixed river alluvium
Physiography:	:	Subrecent channel and basins
Landuse/vegetation	:	Wheat, cotton, citrus and guava garden
Slope	:	Level to nearly level
Climate	:	Semi-arid, subtropical monsoonal
Permeability	:	Moderately slow
Drainage	:	Moderately well-drained
Salinity/sodicity	:	Nil
Watertable depth	:	Beyond 160 cm
Important Profile Characteristics	:	Deep, brown/dark brown to very dark greyish brown, moderately calcareous, silty clay loams, with an ochric epipedon and a moderately deep cambic subsurface horizon
USDA Classification	:	Fine silty, mixed, hyperthermic, Typic Halplocambids

TYPICAL PROFILE

Location		About 2500 feet in the east of the crossing of Chishtian main drain and Hasilpur-Vehari road.
Ap	0-15 cm	Brown/dark brown (10YR 4/3) moist and light brownish grey (10YR 6/2) dry; silt loam; massive; sticky, plastic, friable, hard; few medium, common fine interstitial and few fine tubular pores; few medium, common fine and very fine roots; moderately calcareous; clear smooth boundary; pH 8.3.
Bw1	15-50 cm	Dark greyish brown (10YR 4/2) moist; few faint yellowish brown mottles; silty clay loam; massive to weak coarse subangular blocky; sticky, plastic, firm, hard; common fine and very fine tubular pores; few fine and common very fine roots; few snail shells; moderately calcareous; clear smooth boundary; pH 8.0.
Bw2	50-60cm	Brown/dark brown (10YR 4/3) moist; common faint yellowish brown mottles; silty clay loam; weak coarse subangular blocky; sticky, plastic, firm, hard; common fine and very fine tubular pores; few fine and common very fine roots; few snail shells and charcoal pieces; moderately calcareous; clear smooth boundary; pH 8.2.
Bw3b	60-68 cm	Very dark greyish brown (10YR 3/2) moist; silty clay loam; weak coarse and medium subangular blocky; sticky, plastic, firm, hard; common fine and very fine tubular pores; few fine and very fine roots; common snail shells, moderately calcareous; clear smooth boundary; pH 8.0.
C1	68-78cm	Brown/dark brown (10YR 4/3) moist; very fine sandy loam; very weak coarse subangular blocky; slightly sticky, slightly plastic, friable, slightly hard, few fine and very fine roots; common earth worm casts and pottery pieces; moderately calcareous; clear smooth boundary; pH 8.1.
C2	78-97 cm	Brown/dark brown (10YR 4/3) moist; few faint yellowish brown mottles; very fine sandy loam; massive; slightly sticky, slightly plastic, friable, slightly hard; common

fine and very fine tubular pores; few fine and very fine roots; moderately calcareous; clear smooth boundary; pH 8.1.

C3 97-147 cm — Brown (10YR 5/3) moist; very fine sandy loam; massive; slightly sticky, slightly plastic, friable, slightly hard; common fine and very fine tubular pores; few fine and very fine roots; moderately calcareous; clear smooth bounday; pH 8.1.

C4 147-160 cm — Brown (10YR 5/3) moist; few faint yellowish brown mottles, silt loam; massive; slightly sticky, slightly plastic, friable, slightly hard; few fine and common very fine tubular pores; few fine and very fine roots; moderately to strongly calcareous, with few fine lime nodules, pH 8.1.

Basic Infiltration Rate : 0.06 cm hr^{-1} Very slow

Hydraulic Conductivities

(Inverse Auger Hole Method) : 17-58 cm 1.30 cm hr^{-1} Moderately slow

95-37 cm 6.47 " Moderately rapid.

ANALYTICAL DATA

Lab. No.	Hori-zon	Depth, cm	Mechanical analysis				Bulk density	Pore density, (vol%)	$CaCO_3$ %	Org. matter, %	pH sat. paste	Ec_e, dSm^{-1}
			Sand %	Silt %	Clay %	Text. class						
19384	Ap	0-15	26	50	24	SiL	-	-	5.0	1.02	8.4	1.56
385	Bw_1	15-50	15	51	34	SiCL	1.52	43	5.5	0.68	-	-
386	Bw_2	50-60	15	51	34	SiCL	1.51	43	8.0	0.27	8.40	0.68
387	Bw_3b	60-68	16	55	29	SiCL	-	-	5.0	0.40	8.30	0.91
388	C_1	68-78	32	50	18	SiL	-	-	5.0	0.27	8.30	0.89
389	C_2	78-97	28	44	28	L	1.52	43	4.5	0.13	8.40	0.66
390	C_3	97-147	43	46	11	L	1.38	48	5.5	0.06	8.30	1.00
391	C_4	147-160	22	56	22	Sil	-	-	13.0	0.06	8.30	0.83

Depth, cm	Soluble saturation extractions, meq l^{-1}						SAR	ESP	Micronutrient, mg kg^{-1}			
	CO_3	HCO_3	Cl	SO_4	Ca+Mg	Na			Cu	Fe	Mn	Zn
0-15	A	2.2	5.2	7.9	7.2	8.4	4.4	5.0	1.40	8.40	3.90	0.25
15-50	-	-	-	-	-	-	-	-	1.00	5.00	3.00	0.25
50-60	A	2.4	1.8	2.6	4.0	2.8	2.0	2.8	0.55	3.90	2.60	0.20
60-68	A	3.0	2.5	3.6	6.0	3.1	1.8	2.4	0.85	5.50	2.70	0.25
68-78	A	2.4	2.3	4.2	4.4	4.5	3.0	3.6	0.80	4.80	3.50	0.20
78-97	A	2.4	1.8	2.4	3.2	3.5	2.8	3.0	0.60	3.00	2.70	0.25
97-147	A	2.8	2.6	4.6	6.4	3.6	2.0	2.8	0.35	2.90	3.00	0.20
147-160+	A	1.6	2.3	4.6	3.2	5.1	4.0	4.6	0.30	2.50	2.20	0.20

Soil Series	:	MARIALA SERIES
Parent Material	:	Mixed wind and river reworked alluvium
Physiography	:	Subrecent fringes of the levees
Slope	:	Nearly level
Land use/Vegetation	:	Australian grass for reclamation
Climate	:	Semi arid subtropical monsoonal
Permeability	:	Moderate
Drainage	:	Well drained
Salinity/Sodicity	:	Porous saline-sodic
Watertable Depth	:	Beyond 150 cm
Important Profile Characteristics	:	Deep, brown/dark brown to dark yellowish brown, moderately calcareous, porouse saline sodic, sandy loams/fine sandy loams with an ochric epopedon and deep cambic subsurface horizon.
USDA Classification	:	Coarse loamy, mixed, hyperthermic, Sodic Haplocambids

TYPICAL PROFILE

Location: About 250 feet in the west of Zakheera Village, tehsil and district Bahawalnagar.

Apn 0-11cm — Dark greyish brown (10YR 4/2) moist and light brownish grey (10YR 6/2) dry; loam; massive; slightly sticky, slightly plastic, friable, hard; few very fine tubular pores; few medium, common fine and very fine roots; moderately calcareous; gradual smooth boundary pH.10.0.

BAn 11-31 cm — Brown/dark brown (10YR 4/3) moist and greyish brown (10YR 5/2) dry; loam; massive to weak coarse subangular blocky; slightly sticky, slightly plastic, friable, hard; common fine and very fine tubular pores; few medium, few fine and very fine roots; moderately calcareous; clear smooth boundary; pH. 10.0.

Bn_1 31-43 cm — Brown to dark brown (10YR 4/3) moist and light grey (10YR 7/2) dry; sandy loam; massive; non sticky, non plastic, friable, slightly hard; few fine and very fine tubular pores; few medium, few fine and very fine roots; moderately calcareous; clear smooth boundary, pH 9.8.

Bn_2 43-101 cm — Dark yellowish brown (10 YR 4/4) moist and pale brown (10YR 6/3) dry; sandy loam; weak coarse subangular blocky; slightly sticky, non plastic, friable, slightly hard; common fine and very fine tubular pores; few medium, common fine and very fine roots; moderately to strongly calcareous; gradual smooth boundary; pH 10.0.

C_1 101-118 cm — Dark yellowish brown (10 YR 4/4) moist and pale brown (10 YR 6/3) dry; sandy loam; massive; slightly sticky, slightly plastic, friable, slightly hard; few fine and very fine tubular pores; few fine and common very fine roots; moderately to strongly calcareous; gradual smooth boundary; pH 9.0.

C_2 118-150 cm Greyish brown (2.5Y 5/2) moist and light brownish grey (2.5Y 6/2) dry; loamy fine sand; massive to single grain; non sticky, non plastic, very friable, soft; few very fine tubular pores; few fine and very fine roots; moderately calcareous; pH 8.8.

Basic Infiltration Rate : 0.18 cm hr^{-1} Slow

Hydraulic Conductivities

(Inverse Auger Hole Method) : 36-79 cm 3.27 cm hr^{-1} Moderate

53-98 cm 5.60 cm hr^{-1} Moderately rapid

ANALYTICAL DATA

Lab. No.	Hori-zon	Depth, cm	Mechanical analysis				Bulk density, g cm^{-3}	Pore density, (vol%)	$CaCO_3$ %	Org. matter, %	pH sat. paste	Ec_e, dSm^{-1}
			Sand %	Silt %	Clay %	Text. class						
19407	Apn	0-11	42	42	16	L	-	-	5.5	1.1	10.3	27.20
408	BAn	11-31	41	38	221	L	1.45	45.0	6.0	0.7	10.2	8.30
409	Bn_1	31-43	71	21	8	SL	1.45	46.0	6.0	0.2	10.1	6.42
410	Bn_2	43-101	69	23	8	SL	1.41	47.0	6.5	0.3	9.9	5.96
411	C_1	101-118	71	20	9	SL	-	-	12.0	0.3	9.6	1.16
412	C_2	118-150+	80	15	5	LS	-	-	10.5	0.1	8.8	1.25

Depth, cm	Soluble saturation extractions, meq l^{-1}						SAR	ESP	Micronutrient, mg kg^{-1}			
	CO_3	HCO_3	Cl	SO_4	Ca+Mg	Na			Cu	Fe	Mn	Zn
0-11	107.2	48.4	65.0	51.4	4.0	268.0	189.5	75.0	0.70	21.30	3.40	0.35
11-41	23.2	9.8	13.4	36.6	3.6	79.4	59.2	46.0	1.10	9.05	3.80	0.25
31-43	15.2	9.0	12.8	27.2	3.8	61.4	44.8	39.0	0.45	4.00	2.10	0.25
43-101	5.2	10.4	19.9	23.9	2.8	56.6	47.9	42.0	0.40	3.20	1.60	0.20
101-118	0.8	3.2	2.7	4.9	2.0	9.6	9.6	11.0	0.30	1.60	0.06	0.15
118.150	0.8	5.2	9.7	3.0	2.2	9.3	8.9	10.2	0.15	1.80	0.80	0.20

Soil Series	:	NABIPUR SERIES
Parent Material	:	Mixed river alluvium
Physiography	:	Subrecent level plains
Landuse/vegetation	:	Wheat, cotton, maize and fodders
Slopes	:	Level to nearly Level
Climate	:	Semi-arid, subtropical monsoonal
Permeability	:	Moderate
Drainage	:	Well drained
Watertable depth	:	Beyond 150 cm
Important Profile Characteristics	:	Deep, brown/dark brown, moderately calcareous loams with an ochric epipedon and a moderately deep cambic subsurface horizon.
USDA Classification	:	Fine loamy*, mixed, hyperthermic, Typic Haplocambids

TYPICAL PROFILE

Location — Acre No. 22-173/15, W.C. No. 111770-L of Azim Distributary.

Ap	0-16 cm	Brown/dark brown (10YR 4/3) moist and light brownish grey (10YR 6/2) dry; loam; massive; slightly sticky, slightly plastic, very friable, slightly hard; common fine and very fine interstitial pores; common fine and very fine roots; moderately calcareous; clear smooth boundary; pH 8.4.
BA	16-30 cm	Dark greyish brown (10YR 4/2) moist and light brownish grey (10YR 6/2) dry; loam; massive and dense; slightly sticky, slightly plastic, friable, hard; few fine and very fine tubular pores; few fine and common very fine roots; moderately calcareous; clear smooth boundary; pH 8.4.
BW	30-71 cm	Brown/dark brown (10YR 4/3) moist; few faint yellowish brown mottle, loam; weak coarse and medium angular and subangular blocky; sticky, plastic friable, hard; common fine and very fine tubular pores; few fine and common very fine roots; few sand pockets; moderately calcareous; clear smooth boundary; pH 8.3.
C1	71-111 cm	Yellowish brown (10YR 5/4) moist; silt loam; massive to very weak coarse subangular blocky; slightly sticky, slightly plastic, very friable, slightly hard; few very fine tubular pores; few fine and common very fine roots; moderately calcareous; abrupt smooth boundary; pH 8.2.
C2	111-150 cm	Olive grey (5Y 5/2) moist and light grey (5Y 6/1) dry; fine sand; single grain; non sticky, non plastic, loose; moderately calcareous; pH 8.2.

* Coarse loamy particle size class also exist.

Basic Infiltration Rate	:		0.36 cm hr^{-1}	Slow
Hydraulic Conductivities				
(Inverse Auger Hole Method)	:	52-90 cm	16.16 cm hr^{-1}	Rapid*

ANALYTICAL DATA

Lab No.	Hori-zon	Depth, cm	Mechanical Analysis				Bulk Density g cm^3	Pore Density (vol %)	$CaCO_3$ %	Org. Matter %	pH Sat. paste	Ece dsm^{-1}
			Sand %	Silt %	Clay %	Text. class						
19374	Ap	0-16	32	47	21	L	-	-	8.0	0.95	8.20	3.02
375	BA	16-30	38	39	23	L	1.77	33	6.0	0.40	8.50	3.64
376	BW	30-71	31	43	26	L	1.70	36	10.0	0.27	8.30	3.09
377	C_1	71-111	34	61	5	SIL	1.36	49	5.0	0.13	8.2	3.00
378	C_2	111-150	95	2	3	S	-	-	3.5	0.00	8.4	1.09

Depth, cm	Soluble saturation extractions, meq l^{-1}						SAR	ESP	Micronutrient Analysis, mg kg^{-1}			
	CO_3	HEO_3	Cl	SO_4	Ca+Mg	Na			Cu	Fe	Mn	Zn
0-16	A	2.6	6.9	20.7	11.6	18.6	7.75	8.0	0.90	8.90	3.30	0.45
16-30	A	3.0	10.0	23.4	11.2	25.2	10.65	12.0	0.85	4.80	2.10	0.45
30-71	0.4	2.2	6.0	22.3	11.2	19.7	8.30	9.5	0.60	3.30	2.65	0.30
71-111	0.4	2.2		21.0	14.0	16.0	6.06	8.0	0.25	2.00	2.80	0.15
111-150	0.4	2.2		4.8	4.0	6.9	4.88	4.0	0.15	4.40	1.20	0.10

* Hydraulic conductivity seems too high, may not be true.

Soil Series	:	PACCA SERIES
Parent Material	:	Mixed river alluvium
Physiography	:	Subrecent basins
Slope	:	Level to nearly level
Land use/Vegetation	:	Rice, cotton, wheat and fodders
Climate	:	Semi arid subtropical monsoonal
Permeability	:	Slow
Drainage	:	Moderately well/seasonally imperfectly drained
Salinity/Sodicity	:	Nil
Watertable Depth	:	Beyond 200 cm
Important Profile Characteristics	:	Deep, very dark grayish brown to brown/dark brown, moderately calcareous, silty clays and clays with an ochric epipedon and cambic subsurface horizon.
USDA Classification	:	Fine, mixed, hyperthermic, Typic Haplocambids

TYPICAL PROFILE

Location: Acre No.6-349/1, W.C. No.63620-L of Azim Distributary.

Ap	0-15 cm	Dark gray (10YR4/1) and dark grayish brown (10YR 4/2) moist; silty clay loam; massive and clody; sticky, plastic, firm, hard; few to common, medium and fine interstitial pores; few medium fine and very fine roots; moderately calcareous; clear smooth boundary; pH 8.4.
Abd	15-27 cm	Very dark grayish brown (10YR 3/2) moist; silty clay loam; massive and compact plough pan; sticky, plastic, firm, hard; few very fine tubular pores; few fine and very fine roots; moderately calcareous; gradual smooth boundary; pH 8.4.
Bw_1	27-85 cm	Dark grayish brown (10YR 4/2) moist; silty clay; weak coarse angular and subangular blocky; very sticky, very plastic, very firm, very hard; few fine and very fine tubular pores; few fine and common very fine roots; moderately calcareous; few snail shells in lower parts; gradual smooth boundary; pH 8.2.
Bw_2	85-102 cm	Dark grayish brown (10YR 4/2) to very dark grayish brown (10YR 3/2) moist; silty clay; weak coarse angular and subangular blocky breaking to medium subangular blocky; very sticky, very plastic, very firm, very hard; few to common fine and very fine tubular pores; a crotovina and few snail shells; few very fine roots; moderately calcareous; gradual smooth boundary; pH 8.2.
Bw_3	102-120 cm	Very dark grayish brown (10YR 3/2) moist; silty clay; weak coarse and medium angular blocky breaking into medium angular and subangular blocky; very sticky, very plastic, very firm, very hard; few medium, common fine and very fine tubular pores; few very fine roots; moderately calcareous; few scattered soft lime nodules, gradual smooth boundary; pH 8.2.

Bg 120-140 cm Very dark gray (10YR 3/1) moist; silty clay loam/approaching clay loam; weak coarse subangular blocky; sticky, plastic, firm, hard; common fine and few to medium very fine tubular pores, moderately calcareous; pH 8.2.

Basic Infiltration Rate	:		0.20 cm hr^{-1}	Very slow
Hydraulic Conductivities				
(Inverse Auger Hole Method)	:	45-100 cm	0.73 cm hr^{-1}	Slow
		102-165 cm	1.31 "	Moderately slow

ANALYTICAL DATA

Lab. No.	Hori-zon	Depth, cm	Mechanical analysis				Bulk density, g cm^{-3}	Pore density, (vol%)	$CaCO_3$ %	Org. matter, %	pH sat. paste	Ec_e, dSm^{-1}
			Sand %	Silt %	Clay %	Text. class						
19275	Ap	0-15	20	50	30	SiCL	1.57	41	7.5	1.4	8.4	3.35
276	ABd	15-27	18	50	32	SiCL	1.65	37	7.0	1.2	8.3	2.08
277	Bw_1	27-85	19	41	40	SiC	1.60	40	-	-	-	-
278	Bw_2	85-102	17	41	42	SiC	1.63	38	10.5	0.4	8.2	1.62
279	Bw_3	102-120	17	42	41	SiC	1.60	40	8.5	0.4	8.2	0.74
280	Bg	120-140	22	42	36	CL	1.61	39	6.5	0.3	8.3	0.77

Depth, cm	Soluble saturation extractions, meq l^{-1}						SAR	ESP	Micronutrient, mg kg^{-1}			
	CO_3	HCO_3	Cl	SO_4	Ca+Mg	Na			Cu	Fe	Mn	Zn
0-15	A	2.2	6.5	24.8	20.2	13.5	-	-	1.10	4.40	2.00	0.45
15-27	A	1.8	4.5	14.5	12.4	8.4	3.4	3.0	1.30	8.00	2.75	0.45
27-85	-	-	-	-	-	-	-	-	-	-	-	-
85-102	A	1.8	3.1	11.3	11.4	5.0	2.1	2.8	1.00	8.50	1.45	0.35
102-120	A	2.0	1.8	3.3	7.0	0.4	0.2	0.2	1.30	7.25	1.60	0.30
120-140	A	2.4	1.8	3.5	7.2	0.5	0.3	0.2	1.00	5.50	1.60	0.40

Soil Series	:	RASULPUR SERIES
Parent Material	:	Mixed river alluvium
Physiography	:	Subrecent levees, levelled
Slope	:	Level to nearly level
Land use/Vegetation	:	Cotton, wheat, pulses and fodders
Climate	:	Semi arid, subtropical monsoonal
Permeability	:	Moderate
Drainage	:	Well drained
Salinity/Sodicity	:	Nil
Watertable Depth	:	Beyond 200 cm
Important Profile Characteristics	:	Deep brown/dark brown to dark yellowish brown, moderately calcareous, fine sandy loams/sandy loams with an ochric epipedon and cambic subsurface horizon.
USDA Classification	:	Coarse loamy, mixed, hyperthermic, Typic Haplocambids*

TYPICAL PROFILE

Location: Acre No.14-329/3, W.C. No.63620-L of Azim Distributary.

Ap	0-20 cm	Dark grayish brown (10YR4/2) moist; fine sandy loam; massive; slightly sticky slightly plastic, friable, slightly hard; few fine interstitial and tubular pores; few fine and many very fine roots; moderately calcareous; clear smooth boundary; pH 8.2.
Bw_1	20-54 cm	Brown/dark brown (10YR 4/3) moist; fine sandy loam; massive to very weak coarse subangular blocky; slightly sticky, slightly plastic, friable, slightly hard; few fine and very fine tubular pores; few fine and very fine roots; moderately calcareous; gradual smooth boundary; pH 8.2.
Bw_2	54-80 cm	Brown/dark brown (10YR4/3) moist; few fine faint yellowish brown (10YR5/6) mottles; fine sandy loam; very weak coarse subangular blocky, fine sand bridging on ped faces; slightly plastic, very friable, slightly hard; few very fine hard lime nodules; few fine and very fine pores; moderately calcareous; gradual smooth boundary; pH 8.2.
Bw_3	80-105 cm	Dark grayish brown (10YR4/2) moist; common fine and medium faint yellowish brown (10YR5/6) mottles; fine sandy loam+; very weak coarse breaking into medium subangular blocky; slightly sticky, slightly plastic, friable, hard; few medium, common fine and very fine tubular pores; few fine and very fine roots; strongly calcareous; clear smooth boundary; pH 8.2.
Bw_4k	105-152 cm	Brown/dark brown (10YR4/3) moist; few fine faint rust brown (5YR5/4) mottles; fine sandy loam; weak coarse and medium subangular blocky; slightly sticky; slightly-plastic, friable, hard; few medium common fine and very fine tubular pores; few fine and very fine roots; strongly calcareous; few to common fine and medium lime nodules; gradual smooth boundary; pH 8.2.

* Poorly drained phase is Aquic Haplocambid.

C 152-190 cm Brown/dark brown (10YR4/3) moist; common faint rust brown (5YR5/4) mottles; fine sandy loam; massive; slightly sticky, slightly plastic, very friable, slightly hard; very few very fine tubular pores; moderately calcareous; pH 8.2.

Basic Infiltration Rate : 1.00 cm hr^{-1} Slow to moderate

Hydraulic Conductivities

(Inverse Auger Hole Method) :

20-65 cm	3.14 cm hr^{-1}	Moderate
91-130 cm	4.78 "	"
155-195 cm	4.89 "	"

ANALYTICAL DATA

Lab. No.	Hori-zon	Depth, cm	Mechanical analysis				Bulk density, g cm^{-3}	Pore density, (vol%)	$CaCO_3$ %	Org. matter, %	pH sat. paste	Ec_e, dSm^{-1}
			Sand %	Silt %	Clay %	Text. class						
19281	Ap	0-20	64	23	13	FSL	1.44	46	6.5	0.6	8.3	0.67
282	Bw_1	20-54	63	28	9	FSL	1.57	41	7.0	0.3	8.3	0.54
283	Bw_2	54-80	69	18	13	FSL	1.54	42	10.0	0.3	8.4	0.55
284	Bw_3	80-105	52	32	16	FSL	1.61	39	16.0	0.2	8.4	0.55
285	BwK_4	105-152	52	34	14	FSL	1.58	40	15.0	0.3	8.4	0.63
286	C	152-190	75	16	9	SL	1.58	40	11.5	0.2	8.5	0.64

Depth, cm	Soluble saturation extractions, meq l^{-1}						SAR	ESP	Micronutrient, mg kg^{-1}			
	CO_3	HCO_3	Cl	SO_4	Ca+Mg	Na			Cu	Fe	Mn	Zn
0-20	A	.8	1.3	3.6	6.5	0.2	0.1	-	0.30	2.75	1.60	0.35
20-54	A	2.4	1.3	1.7	5.2	0.2	0.1	-	0.40	2.80	1.10	0.30
54-80	A	2.4	1.7	1.4	5.2	0.3	0.2	-	0.45	3.00	1.70	0.30
80-105	A	2.0	1.3	2.2	5.4	0.1	0.1	-	0.35	1.80	1.00	0.25
105-152	A	2.2	1.9	1.8	6.2	0.1	0.1	-	0.35	2.20	0.80	0.20
152-190	0.4	2.2	1.4	2.4	6.2	0.2	0.1	-	0.20	3.00	0.85	0.20

Soil Series	:	SATGHARA SERIES
Parent Material	:	Mixed river alluvium
Physiography	:	Subrecent basins
Slope	:	Level to nearly level
Land use/Vegetation	:	Barren, sparce vegetation cover of dab and lani/sudan grass for reclamation
Climate	:	Semi arid subtropical monsoonal
Permeability	:	Very slow
Drainage	:	Poorly drained
Salinity/Sodicity	:	Dense strongly saline sodic
Watertable Depth	:	Water table at 160 cm
Important Profile Characteristics	:	Deep, very dark grayish brown to brown/dark brown, moderately calcareous, dense saline-sodic silty clays with an ochric epipedon and a moderately deep cambic subsurface horizon.
USDA Classification	:	Fine, mixed, hyperthermic, Sodic Haplocambids

TYPICAL PROFILE

Location: Acre No.21-507/3, W.C. No.20610-L of Azim Distributary.

Anz	0-12 cm	Dark grayish brown 10YR4/2) moist; loam approaching silt loam; thin platy; sticky, plastic, firm, hard; common medium and fine vesicular and interstitial pores; moderately calcareous; clear smooth boundary; pH 9.6.
Bn_1	12-28 cm	Brown/dark brown (10YR 4/3) moist; silty clay loam+; weak medium and coarse subangular blocky; very sticky, very plastic, very firm, very hard; few very fine tubular pores; moderately calcareous; clear smooth boundary; pH 9.6.
Bn_2	28-50 cm	Brown/dark brown (10YR 4/3) moist; silty clay; weak coarse subangular blocky; very sticky, very plastic, very firm, very hard; few fine and very fine tubular pores; few snail shells; moderately calcareous; clear smooth boundary; pH 9.6.
Bn_3	50-64 cm	Dark grayish brown (10YR 4/2) moist; common fine faint rust brown (5YR 5/6) and yellowish brown (10YR 5/6) mottles; silty clay; moderate medium and coarse subangular blocky; very sticky, very plastic, very firm, very hard; few fine and very fine tubular pores; few snail shells, moderately calcareous; clear smooth boundary; pH 9.2.
BCn	64-92 cm	Brown/dark brown (10YR 4/3) moist; many fine distinct yellowish brown (10YR5/6) mottles; silty clay; massive to very weak coarse subangular blocky; very sticky, very plastic, very firm, very hard; few fine and very fine tubular pores; few snail shells; moderately calcareous; clear smooth boundary; pH 8.8.
Cn_1	92-120 cm	Brown/dark brown (10YR 4/3) moist; few fine faint yellowish brown (10YR 5/6) mottles; silty clay loam; massive; sticky, plastic, firm, hard; few very fine tubular pores; few fine and very fine roots; moderately calcareous, clear smooth boundary; pH 8.8.

Cn2 120-160+ cm Brown (10YR 5/3) and brown/dark brown (10YR4/3) moist; silt loam; massive; sticky, plastic, firm, hard; very few very fine tubular pores; very few fine roots; moderately calcareous; pH 8.8.

Basic Infiltration Rate	:		0.18 cm hr^{-1}	Very slow
Hydraulic Conductivities				
(Inverse Auger Hole Method)	:	12-72 cm	0.02 cm hr^{-1}	Very slow
		99-140 cm	0.04 "	"

ANALYTICAL DATA

Lab. No.	Hori-zon	Depth, cm	Mechanical analysis				Bulk density, g cm^{-3}	Pore density, (vol%)	$CaCO_3$ %	Org. matter, %	pH sat. paste	Ec_e, dSm^{-1}
			Sand %	Silt %	Clay %	Text. class						
19340	Anz	0-12	29	48	23	L	1.41	47	5.5	0.2	10.8	44.50
341	Bn_1	12-28	18	46	36	SiCL	1.71	35	9.0	0.2	10.7	22.60
342	Bn_2	28-50	17	41	42	SiC	1.69	36	9.5	0.2	10.4	8.55
343	Bn_3	50-64	15	42	43	SiC	1.59	40	9.0	0.2	10.4	3.40
344	BCn	64-92	18	41	41	SiC	1.49	44	13.0	0.2	10.1	2.57
345	Cn_1	92-120	18	51	31	SiCL	1.67	37	13.5	0.1	9.7	0.67
346	Cn_2	120-160	17	68	15	SiL	-	-	12.5	0.2	9.6	0.60

Depth, cm	Soluble saturation extractions, meq l^{-1}						SAR	ESP	Micronutrient, mg kg^{-1}			
	CO_3	HCO_3	Cl	SO_4	Ca+Mg	Na			Cu	Fe	Mn	Zn
0-12	356.0	22.0	51.5	15.5	6.0	439.0	253.5	80.0	0.45	5.00	0.70	0.45
12-28	115.2	26.6	26.5	57.5	5.2	220.8	136.9	65.0	0.55	6.20	1.10	0.45
28-50	36.8	23.0	17.8	7.9	5.6	79.9	47.7	43.0	0.60	4.50	0.90	0.30
50-64	16.4	2.0	4.8	10.8	2.4	31.6	28.8	29.0	0.40	2.10	1.00	0.20
64-92	9.6	3.4	3.6	9.1	2.4	23.3	21.2	23.0	0.30	1.50	0.85	0.25
92-120	0.4	3.4	1.8	1.1	3.6	3.1	2.31	2.8	0.35	1.75	1.55	0.30
120-160	0.4	3.0	2.0	0.6	2.0	4.0	4.0	6.0	0.35	1.65	2.15	0.50

Soil Series	:	SHAHDARA SERIES
Parent Material	:	Mixed river alluvium
Physiography	:	Subrecent level plains (back slopes)
Land use/vegetation	:	Maize, wheat, cotton and foddrs
Slope	:	Nearly level
Climate	:	Semi arid, subtropical monsoonal
Permeability	:	Moderately rapid/moderate
Drainage	:	Well drained
Salinity/sodicity	:	Nil
Watertable depth	:	Beyond 200 cm
Important Profile\ Characteristics	:	Deep, brown/dark brown, moderately calcareous, massive/stratified, silt loams and very fine sandy loams with an ochric epipedon and no sub-surface genetic horizon.
USDA Classification	:	Coarse silty, mixed (calcareous), hyperthermic Typic Torrifluent

TYPICAL PROFILE

Location: About 300 meters in the west of Nanga Baloch village in Chishtian tehsil, Bahawalnagar district.

Ap	0-17 cm	Brown/dark brown (10YR 4/3)moist and brown (10YR 5/3) dry; very fine sandy loam; massive; slightly sticky, slightly plastic, very friable, slightly hard; common fine interstitial and few fine tubular pores; common fine and very fine roots; moderately calcareous; clear smooth boundary; pH 8.2.
C1	17-26 cm	Greyish brown (10YR 5/2) moist, loamy fine sand; single grain; non sticky, non plastic, very friable, loose; no pores; few fine and very fine roots; moderately calcareous; clear smooth boundary; pH 8.1.
C2	26-31 cm	Brown/dark brown (10YR 4/3) moist; very fine sandy loam; weak fine platy; slightly sticky, slightly plastic, very friable, slightly hard; few fine and very fine tubular pores; few fine and very fine roots; moderately calcareous; clear smooth boundary; pH 8.0.
C3	31-35cm	Brown/dark brown (10YR 4/3) moist; loamy very fine sand; massive to single grain; non sticky, non plastic, very friable, soft; few very fine tubular pores; few fine roots; moderately calcareous; clear smooth boundary; pH 8.0.
C4	35-62cm	Brown/dark brown (10YR 4/3) moist; very fine sandy loam; massive; slightly sticky, slightly plastic, very friable, slightly hard; common fine and very fine tubular pores; few fine and very fine roots; moderately calcareous; clear smooth boundary; pH 8.0
C5	62-98cm	Brown/dark brown (10YR 4/3) moist, few faint yellowish brown mottles; silt loam; massive but lower part is weak medium platy; slightly sticky, plastic slightly firm, hard; common fine and very fine tubular pores; few fine and very fine roots; common earthworm casts; moderately calcareous; abrupt smooth boundary; pH 8.0

C6	98-103cm	Greyish brown (2.5Y 5/2) moist; loamy fine sand; massive to single grin; non sticky, non plastic, loose; few very fine roots; moderately calcareous; clear smooth boundary; pH 8.0
C7	103-116cm	Brown/dark brown (10YR 4/3) moist; very fine sandy loam; weak fine platy; slightly sticky, slightly plastic, friable, slightly hard; few fine and very fine tubular pores; few very fine roots; moderately calcareous; clear smooth boundary; pH 8.0
C8	116-160cm	Brown/dark brown (10YR 4/3) moist; few fine distinct yellowish brown mottles; silt loam; weak medium platy; slightly sticky, slightly plastic, slightly firm, hard, few fine and very fine tubular pores; few fine and very fine roots; common earthworm casts;abrupt smooth boundary; pH 8.0.
C9	160+cm	Greyish brown (2.5Y 5/2) moist; coarse sand; single grain; moderately calcareous; pH 8.0.

Basic Infiltration Rate	:		2.00 cm hr^{-1}	Moderate
Hydraulic Conductivities				
(Inverse Auger Hole Method)	:	16-60 cm	6.19 cm hr^{-1}	Moderate rapid
		35-88 cm	5.91 "	"

ANALYTICAL DATA

Lab. No.	Hori-zon*	Depth, cm	Mechanical Analysis				Bulk density	Pore density	$CaCO_3$ %	Org. Matter %	pH sat. paste	Ecc, dSm^{-1}
			Sand, %	Silt, %	Clay, %	Text, Class						
19418	Ap	0-17	34	62	4	Sil	-	-	5.5	1.02	8.00	0.88
419	C_1	17-21	74	20	6	LFS	-	-	6.5	0.13	8.31	0.48
420	C_4	35-62	33	58	9	SIL	-	-	5.5	0.27	8.2	0.53
421	C_5	62-98	16	65	19	SIL	-	-	9.5	0.34	8.2	0.67
422	C_7	103-116	26	67	7	SIL	-	-	7.0	0.06	8.2	0.80
423	C_8	116-160	16	69	15	SIL	-	-	6.0	0.06	8.0	0.80
424	C_9	160+	95	3	2	S	-	-	5.5	0.00	8.0	0.35

Depth, cm	Soluble saturation extractions, meq l^{-1}						SAR	ESP	Micronutrient, mg kg^{-1}			
	CO_3	HCO_3	Cl	SO_4	Ca+Mg	Na			Cu	Fe	Mn	Zn
0-17	A	1.8	2.0	5.0	6.0	2.8	1.6	-	0.70	6.90	4.00	0.45
17-21	A	2.0	2.3	0.5	3.2	1.6	1.3	-	0.25	2.90	2.65	0.35
35-62	A	1.8	1.9	1.5	3.2	2.1	1.6	-	0.55	6.50	3.00	0.25
62-98	A	1.8	3.0	1.9	4.0	2.7	1.1	-	0.75	6.20	4.80	0.35
10-116	A	2.2	3.4	2.4	5.6	2.4	1.5	-	0.40	4.30	3.05	0.25
116-160	A	2.2	3.4	2.4	5.2	2.6	1.6	-	0.65	5.50	3.60	0.35
160-+	0.4	1.8	1.4	0.2	2.4	1.1	1.0	-	0.15	2.80	1.30	0.25

* Sample for horizon C_2, C_3 and C_6 were not taken because of little depth.

Soil Series/Varient	:	SODHRA (SODIC VARIANT)*
Parent Material	:	Mixed river alluvium
Physiography	:	Subrecent sand bars
Slope	:	Nearly level to gently undulating
Land use/Vegetation	:	Fair vegetation cover of dab, jawan and sarkanda
Climate	:	Semi arid subtropical monsoonal
Permeability	:	Rapid
Drainage	:	Imperfectly drained
Salinity/Sodicity	:	Non saline sodic
Watertable Depth	:	Water table at 110 cm
Important Profile Characteristics	:	Deep, grayish brown, moderately calcareous, non saline-sodic, massive and single grain, loamy sands and sands with ochric epipedon and no subsurface genetic horizon.
USDA Classification	:	Mixed, hyperthermic, Typic Torripsamments

TYPICAL PROFILE

Location: Acre No.25-506/12, W.C. No.20610-L of Azim Distributary.

An	0-11 cm	Brown/dark brown (10YR4/3) moist; fine sandy loam; massive and weak platy; slightly sticky, slightly plastic, very friable and slightly hard; few vesicular and interstitial pores; few coarse, common medium, many fine and very fine roots; moderately calcareous; clear smooth boundary; pH 9.0.
C1	11-22 cm	Brown (10YR5/3) moist; loamy sand; non-sticky, non-plastic, very friable, loose; few very fine interstitial pores; common medium, many fine and very fine roots; moderately calcareous; gradual smooth boundary; pH 8.8.
C2	22-33 cm	Grayish brown (2.5Y5/2) moist; loamy sand; massive; non-sticky, non-plastic, loose; few medium, common fine and very fine roots; moderately calcareous; gradual smooth boundary; pH 8.6.
C3	33-60 cm	Grayish brown (2.5Y 5/2) moist; fine sand; single grain; non-sticky, non-plastic, loose; few medium, common fine and very fine roots; moderately calcareous; gradual smooth boundary; pH 8.6.
C4	60-110+	Olive gray (5Y4/2) moist; coarse sand (micaceous); single grain; non-sticky, non-plastic, and loose; few fine and very fine roots; moderately calcareous; pH 8.4.

Basic Infiltration Rate	:		0.90 cm hr^{-1}	Slow
Hydraulic Conductivities				
(Inverse Auger Hole Method)	:	19-40 cm	69.48 cm hr^{-1}	Very rapid
		43-70 cm	19.80 "	Rapid
		66-90 cm	2.84 "	Moderate*
(Auger Hole Method)	:	109-148 cm	6.63 "	Moderate rapid**

* Sodhra (Sodic Variant) is not present in the present survey; profile is included to represent Sodhra Series.

** Hydraulic conductivity is low due to wetness in this part.

ANALYTICAL DATA

Lab. No.	Hori-zon	Depth, cm	Mechanical analysis				Bulk density, g cm^{-3}	Pore density, (vol%)	$CaCO_3$ %	Org. matter, %	pH sat. paste	Ec_e, dSm^{-1}
			Sand %	Silt %	Clay %	Text. class						
19347	An	0-11	65	26	9	SL	1.60	40	8.5	0.2	10.4	3.74
348	C_1	11-22	76	19	5	LS	1.47	44	6.5	0.1	10.4	0.86
349	C_2	22-33	90	5	5	S	1.42	46	8.5	0.0	10.2	0.66
350	C_3	33-60	92	3	5	S	-	-	8.0	0.0	10.1	0.66
351	C_4	60-110	86	8	6	S	-	-	10.5	0.0	8.9	0.40

Depth, cm	Soluble saturation extractions, meq l^{-1}						SAR	ESP	Micronutrient, mg kg^{-1}			
	CO_3	HCO_3	Cl	SO_4	Ca+Mg	Na			Cu	Fe	Mn	Zn
0-11	18.4	8.4	5.1	5.5	3.2	34.2	27.1	28.0	0.30	1.80	1.10	0.30
11-22	2.4	3.4	1.9	0.9	4.0	4.6	3.2	4.0	0.20	0.70	0.45	0.50
22-33	1.6	3.6	1.3	0.1	2.8	3.8	3.2	4.0	0.20	3.50	0.80	0.35
33-60	1.6	3.6	1.1	0.3	3.2	3.4	2.7	3.0	0.25	2.90	0.60	0.35
60-110	0.4	2.4	1.0	0.2	3.8	0.2	0.1	-	0.15	2.40	0.95	0.30

Soil Series	:	SULTANPUR SERIES
Parent Material	:	Mixed river alluvium
Physiography	:	Subrecent level plains
Slope	:	Level
Land use/Vegetation	:	Sugarcane, cotton, wheat and fodders
Climate	:	Semi arid subtropical monsoonal
Permeability	:	Moderate
Drainage	:	Well drained
Salinity/Sodicity	:	Nil
Watertable Depth	:	Beyond 200 cm
Important Profile Characteristics	:	Deep/very deep, brown to brown/dark brown, moderately calcareous, silt loam and very fine sandy loams with an ochric epipedon and cambic subsurface horizon.
USDA Classification	:	Fine silty*, mixed, hyperthermic, Flurentic Haplocambids

TYPICAL PROFILE

Location: Acre No.11-506/10, W.C. No.20610-L of Azim Distributary.

Ap 0-15cm — Brown/dark brown (10YR 4/3) moist; loam; massive; slightly sticky; slightly plastic, very friable, slightly hard; common fine and very fine interstitial pores; few medium, common fine and many very fine roots; moderately calcareous; gradual smooth boundary; pH 8.2.

BA 15-33 cm — Brown/dark brown (10YR 4/3) moist; very fine sandy loam; massive to very weak coarse subangular blocky; slightly sticky, slightly plastic, very friable, slightly hard; common fine and very fine tubular pores; few earth worm casts; few fine and very fine roots; moderately calcareous; clear smooth boundary; pH 8.0.

Bw_1 33-44 cm — Brown/dark brown (10YR 4/3) moist; common fine faint yellowish brown (10YR 5/6) mottles; silt loam; very weak coarse subangular blocky; sticky, plastic, firm, hard; few medium, common fine and very fine tubular pores, few earthworm casts; few fine and common very fine roots; moderately calcareous; gradual smooth boundary; pH 8.0.

Bw_2 44-70 cm — Brown/dark brown (10YR 4/3) moist; few faint rust brown (5YR 5/6) mottles; silt loams; weak coarse subangular blocky; slightly sticky, slightly plastic, friable, slightly hard; few medium, common fine and very fine tubular pores; few medium, fine and very fine roots; few snail shells; moderately calcareous; clear smooth boundary, pH 8.0.

BC 70-95 cm — Yellowish brown (10YR 5/4) moist; silt loam; very weak coarse subangular blocky; slightly sticky, slightly plastic, very friable, slightly hard; few medium, many fine and

* Coarse silty particle size class also exist.

very fine tubular pores: common very fine roots; moderately calcareous; gradual smooth boundary; pH 8.0.

C 95-170 cm Yellowish brown (10YR 5/4) moist; silt loam; massive; slightly sticky, slightly plastic, very friable, slightly hard; many fine and very fine tubular pores; few moderately calcareous; pH 8.0

Basic Infiltration Rate	:		0.30 cm hr^{-1}	Slow
Hydraulic Conductivities				
(Inverse Auger Hole Method)	:	13-50 cm	3.56 cm hr^{-1}	Moderate
		51-75 cm	1.96 "	"
		115-150 cm	1.68 "	"

ANALYTICAL DATA

Lab. No.	Hori-zon	Depth, cm	Mechanical analysis				Pore density, (vol%)	Hyd. conduc. cm hr^{-1}	$CaCO_3$ %	Org. matter, %	pH sat. paste	Ec_e, dSm^{-1}
			Sand %	Silt %	Clay %	Text. class						
19334	Ap	0-15	39	45	15	L	1.38	48	5.0	0.9	8.3	0.66
335	BA	15-23	54	35	11	VFSL	1.58	40	6.5	0.2	8.4	0.45
336	Bw_1	33-44	21	56	23	SiL	1.55	42	11.5	0.2	8.4	0.50
337	Bw_2	44-70	19	54	27	SiL	1.49	44	10.0	0.4	8.4	0.51
338	BC	70-95	21	62	17	SiL	1.46	45	8.5	0.2	8.4	0.55
339	C	95-115	21	62	17	SiL	1.40	47	7.0	0.2	8.4	0.50

Depth, cm	Soluble saturation extractions, meq l^{-1}						SAR	ESP	Micronutrient, mg kg^{-1}			
	CO_3	HCO_3	Cl	SO_4	Ca+Mg	Na			Cu	Fe	Mn	Zn
0-15	A	2.4	1.4	2.8	5.2	1.4	0.8	-	0.60	4.00	1.80	0.20
15-33	A	1.8	1.3	1.4	4.2	0.3	0.2	-	0.40	2.00	1.10	0.20
33-44	A	2.2	1.7	1.1	4.8	0.2	0.1	-	0.40	1.85	1.55	0.20
44-70	A	2.6	1.4	1.1	4.8	0.3	0.2	-	0.45	2.15	1.40	0.20
70-95	A	2.2	1.6	1.7	5.4	0.1	0.1	-	0.35	1.50	1.10	0.20
95-115	A	2.6	1.8	0.6	4.8	0.2	0.1	-	0.35	1.85	1.55	0.25

IIMI-PAKISTAN PUBLICATIONS
RESEARCH REPORTS

Report No.	Title	Author	Year
R-1	**Crop-Based Irrigation Operations Study in the North West Frontier Province of Pakistan** Volume I: Synthesis of Findings and Recommendations	Carlos Garces-R D.J. Bandaragoda Pierre Strosser	June 1994
	Volume II: Research Approach and Interpretation	Carlos Garces-R Ms. Zaigham Habib Pierre Strosser Tissa Bandaragoda Rana M. Afaq Saeed ur Rehman Abdul Hakim Khan	June 1994
	Volume III: Data Collection Procedures and Data Sets	Rana M. Afaq Pierre Strosser Saeed ur Rehman Abdul Hakim Khan Carlos Garces-R	June 1994
R-2	Salinity and Sodicity Research in Pakistan - Proceedings of a one-day Workshop	J.W. Kijne Marcel Kuper Muhammad Aslam	Mar 1995
R-3	Farmers' Perceptions on Salinity and Sodicity: A case study into farmers' knowledge of salinity and sodicity, and their strategies and practices to deal with salinity and sodicity in their farming systems	Neeltje Kielen	May 1996
R-4	Modelling the Effects of Irrigation Management on Soil Salinity and Crop Transpiration at the Field Level (M.Sc Thesis - published as Research Report)	S.M.P. Smets	June 1996
R-5	Water Distribution at the Secondary Level in the Chishtian Sub-division	M. Amin K. Tareen Khalid Mahmood Anwar Iqbal Mushtaq Khan Marcel Kuper	July 1996
R-6	Farmers Ability to Cope with Salinity and Sodicity: Farmers' perceptions, strategies and practices for dealing with salinity and sodicity in their farming systems	Neeltje Kielen	Aug 1996
R-7	Salinity and Sodicity Effects on Soils and Crops in the Chishtian Sub-Division: Documentation of a Restitution Process	Neeltje Kielen Muhammad Aslam Rafique Khan Marcel Kuper	Sept 1996
R-8	Tertiary Sub-System Management: (Workshop proceedings)	Khalid Riaz Robina Wahaj	Sept 1996
R-9	Mobilizing Social Organization Volunteers: An Initial Methodological Step Towards Establishing Effective Water Users Organization	Mehmoodul Hassan Zafar Iqbal Mirza D.J. Bandaragoda	Oct 1996
R-10	Canal Water Distribution at the Secondary Level in the Punjab, Pakistan (M.Sc Thesis published as Research Report)	Steven Visser	Oct 1996
R-11	Development of Sediment Transport Technology in Pakistan: An Annotated Bibliography	M. Hasnain Khan	Oct 1996