REPORT NO. R-7

SALINITY AND SODICITY EFFECTS ON SOILS AND CROPS IN THE CHISHTIAN SUB-DIVISION:

Documentation of a Restitution Process

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Table of Content

INTRODUCTION 1

Background 1

Objectives of the Restitution Exercise 2

Approach 2

Restitution Process 3
Identification of issues 3
Preparation of topics for restitution 3
Preparation of farmer's meetings 3
Farmer's Restitution Meeting 4
Evaluation 4

DESCRIPTION OF THE RESEARCH AREA 5

Watercourse Fordwah 14-R 5
Soils 5
Groundwater table depth and quality 7
Crops and cropping intensities 7
Canal water supply and distribution 8
Tubewell use and quality 8
Salinity and sodicity status 10
Farm characteristics 10

Watercourse Fordwah 130-R 11
Soils 11
Groundwater table depth and quality 11
Crops and cropping intensities 13
Canal water supply and distribution 13
Tubewell use and quality 13
Salinity and sodicity status 14
Farm characteristics 15

Watercourse Azim 111-L 16
Soils 16
Groundwater table depth and quality 16
Crops and cropping intensities 18
Canal water supply and distribution 18
Tubewell use and quality 18
Salinity and sodicity status 20
Farm characteristics 20

CONTENTS OF THE RESTITUTION EXERCISES 21

Salinity and Sodicity Processes 21
Salinity process 21
Sodicity process 22

Salinity and Sodicity Problems 23
Watercourse Azim 111-L 23
Watercourse 130-R 25
Watercourse Fordwah 14-R 27

Influence of Salinity and Sodicity on Crop Production 28

Options for Salinity Management 31
Options for prevention of salinity and sodicity, and reclamation of soils 31
Options for sustained/improved crop production 33

RESULTS OF THE RESTITUTION MEETING 35

Discussions on Experiences, constraints, and Options 35
Watercourse Fordwah 14-R 35
Watercourse Fordwah 130-R 35
Watercourse Azim 111-L 36

Identification of Demand for Action-oriented Research 37
Watercourse Fordwah 14-R 37
Watercourse Fordwah 130-R 37
Watercourse Azim 111-L 37

CONCLUSIONS AND RECOMMENDATIONS 38

General Conclusions 38

Conclusions by Watercourse 38
Watercourse 130-R 38
Watercourse Azim 111-L 39
Watercourse Fordwah 14-R 39

General Recommendations 39

Site Specific Recommendations 40

Annex 1: Set-Up of Semi-structured Interviews **41**

Annex 2: Program of the Restitution Meetings **42**

List of Tables

Table 1: Tubewell water qualities of Watercourse Fordwah 14-R. 9
Table 2: Tubewell water qualities of Watercourse Fordwah 130-R. 15
Table 3: Tubewell water qualities of Watercourse Azim 111-L. 19

List of Figures

Figure 1: Water table depths in Watercourse Fordwah 14-R. 7
Figure 2: Total number of tubewells installed in Watercourse Fordwah 14-R. 9
Figure 3: Water table depths in Watercourse Fordwah 130-R. 11
Figure 4: Total number of tubewells installed in Watercourse Fordwah 130-R. 14
Figure 5: Water table depths in Watercourse Azim 111-L. 16
Figure 6: Total number of tubewells installed in Watercourse Azim 111-L. 19
Figure 7: Salinisation through irrigation.
Figure 8: Capillary salinisation. 22
Figure 9: Salts dissolved in irrigation water.
Figure 10: Sodification through irrigation. 23
Figure 11: Physical properties of sodic soils.
Figure 12: Salinity situation in WC 111-L. 24
Figure 13: Salinity of tubewells (WC 111-L).
Figure 14: Sodicity of tubewells (WC 111-L). 25
Figure 15: Salinity/sodicity situation in Watercourse 130-R 26
Figure 16: Salinity of tubewells (WC 130-R).
Figure 17: Sodicity of tubewells (WC 130-R). 26
Figure 18: Salinity and sodicity situation in WC 14-R 27
Figure 19: Salinity of tubewells (WC 14-R).
Figure 20: Sodicity of tubewells (WC 14-R). 28
Figure 21: Effect of salinity on crop growth. 29
Figure 22: Disturbed water uptake. 29
Figure 23: Sensitivity of plants at different stages.
Figure 24: Effect of sodium on crop growth. 30
Figure 25: Leaching of salts.
Figure 26: Options for sodic soils. 32
Figure 27: Effects of janter on soil structure. 33
Figure 28: Management of wheat and cotton.
Figure 29: Crop management under sodicity. 34

Chapter 1

Introduction

Background

IIMI Pakistan began its research activities in Pakistan in September 1986, with the objective to foster irrigated agriculture in Pakistan through improvements in water management. During the period 1987-1995, IIMI Pakistan has undertaken various research activities in different areas of the country, mainly in the Province of Punjab, which has the largest irrigation system network in the country.

IIMI started its research activities in Hasilpur and Chishtian area in 1990. Presently, the research program is in its second phase under the Dutch-funded Project 'Managing Irrigation for Environmentally Sustainable Agriculture in Pakistan'. Initially, the research outputs, in the shape of reports and research papers, were related to donors, researchers, policy makers, system managers, etc. The farmers, who are supposed to be one of the end users and beneficiaries of the research, were not included in this list. Up to this moment, IIMI's research has been one-sided in that farmers were only information providers, and no direct incentives in terms of feedback to farmers has been given. On the basis of IIMI's experience with farmers, it was concluded that feedback should be given to the farmers, preferably in the shape of research results and practical advice. Until this stage, the purpose for restitution of IIMI's research results was to satisfy the farmers' complaints, because IIMI wanted to ensure farmers' co-operation as data providers for research activities. Though, the objectives for restitution can be many fold, including: cross-checking of research findings (validity); obtain feedback from farmers; invite comments and criticism; and establish possibilities for follow-up research. Donors of IIMI have emphasised the importance of dissemination of research results to the farmers. The problem felt by IIMI was that they are a research institute and not an extension services provider; also knowledge on restitution and dissemination of research results was not available in IIMI. So, there was a need to overcome this knowledge gap. At the end of 1994, IIMI introduced Participatory Rural Appraisal (PRA) and organised an 8-day PRA training session and a 5-month field research effort. This research focused on farmers' perceptions on irrigation performance in the Hasilpur area. However, the PRA study did not achieve the expected outcomes in that other researchers did not know how to incorporate these techniques and approaches into their own ongoing research. In March 1995, IIMI decided to introduce another participatory methodology, Rapid Appraisal of Agricultural Knowledge Systems (RAAKS), which focused on the identification of collaborative arrangements with line agencies related to dissemination of IIMI's research results.

In April 1994, the Department of Communication and Innovation Studies of the Wageningen Agricultural University (WAU), The Netherlands was involved in conducting a RAAKS training in IIMI Pakistan, and to initiate RAAKS studies. A 10-day training was organised by IIMI in collaboration with WAU at IIMI Pakistan, Headquarters, Lahore. After the training, a study was undertaken at the Hasilpur, Bahawalnagar, and Haroonabad Field Stations by three Dutch graduates trained in the RAAKS methodology, who worked with IIMI field staff in implementing this approach (report is forthcoming). In the light of the recommendations from this study, and the outcomes of discussions held in a workshop on this study, the following decisions on follow-up activities were made:

1. For any research conducted in the future, restitution will be part of each researcher's work plan;
2. Farmers should be involved in the restitution process when they are a partner in the research;
3. During and after the restitution, there is a need for monitoring and evaluating the outcome;
4. Restitution should be the first step in the attempt to disseminate research results (in this respect, it is useful to involve other experts in the restitution process); and
5. In order to make collaborative efforts sustainable, they must eventually become institutionalised.

Objectives of the Restitution Exercise

The restitution activities, as presented in this report, are in line with the aforementioned agreements for follow-up activities. The objectives for this restitution exercise were formulated as follows:

1. Restitute present research findings to the farmers;
2. Give site-specific recommendations to the farmers; and
3. Identify possibilities for *Action-Oriented Research*, as follow-up activities of ongoing salinity and sodicity research.

These objectives are concerned with the primary expected output of the restitution exercise. Since restitution is a fairly new activity within IIMI-Pakistan, several secondary objectives, including learning objectives, were included as well:

1. Identify possible ways through which research finding can be disseminated;
2. Make a first attempt to collaborate with line-agencies as a first step in broader dissemination of research findings; and
3. (Learn how to) involve farmers in (future) research activities.

Approach

The salinity and sodicity research showed that there are three different conditions under which present salinisation and sodification processes take place: 1) Indigenous salinity and sodicity enhanced by irrigation practices; 2) Salinisation and sodification due to the use of poor quality tubewell water; and 3) Capillary salinisation and sodification due to capillary rise from high ground water tables that are also saline. Various combinations of the aforementioned conditions exist as well. In order to facilitate the learning process during the restitution, the activities focused on three sample watercourses where distinct situations exist.

IIMI's salinity and sodicity research has resulted in a large amount of data that has now been analysed which, potentially, could be prepared for restitution. Since farmers should be the beneficiaries from this restitution exercise, the farmers from the three watercourses were consulted. Together with the researchers, they identified the issues to be elaborated on in the restitution. In this way, farmers' interest was increased. IIMI has a lot of expertise on salinity and sodicity related topics, but it was recognised that certain agents were more experienced in certain topics than IIMI. For this reason, and to serve the objective of making a first attempt to collaborate with line-agencies, relevant agencies were contacted and involved in the preparation of this restitution.

The restitution itself was done in the form of a series farmers' meetings. In the farmers' restitution meetings, the research findings and recommendations were verbally communicated to the farmers with the help of several aids like posters, maps, etc. The farmers' meetings took place at the watercourse level and were hosted by the farmers. The meeting also facilitated discussions on follow-up activities. One of the objectives of the follow-up research will be to test the impact and workability of the recommendation under present physical conditions and constraints set by the farming systems. During these discussions, new issues to be explored would have come up.

The whole restitution exercise was monitored and in order to allow evaluation and to serve as a learning example for future restitution exercises. Farmers were contacted after the restitution again. Since they should be the beneficiaries of the restitution exercise, it was found to be of utmost importance to obtain their viewpoints on the restitution exercises.

Restitution Process

Identification of issues

In order to identify the issues for restitution, as well as to assess the expectations of farmers regarding the restitution exercises, semi-structured interviews were held with farmers. Since different processes and problems play a role in the three selected watercourses, the identification was done for each watercourse. The selection of farmers included those with different farm characteristics and different constraints. The set-up of the interviews is presented in Annex 1.

Preparation of topics for restitution

In the first place, a presentation of the research results, including the salinity and sodicity processes, for each watercourse. This presentation served two purposes: 1) it was used as a basis for discussion with experts from other agencies; and 2) it could be used, after some alteration, for the farmers' restitution meetings. The salinity and sodicity research has provided detailed insights into current processes, the influence of farmers practices on these processes, and farmer's constraints to deal with current problems. During the preparations, farmers expressed that they were not only interested in current processes, but were even more interested in solutions to the problems. At this point, experts from line-agencies were contacted and requested to co-operate in the formulation of options for improved management of salinity and sodicity problems and to explain certain issues related to crop growth, nutrient uptake, pest and diseases, and salinity/sodicity. The list of topics and questions, as prepared with the farmers, together with a brief description of the salinity and sodicity situation for each watercourse was sent to the experts before the actual visit took place. During the visits, a small presentation about IIMI, IIMI's research, the goals and objectives of the restitution exercise, and the salinity and sodicity situation for each watercourse was prepared. On the basis of the identified questions and topics, the discussion took place. Line-agencies which were visited were: 1) the Department of Soil Science, University of Agriculture, Faisalabad (UAF); 2) Soil Survey of Pakistan; and 3) dr. Shah Muhammad (retired professor of the UAF)

Preparation of farmer's meetings

After the meetings with the experts from different agencies, the content of the farmer's meeting was prepared. The site and the time for these meetings were set by the farmers, who also hosted the meetings. The aim of each meeting was to communicate IIMI's findings on the salinity and sodicity processes to the farmers, present current processes within each watercourse, discuss with the farmers, the possibilities to adopt the proposed salinity and sodicity management options, and to identify the needs for follow-up research. Since salinity and sodicity processes are very complex, drawings were made on flip-charts, to be used as an aid in explaining the current processes, and the impact of potential options for improved salinity and sodicity management. Before the actual restitution meeting, the entire presentation was rehearsed in order to improve the presentation. Two field assistants were asked to assist in observing and giving comments regarding the presentations during the rehearsal. The first meeting in the field was evaluated as well.

Farmer's Restitution Meeting

Separate meetings were organised in the three selected watercourses. The contents of the meetings are presented in Annex 2. The restitution meeting was conducted in Punjabi. The introductions and explanations on the current salinity and sodicity processes presented by two English-speaking researchers were translated into Punjabi. The discussions by farmers were translated into English.

Evaluation

Three different methods of evaluation took place: 1) evaluation by the researchers after the last restitution meeting; 2) group evaluation by two neutral observers directly after the restitution meeting; and 3) individual conversations with farmers, one week after the restitution exercises, in the form of unstructured interviews. Relevant questions during these interviews were: was it according to farmers expectations?; were the issues selected by them properly elaborated upon?; did they learn from the restitution?; was the message clear?; what did they think about the form of the restitution; were the proposed options for improved salinity and sodicity management useful?; are they satisfied with the proposals for follow-up research?; and, do they have suggestions for future restitution exercises?

Chapter 2

Description of the Research Area

The present salinity and sodicity status in the Indus Basin is caused by three different processes, some of which occur as combined processes. The three watercourses in which restitution took place represent broadly these three processes:

1. Indigenous salinity and sodicity originated due to water action (Azim 111-L);
2. Salinisation and sodification due to the use of poor quality tubewell water (Fordwah 130-R); and
3. Salinisation and sodification due to capillary rise from high ground water tables (Fordwah 14-R).

In the next sections, a detailed description of the three watercourses is presented.

Watercourse Fordwah 14-R

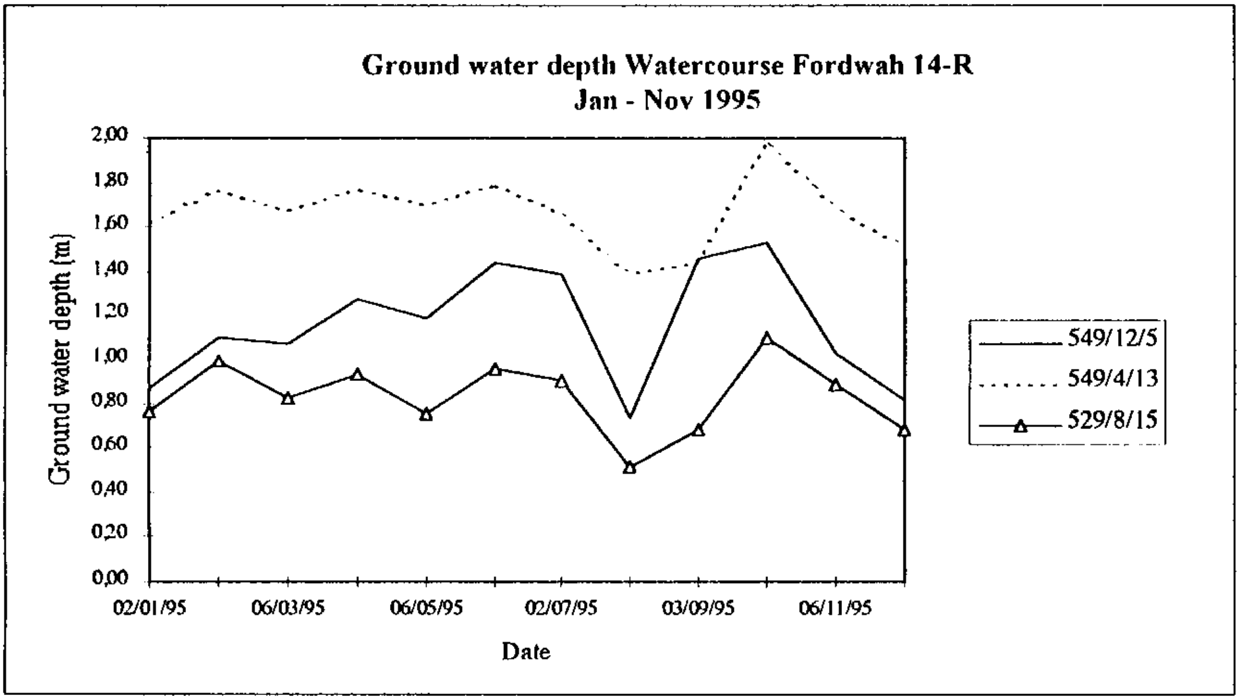
Soils

In 1995, the Soil Survey of Pakistan (SSoP) carried out a detailed soil survey of IIMI's eight sample watercourses. Map 1 presents the soil map for Watercourse 14-R. The watercourse command is located in the Rasulpur terrace, comprising soils which developed in subrecent river alluvium mixed with aeolian (Pleistocene) deposits from the Cholistan Desert. The different physiographic units of this land form identified in Watercourse 14-R are level plains, basins, levelled levees, and nearly level to gently undulating levees. Basins refer to the lowest part of this land form. The Matli soil series has developed in the lowest position of this unit. This unit covers less than 2 percent of the command area. The Matli soil series belongs to the fine-textured textural groups, which are imperfectly to moderately well drained, and have a moderately slow permeability. Level plains are the level parts of the subrecent flood plains. The Bagh and Harunabad soil series have developed on the slightly higher raised parts of this physiographic unit. This unit covers 32 percent of the command area. These soils are medium textured, mostly imperfectly drained with a moderate permeability. The Rasilpur and Jhang soil series belong to the subrecent levelled, nearly level to gently undulating levees. This physiographic unit refers to low bridges parallel to a river course. The Rasilpur soil series are mapped on loamy levee positions and the Jhang at sandy positions. The loamy Rasilpur soils belong to the moderately coarse textured soils and the sandy Jhang soils to the coarse textured soils. This unit covers 66 percent of the command area, of which only 3 percent is covered by the Jhang series. The soils of this unit are imperfectly to somewhat excessively drained, and moderately rapid to rapidly permeable. Fourteen percent of the soils in this watercourse were identified to have a saline-sodic crust, and 6 percent a saline-sodic surface, which are found in the tail-end of the watercourse.

Groundwater table depth and quality

Figure 1 presents the water table depths as they were measured in 1995, along with the position of the observation wells. The deepest ground water levels were observed in the middle of Watercourse 14-R. At this place, the water table fluctuates between 2.00 m (October) and 1.40 m measured in August. In the tail area, the most shallow water table levels are observed fluctuating between 0.5 m (August) and 1.05 m (October).

Figure 1: Water table depths in Watercourse Fordwah 14-R.

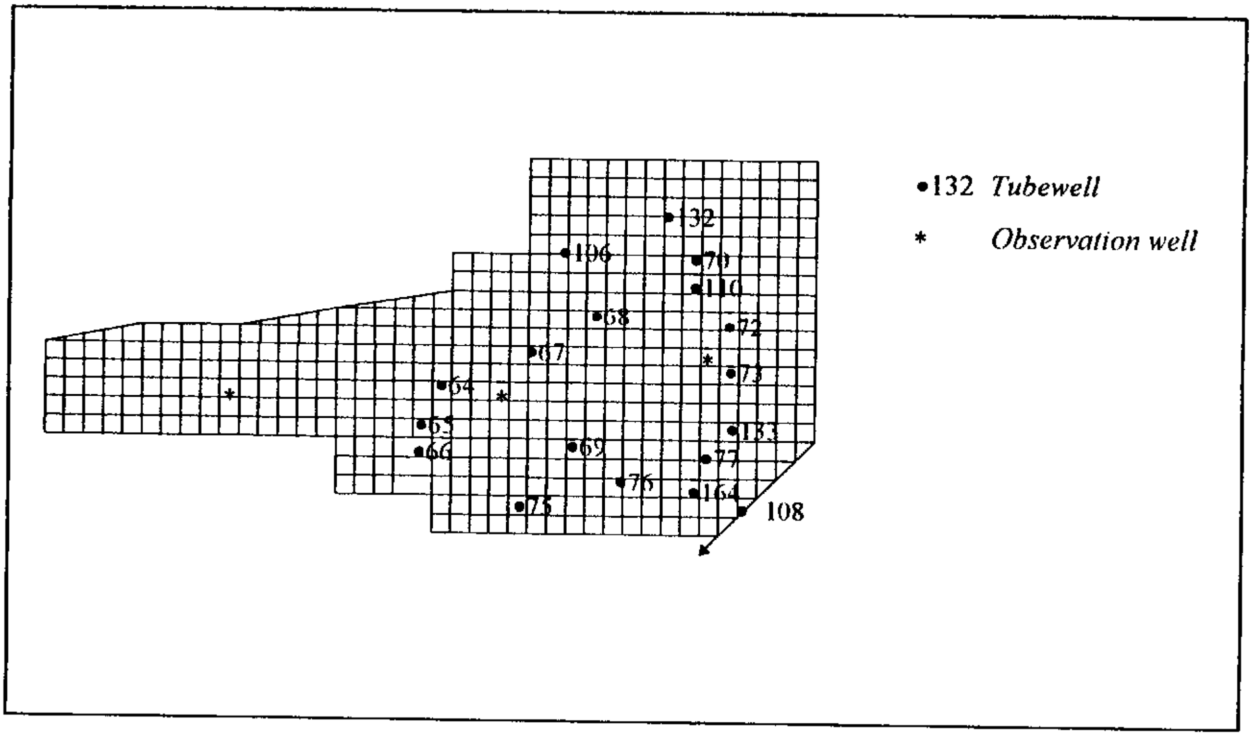


An indication of the quality of the ground water can be obtained from the tubewell samples. Tubewells in the head of Watercourse 14-R have an approximate EC of 1 dS/m, SAR 1.5, and an RSC-value of -3. The quality of ground water decreases with the distance from the distributary. The quality of the tubewells in the middle of Watercourse 14-R are approximate: EC 3 dS/m, SAR 11, and RSC -6. No tubewells are present in the tail of Watercourse 14-R, but it might be expected that the quality is similar to, or poorer than, the ground water quality in the middle of the watercourse. On Map 2, the locations of the observation wells are plotted.

Crops and cropping intensities

Major crops during Rabi are wheat and fodder. During Kharif the main crops are cotton, sugarcane and fodder. Sugarcane is grown by several farmers in the head and middle of the watercourse. Average yearly cropping intensities are 130 percent. The average cropping intensities in Rabi and Kharif are 65 percent. The cropping intensities differ greatly per farm and especially per location in the watercourse. Farmers at the head of the watercourse have yearly cropping intensities ranging between 140 and 200 percent; while in the tail of the watercourse, the yearly cropping intensities do not exceed 90 percent. In Kharif, the cropping intensities in the tail of the watercourse are very low (around 30 percent).

Map 2: Location of observation wells and tubewells in Watercourse Fordwah 14-R.



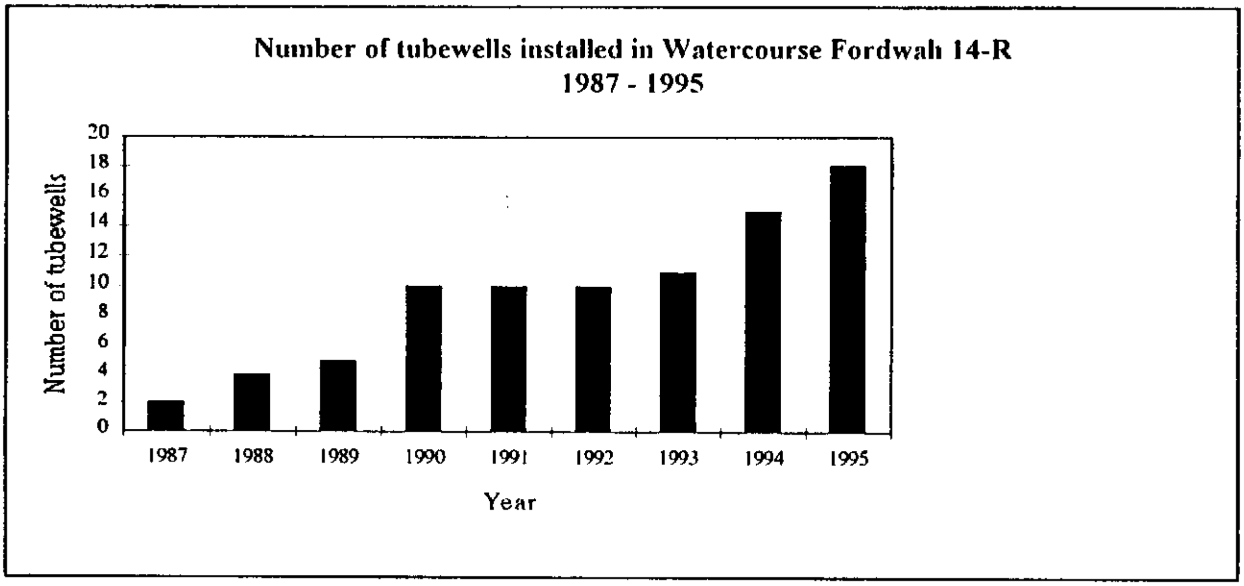
Canal water supply and distribution

A study carried out by IIMI in 1996 showed that farmers located at the tail of the watercourse have received a lower canal water supply during Kharif 1994. The highest canal water supplies were observed in the head of the watercourse. This area has the highest cropping intensities.

Tubewell use and quality

In 1987 the first tubewell was installed in Watercourse 14-R. Since that time, the number has steadily increased to a total number of 21 (Figure 2). Most tubewells are located in the head and middle of Watercourse 14-R. As discussed before, the best quality tubewells are found near the Fordwah Distributary. The tubewell water, installed closest to the distributary, has an EC of 0.5 dS/m, SAR of 1, and a RSC-value of -1. The tubewells away from the distributary have great variability in quality (Map 2). All tubewells, except for one, have a RSC-value smaller than zero (Table 1).

Figure 2: Total number of tubewells installed in Watercourse Fordwah 14-R.



The farmers in the tail of the watercourse, who received a low canal water supply, do not compensate their poor canal water supply with tubewell water. This results in low total water supply in the tail and the middle of the watercourse.

Table 1: Tubewell water qualities of watercourse Fordwah 14-R.

TW NMR	Depth (feet)	EC (dS/m)	SAR	RSC
64	60	2,80	9,5	-6,2
65	60	3,70	13,6	-6,3
66	60	3,00	11,9	-5,1
67	58	3,10	16,9	-0,1
68	60	2,10	8,4	-1,2
69	60	0,60	0,36	-1,0
70	62	1,85	6,2	-2,9
72	65	3,80	26,4	4,3
73	56	2,40	15,2	-0,4
74	58	2,02	9,1	-2,0
75	58	1,50	5,0	-3,1
76	55	1,03	2,5	-1,9
77	54	0,92	1,5	-3,6
106	40			
108	52	0,45	1,0	-1,0
110	60	2,10	10,1	-0,3
133	55	0,82	1,5	-3,0
164	58	0,70	0,34	-2,2

Salinity and sodicity status

Two causes for the present salinity and sodicity can be identified: 1) salinisation-sodification due to the use of poor quality tubewell water, especially in the middle of the watercourse; and 2) salinisation-sodification due to capillary rise from high saline-sodic ground water tables, especially in the tail of the watercourse. Due to the nature of the groundwater in the area, soil degradation due to sodification is not a major concern.

Farm characteristics

The two major groups of farmers represented in Watercourse 14-R are: 1) Farmers with a rather small total operated area (average 4.5 ha), low level of capital, adequate and reliable water supply, and high percentage of total operated area under sugarcane; and 2) Farmers with large families, a large number of family members working outside the farm, inadequate canal water supply, low purchase of tubewell water, low cropping intensities, and high percentage of salinity affected fields. These two farm groups are located in the head and in the middle/tail of the watercourse, respectively.

Due to a good canal water supply and sufficient drainage, farmers belonging to the first group do not have salinity problems. Farmers belonging to the second group have large salinity problems. Due to the low cropping intensities and high ground water tables, many plots are highly saline-sodic. Farmers who receive moderate canal water supply and have to compensate for a lack of canal water with tubewell water have salinity-sodicity problems created by the use of low quality tubewell water. Many of those farmers are tenants, where labour and credit, besides water, are the major farm constraints, severely reducing the possibilities to cope with salinity and sodicity problems.

Watercourse Fordwah 130-R

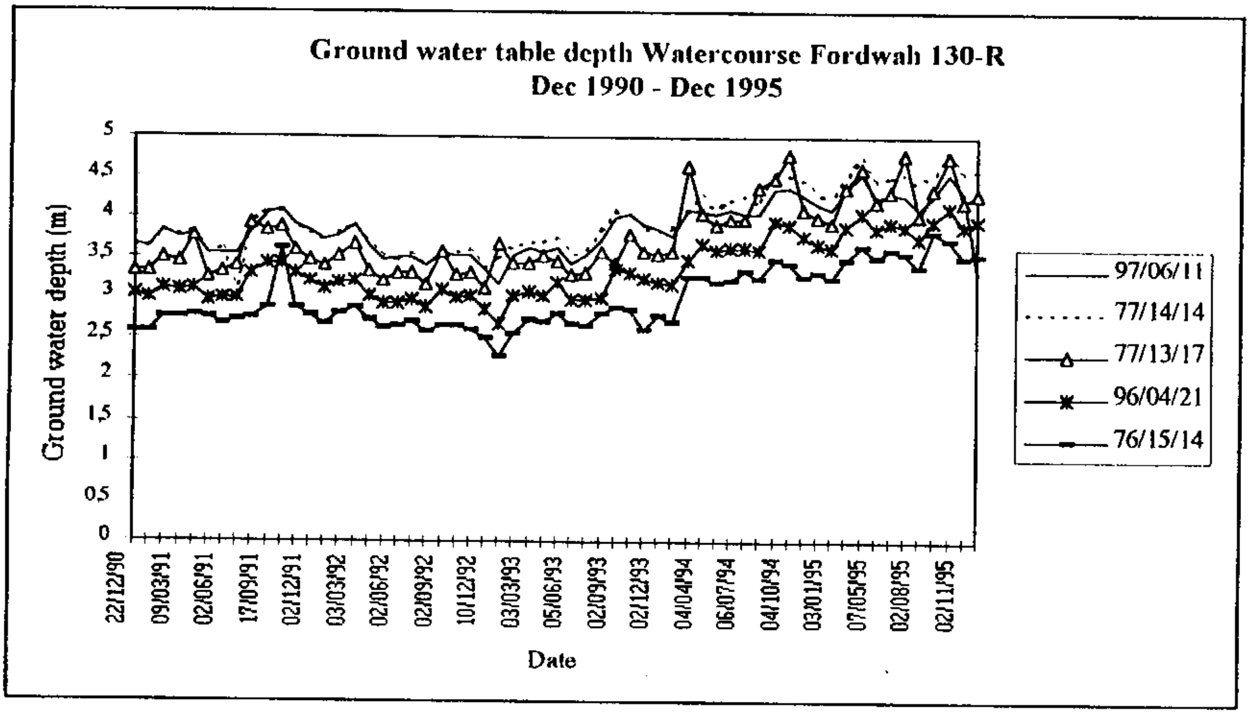
Soils

Map 3 presents the soil map for Watercourse Fordwah 130-R. The watercourse command is located in the Rasulpur terrace, comprising soils which developed in subrecent river alluvium mixed with aeolian deposits from the Cholistan Desert. The different physiographic units of this land form identified in Watercourse 130-R are level plains, levelled levees, and nearly level to very gently and gently undulating levees. Only 4.5 percent of the command area is covered by level plains. The Harunabad soil series have developed on the slightly raised part of this unit. The soils are medium textured, well drained, and are moderately permeable. Sixty three percent of the command area is covered by levelled levees. The loamy soils (Rasulpur) cover slightly more than 50 percent of this unit. The other half is occupied by the moderately coarse textured Jhang soil series. The Rasulpur soil series are somewhat excessively drained and have a moderate rapid to rapid permeability. The Jhang series are excessively drained and have a rapid permeability. The remaining 30 percent in this command area is covered by nearly levelled gently undulating levees. Thirty percent developed on more loamy soils and are therefore classified as belonging to the Rasilpur soil series. The remaining area is covered by Jhang soil series. It should be noted that 62 percent of the soils were identified to have a saline-sodic crust, 27 percent a saline-sodic profile, and only 11 percent of the soils in this watercourse do not have any saline-sodic properties.

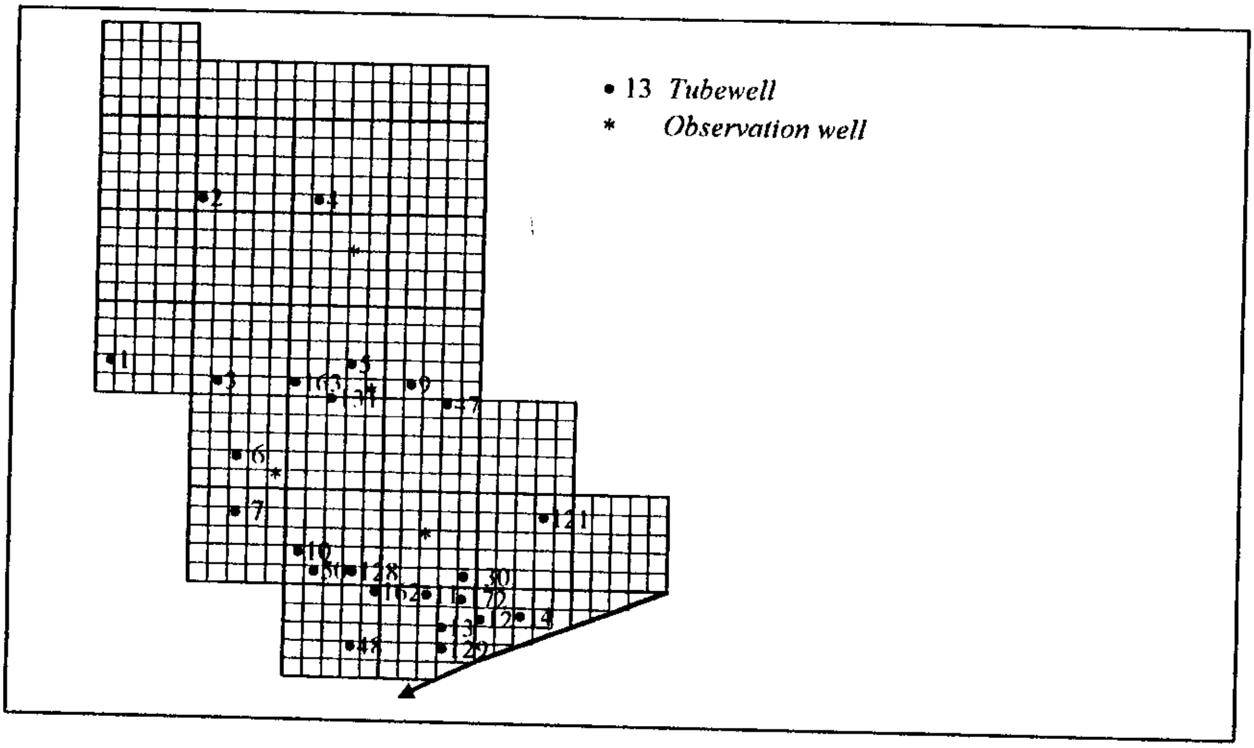
Groundwater table depth and quality

Since 1990, the water table depth in this watercourse has dropped by approximately one metre (Figure 3).

Figure 3: Water table depths in Watercourse Fordwah 130-R.



Map 4: Location of observation wells and tubewells in Watercourse Fordwah 130-R.



The difference in water table depth between the head of the watercourse, where most tubewells are installed, and the middle-tail area of the watercourse is one metre. The water table depth in the middle-tail area fluctuates between 3.2 m (February) and 3.8 m (October). In the head the water table depth fluctuates between 4.2 m (February) and 4.8 m (October). The quality of ground water differs per location and is not related to the distance from the watercourse. The EC values, as measured in the different tubewell waters, range between 0.8 and 1.5 dS/m, the SAR between 3.6 and 17.2 and the RSC-value between 0.8 and 5.7 meq/l. Map 4 shows the locations of the observation wells.

Crops and cropping intensities

Wheat, cotton, fodder, and sugarcane are the major crops grown in this watercourse. Wheat is grown by 100 percent of the farmers. Average wheat intensity is 65% (8-100%). During Rabi, fodder is the second most important crop. It is grown by 90% of the farmers. During Kharif, 94% of the farmers grow cotton, 84 % fodder, and 30% sugarcane. The cropping intensities are not related to a specific location within the irrigation scheme. The average cropping intensities during Rabi are 78% (ranging between 0 and 100%) and the average cropping intensity during Kharif is 81% (ranging between 10 and 100%). The average yearly cropping intensity is 159%.

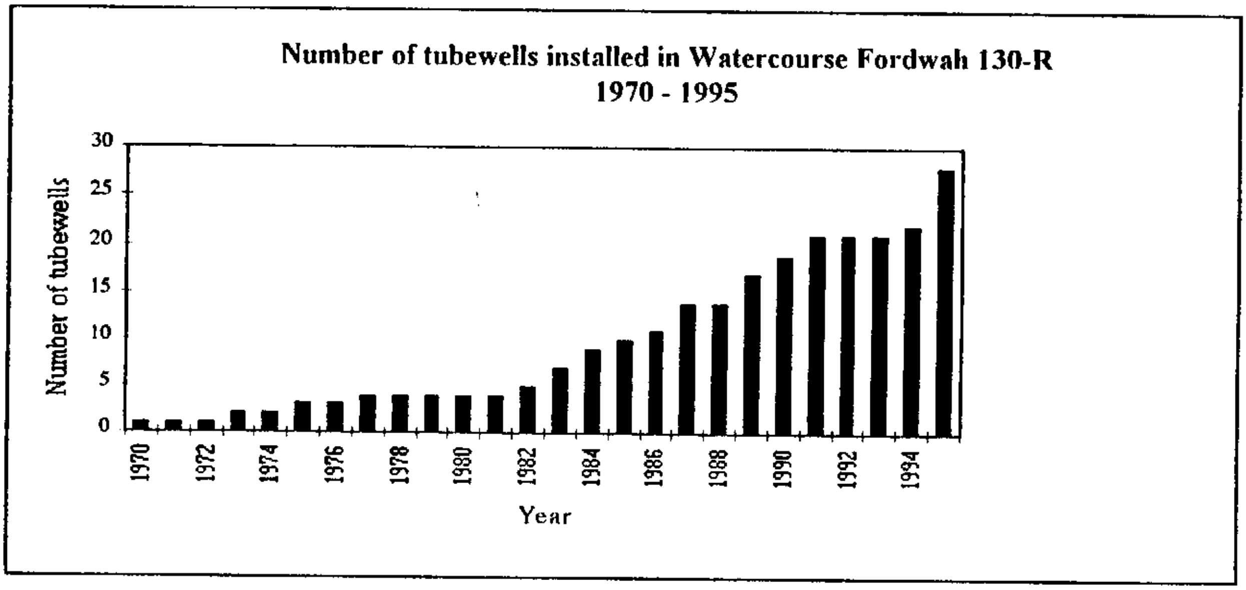
Canal water supply and distribution

Canal water supply is insufficient for optimal crop growth. Slightly more then half of the irrigation water in this watercourse is supplied by tubewell. The canal water distribution to the individual farms is not directly related to a location on the watercourse.

Tubewell use and quality

In 1970, the fist tubewell was installed in Watercourse 130-R. From 1982, a rapid incline in the number of tubewells can be observed (Figure 4).

Figure 4: Total number of tubewells installed in Watercourse Fordwah 130-R.



The quality of the tubewells in this watercourse is generally poor. The actual quality differs from location to location and from bore depth to bore depth. Table 2 gives an overview of the tubewell water qualities. All tubewell waters have slight to moderate salinity levels and the SAR levels range from low to high. A prominent characteristic for the tubewell water quality in this watercourse is the high RSC levels found in the majority of tubewell water. See Map 4 for the location of the tubewells.

Salinity and sodicity status

Since canal water supply to Watercourse 130-R is low, water tables are deep, and the quality of used tubewell water is very poor in general, the major cause of salinity and sodicity in this watercourse is the use of tubewell water for irrigation. Salinity and sodicity is an increasing problem since the installation of tubewells. In the tail area of the watercourse some saline-sodic soils are present. This soil salinity and sodicity is caused by the existence of shallow saline-sodic water tables in the recent past. Major concern in this watercourse is physical soil degradation due to the use of highly sodic tubewell water.

Table 2: Tubewell water qualities of Watercourse Fordwah 130-R.

TW NMR	Depth (Feet)	EC (dS/m)	SAR	RSC
1	120	1,48	8,6	0,9
2	190	1,38	11,4	4,1
3	80	1,45	10,1	1,7
4	150	1,20	4,64	3,2
5	80	1,60	17,2	4,8
6	190	1,30	8,2	2,2
7	160	1,10	5,4	1,7
9	190	1,55	12,3	3,7
10	150	1,45	10,3	3,5
11	110	1,65	12,5	5,7
12	100	0,90	4,4	1,5
13	155	1,40	11,7	2,9
14	150	0,84	7,7	2,7
47	60	2,00	24,2	9,0
48	55	1,07	7,5	2,4
95	80	0,79	5,0	1,4
96	60	0,76	0,43	-1,8
113		1,07	7,5	2,8
114		0,85	4,9	1,2
115		0,65	0,54	-1,6
116		0,98	5,23	3,0
121	60	1,00	11,9	4,0
128	83	1,60	10,0	3,8
129	70	0,93	3,6	0,8
130		0,92	4,7	0,9
131	60	1,60	7,7	1,3

Farm characteristics

Three major farm groups are present in this watercourse: 1) farmers with a small total operated area, low level of capitalisation, low and unreliable water supply, high cropping intensities, high use of inputs, high farm output, and high purchase of tubewell water; 2) farmers with a small total operated area, low level of capitalisation, low and unreliable water supply, low cropping intensities, high use of inputs, and low farm output; and 3) very small land holdings, large family, high percentage of joint tubewell owners, better canal water supply than most farmers in the watercourse, high farm outputs.

Besides of a lack of canal water and good quality tubewell water, a constraint for many farmers in this watercourse is the lack of knowledge for overcoming the salinity and sodicity problems. Some farmers have invested resources in trying to solve the problem, but up to now most attempts have failed. In this way, other farmers are discouraged from trying to solve their salinity and sodicity problems.

Watercourse Azim 111-L

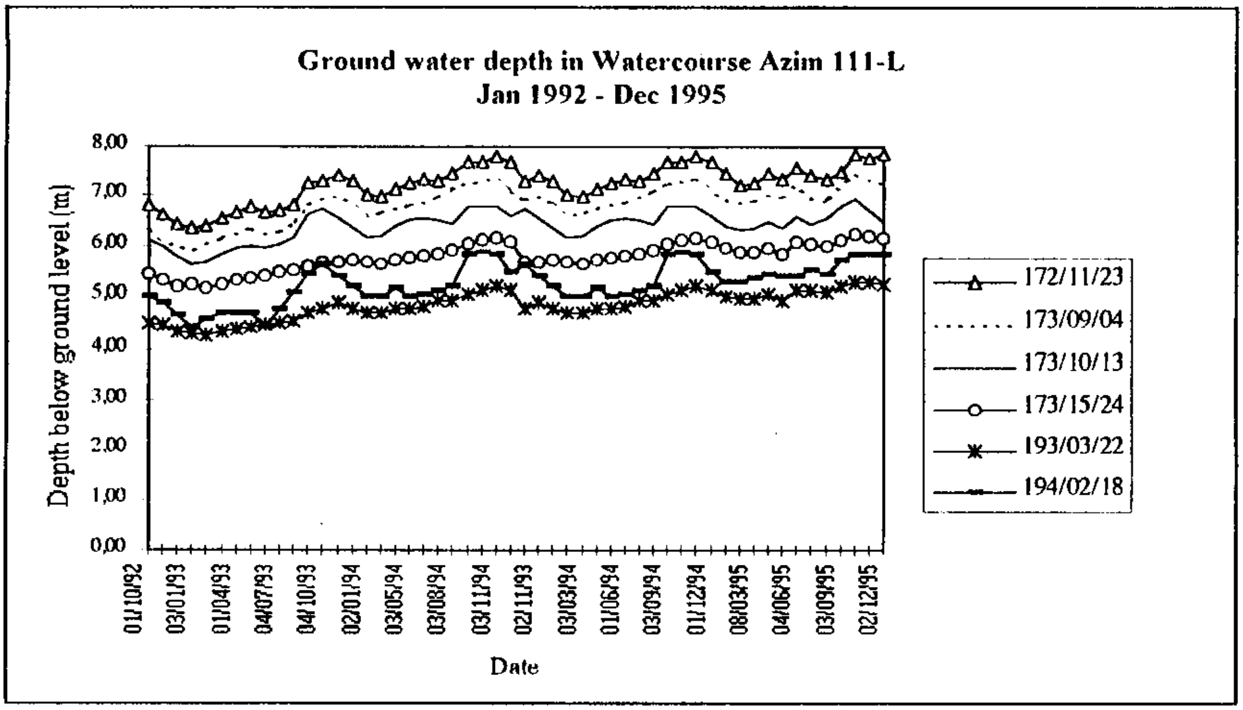
Soils

Map 5 presents the soil map for Watercourse Azim 111-L. The watercourse comprises soils which developed in subrecent flood plains. The different physiographic units of this land form identified in Watercourse 111-L are level plains and basin margins. Fifty three percent of the soils in this watercourse have developed in the level plains. The soils series in this unit are Sultanpur and Nabipur loam. These soils are medium textured, are well drained, and have a moderate permeability. Twenty nine percent of the plots in these soil series have a saline-alkaline crust. On the slightly raised parts of this physiographic unit, the Jhakkar and Grandhra loam series developed. They comprise 25 percent of the command area. They are medium textured, well drained, and are moderately permeable. In these soil series, genetic salinity and sodicity is present. At the subrecent basin margins, the Adilpur - Jhakkar loam series have been mapped. The soils are mostly barren and have a genetic saline-sodic profile. The soils are medium to moderately fine textured, moderately well drained, and have a moderately slow permeability. Very small areas are covered by Adilpur loam and Sodrha loam, which developed in basin margins and covered sand bars, respectively.

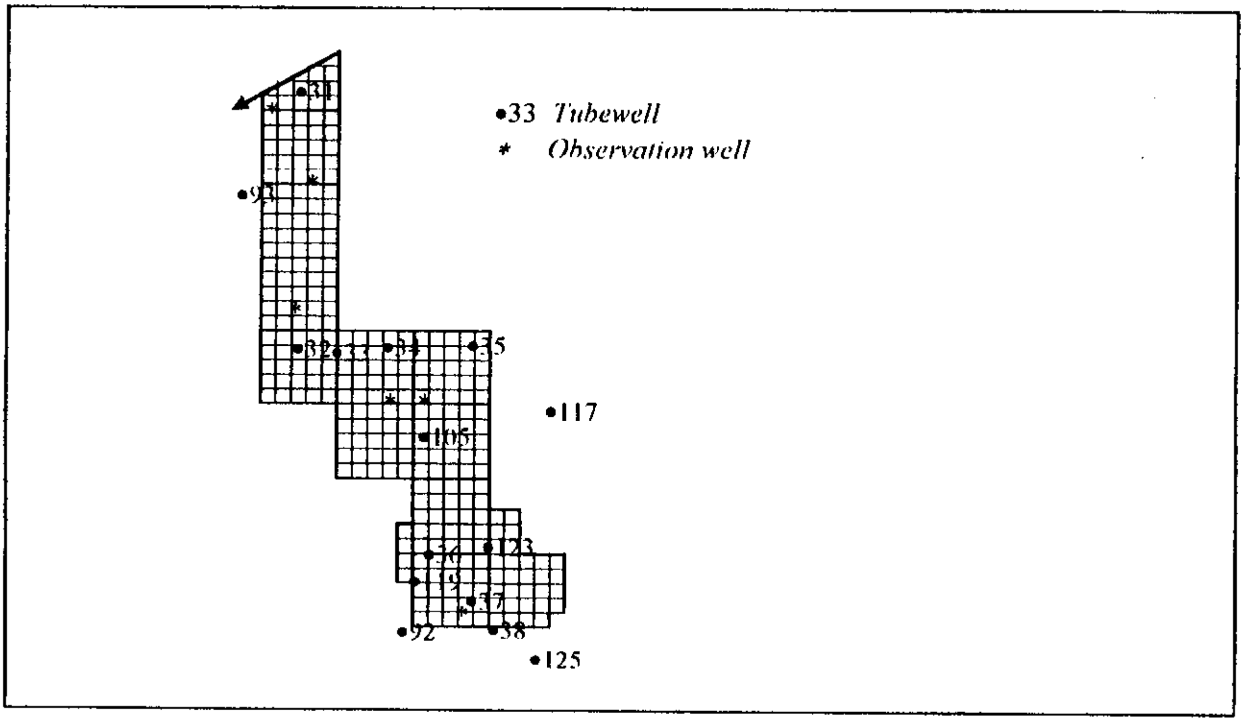
Groundwater table depth and quality

The water table depth at the head of the watercourse is two to three meters deeper than the depth at the tail of the watercourse. Since 1992, a decline in water table depth can be observed (Figure 5). For 1995 the deepest ground water table occurred in April. At the head, the water table depth was 7.2 m and at the tail 5.2 m. The highest ground water tables occurred in October. At the head, the depth was 7.9 m and at the tail 5.8 m. For the location of the observation wells see Map 6.

Figure 5: Water table depths in Watercourse Azim 111-L.



Map 6: Location of observation wells and tubewells in Watercourse Azim 111-L.



The best quality ground water is found at the head of the watercourse (EC: 0.7; SAR: 3; and RSC: -0.7). The middle and tail have poorer quality ground water, Ground water quality differs from place to place (EC: 0.8 - 1.7; SAR: 3 - 8; and RSC: -0.5 - 2.3).

Crops and cropping intensities

Major crops grown during Rabi are wheat and fodder. Wheat is grown by 100 percent of the farmers, while fodder is grown by 70 percent of the farmers. Average cropping intensity for wheat is 62 percent. The average cropping intensity for fodder in the Rabi season is 10 percent. The major crops grown during the Kharif season are cotton, rice and fodder. Sixty five percent of the farmers grow cotton, with an average cropping intensity of 57 percent (ranging between 30 and 97%). Rice is grown by 70 percent of all farmers. Average cropping intensity of rice is 17 percent (ranging between 1 and 38%). Fodder in Kharif is grown by 65 percent of the farmers with an average cropping intensity of 26 percent. Average yearly cropping intensities are 146 percent (90 - 200%). The average cropping intensity during Rabi is 73 percent (37 - 100 %) and during Kharif 73 percent (20 - 100%). Cropping intensities are not related to the location within the water course.

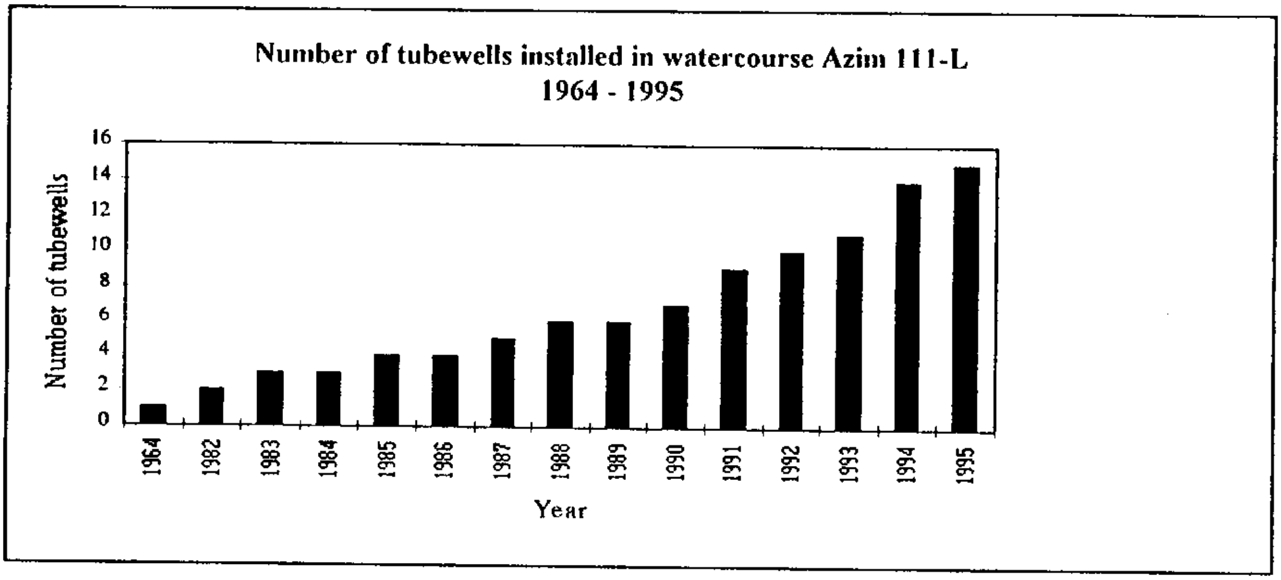
Canal water supply and distribution

No canal water reaches this watercourse. Farmers completely rely on tubewell water supply.

Tubewell use and quality

The first tubewell was installed in 1964. The second tubewell was installed 18 years later. Since then, a steady increase in the number of installed tubewells can be observed (Figure 6).

Figure 6: Total number of tubewells installed in Watercourse Azim 111-L.



The quality differs significantly from one location to the other and with depth. Table 3 gives an overview of the quality of the different tubewells, along with the bore depth. The location of the tubewells are plotted on Map 6.

Table 3: Tubewell water qualities of Watercourse Azim 111-L.

TW NMR	Depth (Feet)	EC (dS/m)	SAR	RSC
31	65	0,82	3,0	-0,7
32		0,59	2,7	0,7
33	205	1,55	6,7	-0,5
34	120	1,70	9,6	1,9
35	180	0,78	3,6	0,7
36	100	1,15	7,7	2,3
37	100	1,20	6,1	1,6
38	80			
92	150	1,05	4,2	-0,5
93	90	0,80	4,1	0,6
105	201	0,78	3,2	0,5
117		0,57	3,2	1,2
119	120	1,38	4,8	-1,4
123	150			
125		0,92	6,0	0,7

Salinity and sodicity status

Large areas within this watercourse are covered by saline-sodic soils. Since the water table is deep and canal water does not reach this watercourse, recent developments in salinity and sodicity are related to the use of different qualities tubewell water and on the salinity and sodicity management of the farmers.

Farm characteristics

The majority of the farmers in this watercourse can be categorised in two groups: 1) large investment capacity, high percentage of tubewell owners, and intensive cultivation; and 2) small total operated area, high percentage of tubewell owners, intensive cotton cultivation, high cotton outputs, and rice is cultivated in response to salinity and sodicity.

Besides the lack of canal water, credit is a major constraint for many farmers not belonging to the first category of farmers. Since methods to reduce the salinity and sodicity are expensive and time consuming, many farmers are not able to invest much in reclamation. Large areas are left barren. Farmers belonging to the first group do not have credit constraints. In combination with their large investment capacity and intensive cultivation, the first group are able to invest in reclamation and the prevention of soil salinity and sodicity.

Chapter 3

Contents of the Restitution Exercises

Salinity and Sodicity Processes

Salinity process

Soil salinity can have two different origins: 1) Soils could have been developed in saline-sodic parent material such as old marine depositions, or under the influence of water action during their formation, soils might have become saline-sodic; 2) Salinisation in the recent past which is called secondary salinisation. Soils which are originally saline-sodic, called indigenous saline-sodic soils, are very rare in Chishtian Sub-division. An example of indigenous saline-sodic soils can be found in the command area Watercourse Azim 111-L (WC 111-L).

Secondary salinisation is more common in Chishtian, which can be caused by capillary rise from a high saline-sodic ground water table or due to the use of poor quality irrigation water. After irrigating soil moisture in a wet soil profile decreases due to transpiration of crops and evaporation of water from the soil surface (Figure 7). The two processes together are called evapotranspiration. Due to evapotranspiration, water in the soil profile is depleting. When the water content in the soil has dropped below a certain percentage, crops need to be irrigated again in order to prevent yield losses or even permanent wilting. After irrigating the new storage of soil moisture is consumed by the crop again. When irrigation takes place with saline water, like the water from most tubewells, water and dissolved salts enter the root zone. The crops consume the water from the soil profile and the salts are left behind in the root zone. If subsequent irrigation takes place with saline water again, more salts are brought into the root zone. After all soil moisture has been used for evapotranspiration, a larger amount of salts has been left in the root zone. In the long run, this practice will turn good soils (non saline) into saline soils. Salts can be seen on the soil surface as a white powder or white crust.

Salinisation of the soil profile can also occur due to the presence of a high saline ground water table (Figure 8). Due to evaporation or transpiration by crops, ground water and salts are moved towards the soil surface under the influence of capillary forces. Groundwater which enters the root zone is transpired by the crop or evaporates at the soil surface. Consequently, salts are left behind in the upper soil layers. If this process continues for an extended period of time (length of the process depends on the height and the salinity of the ground water), good soils are turned into saline or saline-sodic soils. For example, capillary salinisation occurs in the tail of Watercourse Fordwah 14-R (WC 14-R).

Figure 7: Salinisation through irrigation

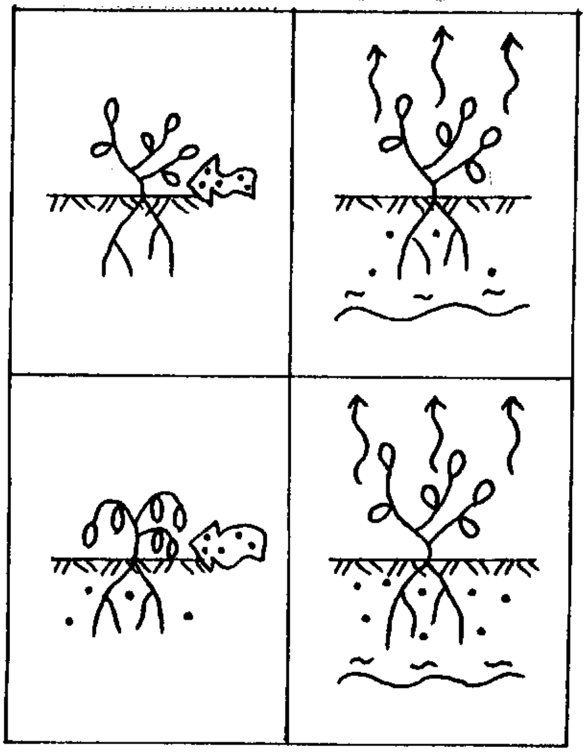
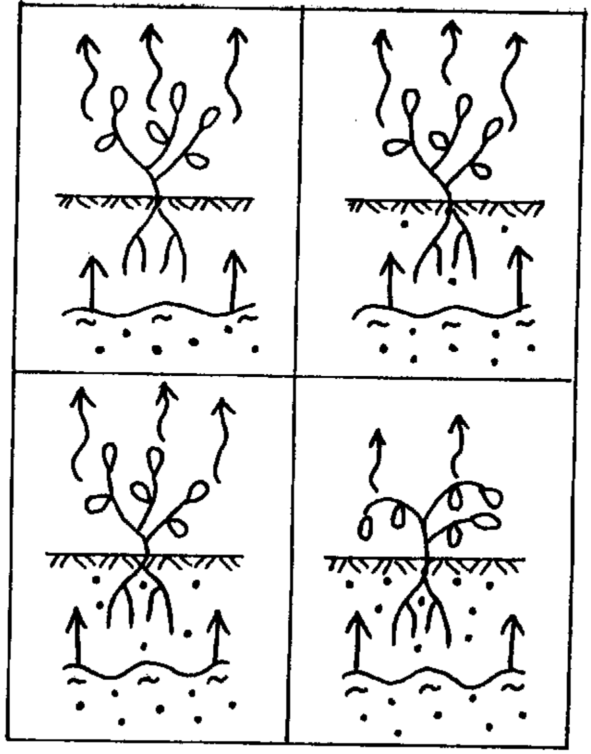


Figure 8: Capillary salinisation



Sodicity process

Irrigation and ground water do not contain one type of salt. A variety of different salts are dissolved in irrigation water (Figure 9). The salts that are dominant in irrigation water from tubewells, which influence the physical properties of the soil, are calcium, sodium, and carbonates. Calcium is an important salt for the stability of the soil structure. As long as the amount of calcium in the soil profile dominates over the amount of sodium, the soil is likely to have a good structure. When sodium dominates over calcium, the soil aggregates are unstable and the soil easily loses its structure. Also, carbonates play an important role with regard to the physical conditions of the soil. Due to their composition, carbonates precipitate easily with calcium. Once calcium carbonates have precipitated, calcium is not available for the maintenance of a good soil structure anymore. As more calcium precipitates, the sodium/calcium ratio becomes higher in the soil, and the physical conditions of the soil degrade.

Two processes of sodification due to the use of poor quality tubewell water can be distinguished (Figure 10). The first type of sodification process takes place by using irrigation water which has high sodium, but low calcium, concentrations. This type of water has a, so-called, high Sodium Adsorption Ratio (SAR). When irrigation water with a high SAR is used, the soil loses its good structure easily, since more sodium than calcium is brought into the soil profile. The second type of sodification process takes place when water with a high concentration of carbonates is used for irrigation. When the amount of carbonates is higher then the amount of calcium in the water, much of the calcium brought into the soil profile precipitates as calcium carbonate. Free calcium, which is present in the soil profile, will precipitate with the carbonates as well. Due to the precipitation of the calcium salts, more sodium than calcium will be present in the soil profile, and the soil structure will easily deteriorate, thereby resulting in the hydraulic conductivity being significantly reduced. Unfortunately, sodic soils are difficult, thus expensive, to reclaim.

Figure 9: Salts dissolved in irrigation water.

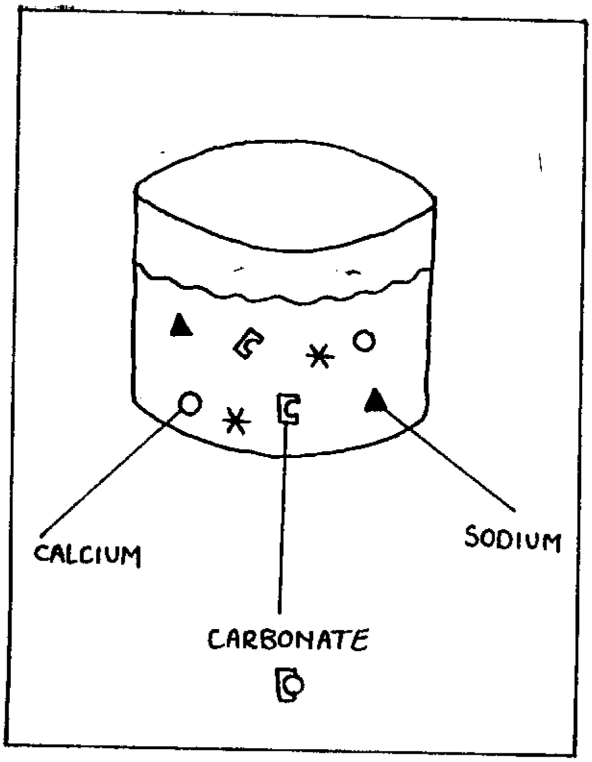


Figure 10: Sodification through irrigation.

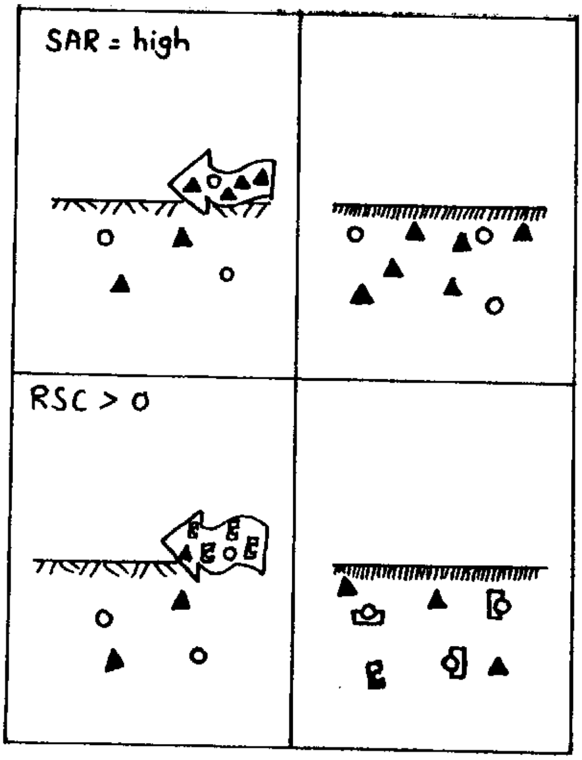


Figure 11 shows the physical properties of soils with a high calcium concentration and of soils with a high sodium concentration (sodic soils). Soils with high calcium concentration have, in general, a good infiltration rate. This means that water infiltrates easily into the soil. Sodic soils have often very low infiltration rates due to crust formation at the soil surface. After an irrigation event, water stays for a long period of time on the soil surface. Soils with high calcium concentration have mostly a good structure. They have a good permeability (flow of water through the soil profile), water holding capacity, and aeration. These characteristics are favourable for root development and nutrient uptake. On the other hand, sodic soils have often a poor structure. The soils are dense and hard, they have a low permeability, water holding capacity, and poor aeration. Root development, water availability, and nutrient uptake are disturbed in these types of soils.

Salinity and Sodicity Problems

Watercourse Azim 111-L

Large areas in this watercourse are covered by indigenous saline-sodic soils (Figure 12). This are soils which have natural salinity and sodicity. During the creation of these soils, salinity has build-up in the soil profiles. These soils are characterised by high salinity and sodicity levels, and a dense soil structure. The soils are largely uncultivated in Watercourse Azim 111-L. Reclamation of these soils is very expensive and time consuming.

Figure 11: Physical properties of sodic soils.

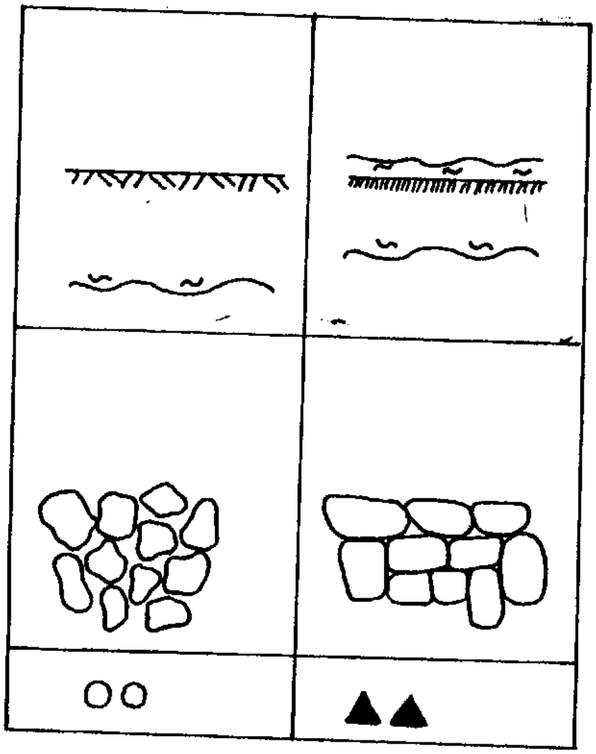
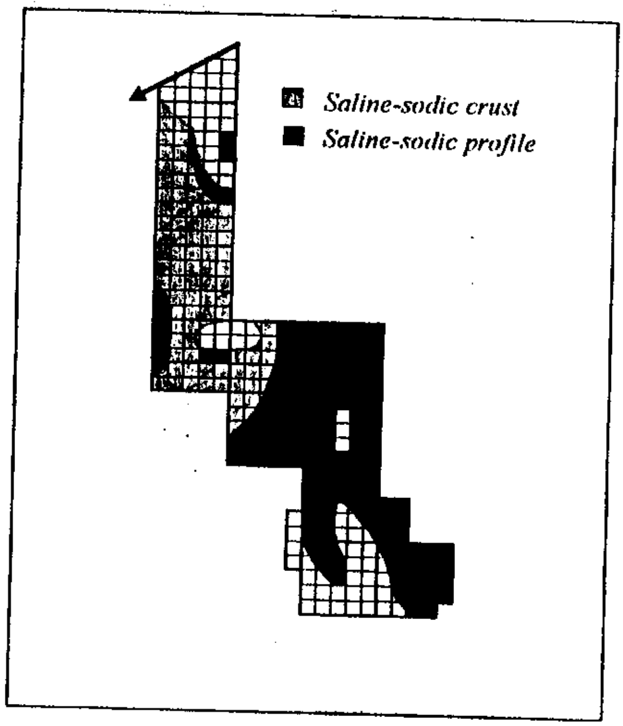


Figure 12: Salinity situation in WC 111-L.



Present salinity and sodicity processes are influenced by the use of different qualities of tubewell water. Large areas have saline-sodic crusts (Figure 12) due to the use of saline, high SAR, high RSC tubewell water for irrigation. The tubewells of this watercourse can be classified in the following groups: low saline, slightly to moderately saline, highly saline irrigation water (Figure 13) and high SAR and/or high RSC irrigation water (Figure 14).

Figure 13: Salinity of tubewells (WC 111-L).

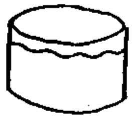
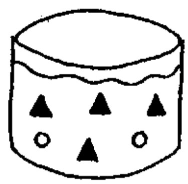
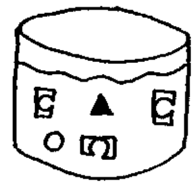
EC < 0.7 	EC = 0.7 - 2.5 	EC > 2.5 
H Sharif	M Ahmad	
M Arshad	Q Nazeer	
	Abid Shah	
	Ch Manwar	
	Lal Khan	
	Tufail	
	Manzoor	
	Qazi M	
	A Sittar	
	R Shah	

Figure 14: Sodicity of tubewells (WC 111-L).

SAR = high 	RSC > 0 
	H Sharif
	Abid Shah
	Lal Khan
	Ch Manwar
	Tufail
	Qazi M
	A Sittar
	M Arshad

Watercourse 130-R

Watercourse Fordwah 130-R (WC 130-R) has original fertile, light textured soils. Only an area in the tail of this watercourse has a saline-sodic profile (Figure 15). This salinity was created recently by the action of saline-sodic ground water.

At present, farmers use tubewell water with a moderate salinity content but with high sodicity and residual carbonates, due to a lack of canal water. Major problem created by using this water for irrigation is the degradation of soil structure and poor fertility due to high sodium content. Since the soils are light textured, the sodicity problems could be easily controlled by the use of gypsum and acids. The classification of the different tubewells is given in Figures 16 and 17.

Figure 15: Salinity/sodicity situation in Watercourse 130-R

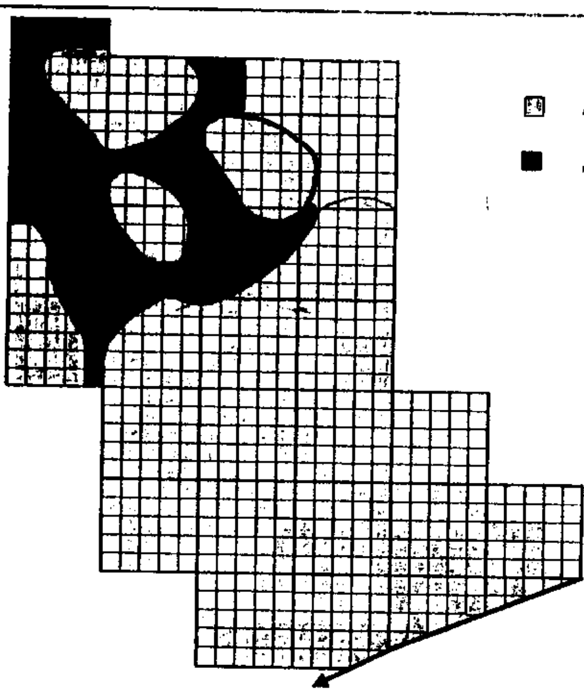


Figure 16: Salinity of tubewells (WC 130-R).

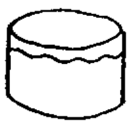
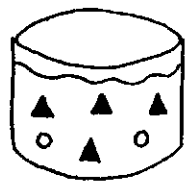
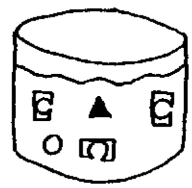
EC < 0.7	EC = 0.7 - 2.5	EC > 2.5
		
H Bakshs	Sadique	
Ghulam	Maqsood	
A Latif	M Irshad	
M Iqbal	Ashique	
	M Sadiq	
	Siddique	
	A Latif	
	Fazal M	
	Said M	

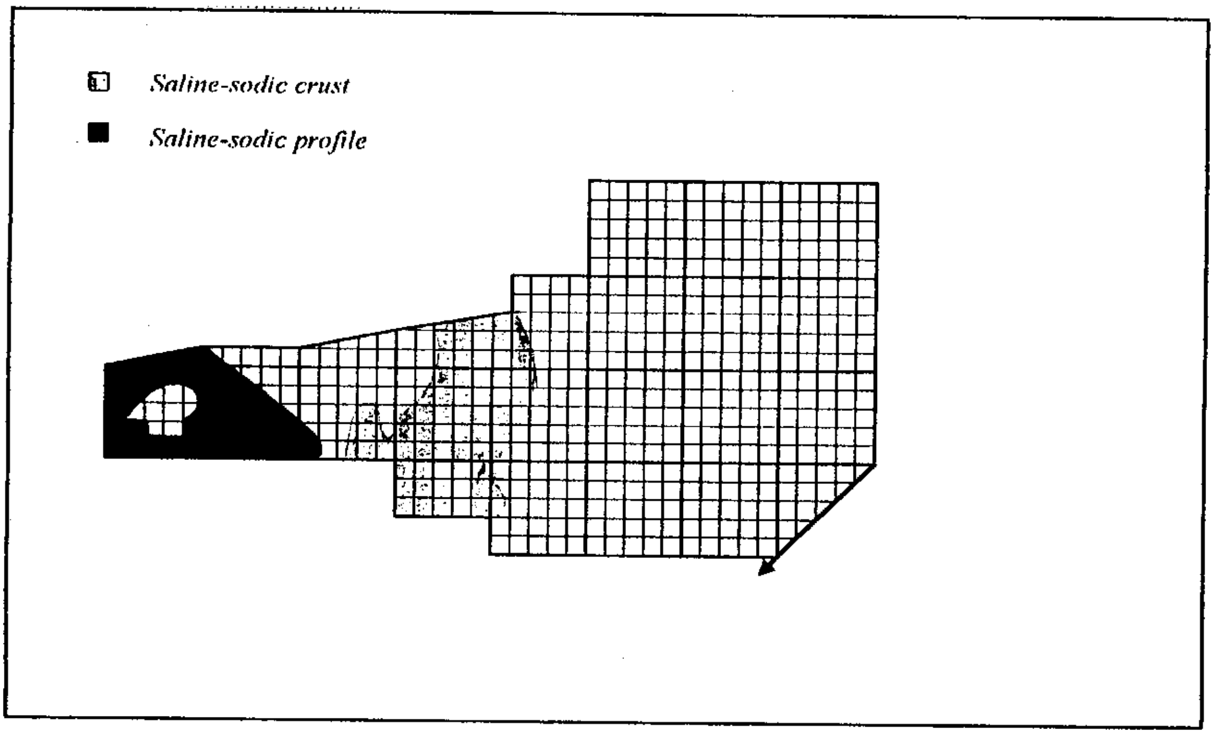
Figure 17: Sodicity of tubewells (WC 130-R).

SAR = high	RSC > 0
	
M Sadiq	Siddique
M Akthar	M Sadiq
Said M	M Akthar
Ghulam S	M Irshad
M Sharif	Ashique
M Yaqoob	Ghulam S
Ch Hanif	M Sharif
	A Latif
	Said M
	Nazeer

Watercourse Fordwah 14-R

Watercourse Fordwah 14-R has medium to moderately coarse textured soils. The whole watercourse command area has high groundwater tables. This largely influences the salinity and sodicity processes. In the tail end of the watercourse, where no tubewells have been installed, the ground water tables are extremely high. In this area, highly saline-sodic profiles occur (Figure 18). In the middle of the watercourse command area two salinity processes play a role. Capillary salinisation takes place when plots are left fallow for an extensive period of time. On the other hand, due to a lack of canal water, salinisation and sodification due to the use of highly saline-sodic tubewell water takes place. The areas having saline-sodic crusts are indicated in Figure 18. Conversation with farmers, along with mapping of the salinity situation, showed that an even larger area is affected by salinity and sodicity than the areas indicated by the Soil Survey of Pakistan.

Figure 18: Salinity and sodicity situation in WC 14-R



At the head of the watercourse, farmers do not face any salinity problems. The ground water is of good quality and farmers receive, in general, sufficient canal water. The salinity and sodicity classifications of the tubewells in the WC 14-R command area are given in Figures 19 and 20.

Figure 19: Salinity of tubewells (WC 14-R).

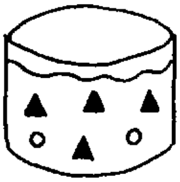
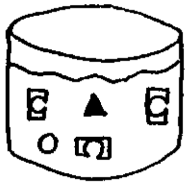
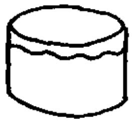
SAR = high	RSC > 0
	
M Ashraf M Aslam Zikar M M Boota Naik M	Naik M

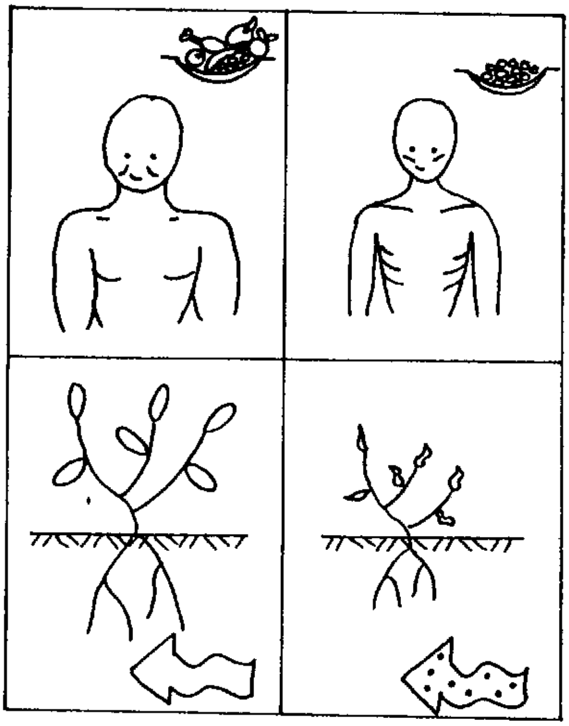
Figure 20: Sodicity of tubewells (WC 14-R).

EC < 0.7	EC = 0.7 - 2.5	EC > 2.5
		
A Haque M Aslam S Saya M Anwar	Ghulam A Sadique Munir A M Niaz Zikar M Bashir H Ullah Fazal M	M Aslam M Ashraf M Boota Naik M

Influence of Salinity and Sodicity on Crop Production

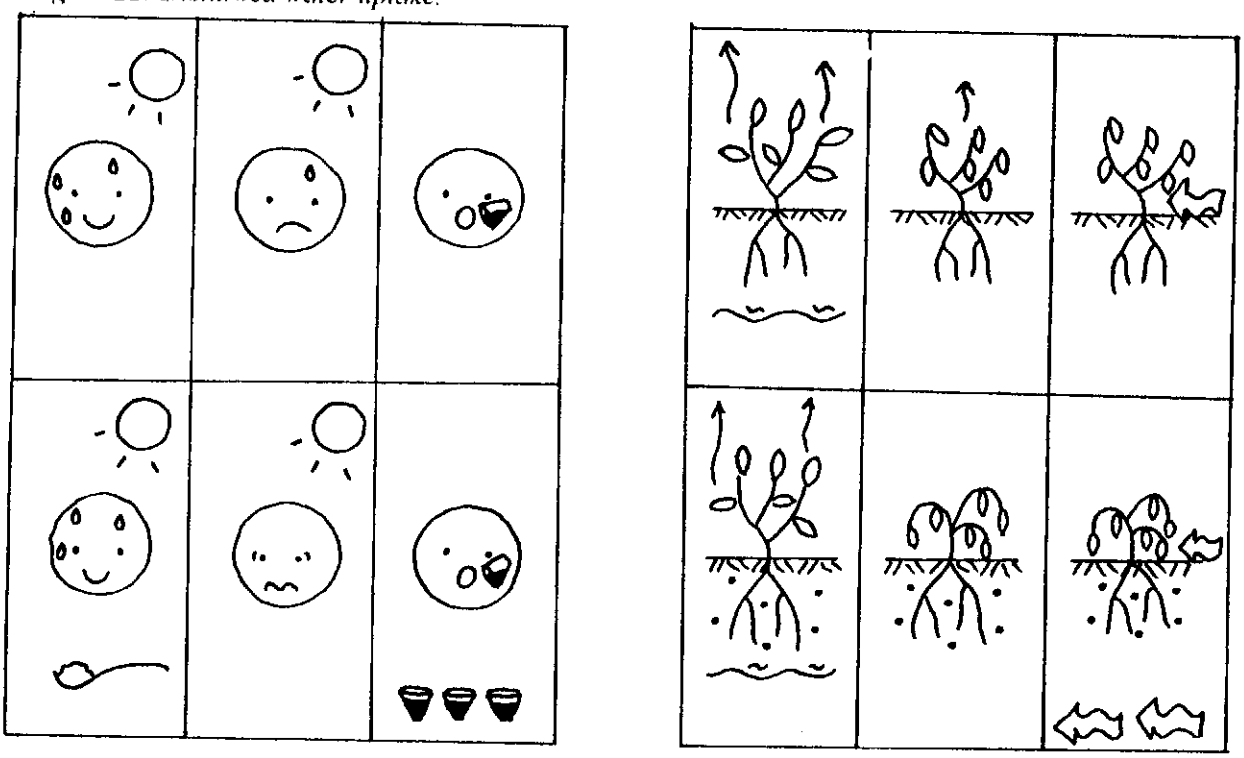
The overall negative effects of salinity and sodicity on crop production can be compared with the diet of people (Figure 21). People who have a diet containing sufficient calories, along with all of the necessary vitamins and minerals, are in general strong and healthy people. On the contrary, people who have a diet which might be high in calories, but low in essential vitamins and minerals, are weak and have poor health. This analogy also applies to crops. Crops irrigated with good quality irrigation water are healthy and strong and more resistant to pests and diseases. Crops which are irrigated with poor quality water are weak and vulnerable to pests and diseases. The use of high saline water disturbs the water and nutrient uptake of plants.

Figure 21: Effect of salinity on crop growth.



To illustrate the disturbed water uptake under saline conditions a comparison is made with people who have been eating salty food (Figure 22).

Figure 22: Disturbed water uptake.



Under a normal salt intake, people will sweat in a hot climate. During sweating, a lot of fluids are lost and these have to be replaced by drinking. When very salty food has been consumed, the same person will feel thirstier under similar conditions. Drinking in this case is not only to supply the fluid level in the body, but also to 'dilute' the salts in the body. Therefore, in comparison with the situation when this person had a normal salt intake, the amount of water the person will drink after eating salty food will be much higher than under normal conditions. Similarly, plants use water for transpiration. When all of the soil moisture has been consumed, irrigation is needed to replenish the soil moisture content and to prevent the plant from wilting. Under saline conditions, the crop is not able to extract as much water from the soil profile as under non-saline conditions. Therefore, long before all the soil moisture has been used by the crop for transpiration, the soil moisture has to be replenished to prevent the crop from wilting. Since less water is available in the soil profile, soon after an irrigation event the crop needs another irrigation. So, the frequency of irrigation needs to be much higher under saline conditions than under normal conditions.

Not all crops are similarly sensitive to salinity. Some plants have mechanisms to grow under saline conditions. Good examples of very salt tolerant crops are kallar grass and janter. Also, cotton and wheat can stand high salinity levels before yield reduction will be observed. However, cotton is the least sensitive of these two crops. Sugarcane and many fodder crops are much more sensitive to salinity. Yield reductions will occur even under low salinity levels. Not all crops are equally sensitive to salinity. Crops have varying sensitivity to salinity during different growing stages (Figure 23). For example, cotton is very sensitive to salinity during seedling emergence and during boll formation, whereas the ripening stage is least sensitive.

Figure 23: Sensitivity of plants at different stages.

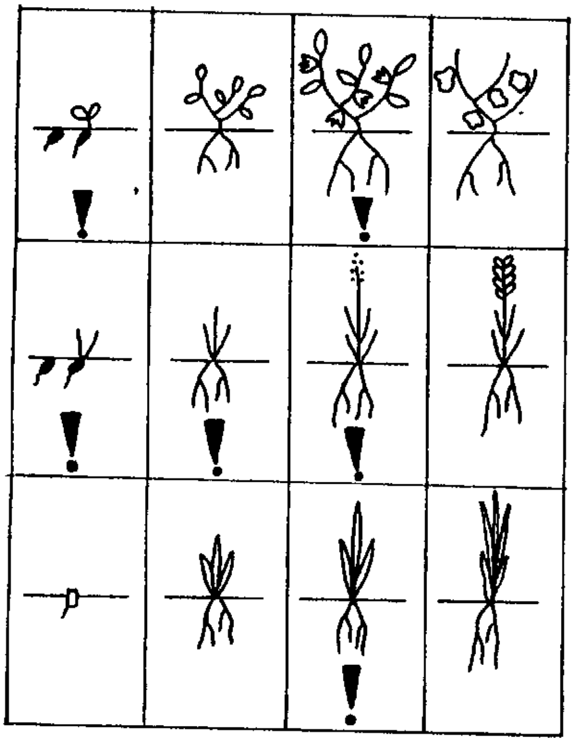
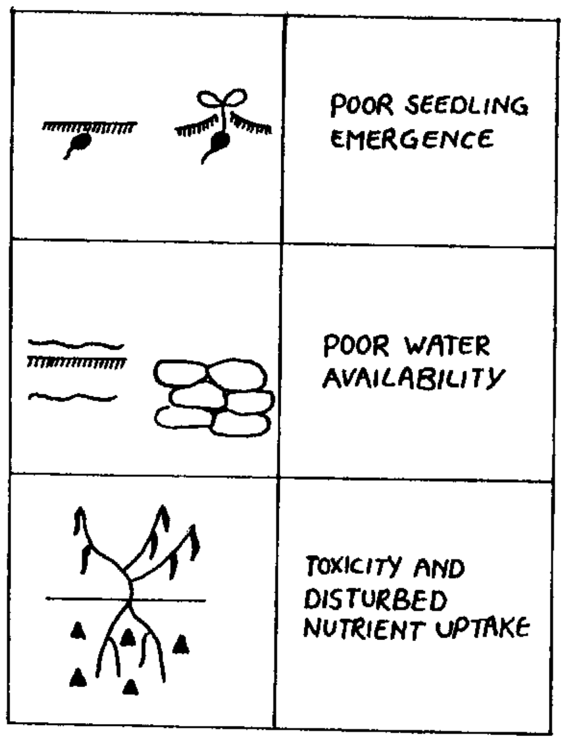


Figure 24: Effect of sodium on crop growth.



Wheat is sensitive to salinity up to its early reproductive stage. From the grain filling stage and onwards, the crop is less sensitive to salinity and can stand much higher levels of salinity. Though, sugarcane is much more sensitive to salinity than wheat and cotton, it has only one stage during which it is more sensitive to salinity than in the other stages; this most sensitive stage for sugarcane is during maximum vegetative growth.

Not only the overall amount of salt in the soil has a negative effect on crop production, some type of salts have a special negative effect on crop production. The only salts that will be discussed here is the effect of sodium (Figure 24). The first negative effect on crop growth occurs during seedling emergence. Often sodic soils have a crust on the soil surface. This crust prevents easy seedling emergence. The seedlings have to break through the crust. A lot of energy is used to do so. Due to the high energy consumption during seedling emergence, the seedlings are weak and very vulnerable to attacks of diseases and fungus. The second negative effect of sodium on crop production is due to a degraded soil structure. Crust formation reduces the infiltration rate of irrigation water into the soil. The water will enter the soil at a slow rate, and leave water standing for a long time on the soil surface. During this period, soil aeration will be greatly reduced, thereby significantly inhibiting root respiration; thus, the plants will suffocate and the leaves will turn yellow. When water has finally disappeared from the soil surface, less water has been infiltrated into the soil than the amount which would have infiltrated in good soils. When the soil structure is degraded over a larger depth, the water holding capacity will also have been reduced, the aeration of the soil will be poor, and root development of crops is extremely difficult. Besides the negative effects of sodium on crop production through soil degradation, high sodium concentration can be toxic for some crops. Also, high sodium concentrations disturb the nutrient uptake and cause yellow leave tips.

Options for Salinity Management

Options for salinity management can be divided into measures for reclamation of saline-sodic soils and prevention of salinity and sodicity, and measures for improved crop production under saline-sodic conditions.

Options for prevention of salinity and sodicity, and reclamation of soils

Saline soils can be reclaimed by using more irrigation water than required for evapotranspiration (Figure 25). In this way, the salts are leached downwards through the root zone. Most effective is the use of low salinity water; though, moderately saline water can be used as well, but more water is required and the final salinity level will never be less than the salinity of the water which is used for leaching. Leaching of salts from the root zone, by using extra irrigation water, can be used to prevent salinisation as well.

Reclamation of sodic soils is more difficult, since sodium has to be replaced by calcium in order to improve the soil structure. There are three options for the reclamation of sodic soils (Figure 26). The first option is to apply gypsum. Gypsum is high in calcium content and, therefore, directly provides calcium for exchanging with sodium adsorbed onto the soil particles. For the reclamation of soils with a crust, 500-1000 kg/acre is required. Soils with a saline-sodic profile require 2000-3000 kg/acre of gypsum. To be most effective, the gypsum has to be worked into the soil profile with a plough. Gypsum can be used for maintenance purposes as well. In case sodic water is used for irrigating, gypsum can be applied once a year or every season to prevent the soils from going hard. The amount of gypsum which is required for the maintenance of a good soil structure depends largely on the amount of water and the sodicity of the irrigation water.

A second option for the reclamation of sodic soils is the application of acids. The use of acids for reclamation purposes is only an option when the soil contains calcium carbonates. Under the influence of acid, calcium carbonates dissolve into calcium and carbonate ions. The calcium ions will replace some of the sodium ions adsorbed onto the soil particles; then, and the sodium can be leached downwards through the root zone by using extra irrigation water. In cases where water with a high concentration of carbonates is used for irrigation, acids could be used for maintenance purposes as well. Acids will prevent the precipitation of calcium carbonates in the soil. In this way, a high calcium concentration is maintained. The advantage of using acids is that they are highly effective, whereas the disadvantages are: 1) the cost of acids is five times higher than the cost of gypsum; 2) acids are dangerous for human health; 3) they are only issued under license; and 4) continuous use of acids will deplete the natural calcium buffer in the long run if no calcium is added to the soil profile.

Figure 25: Leaching of salts.

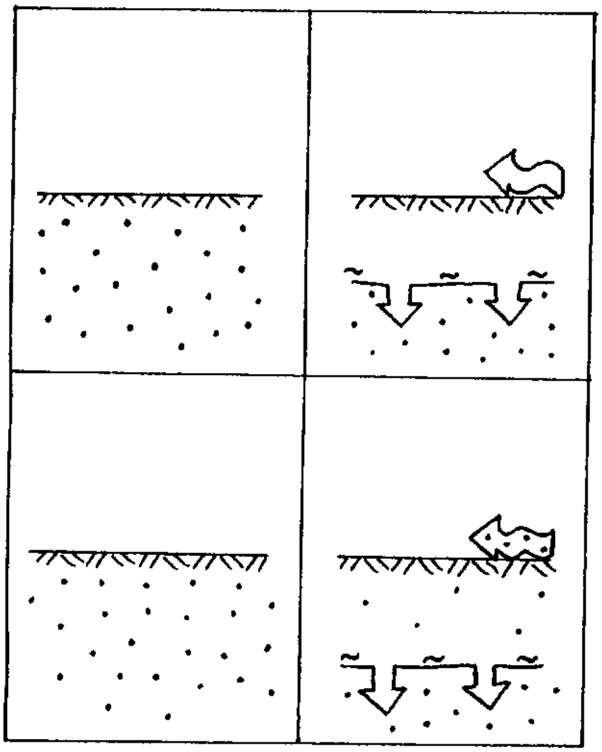
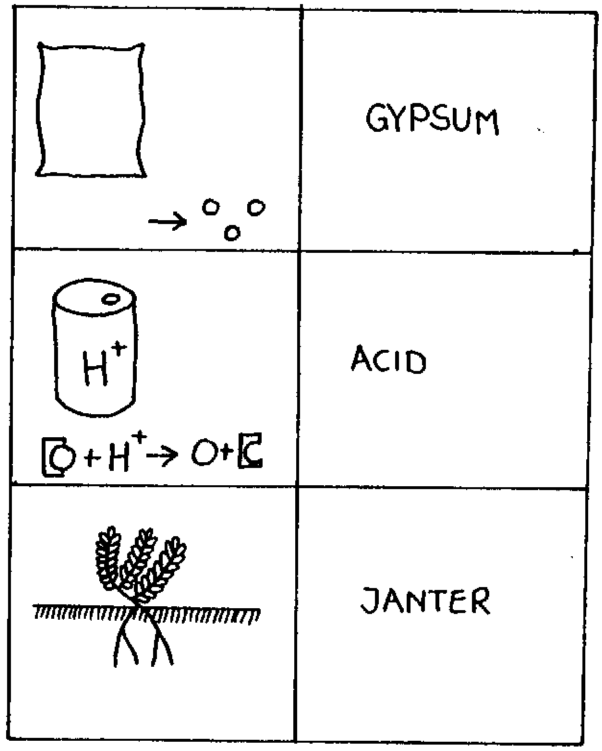
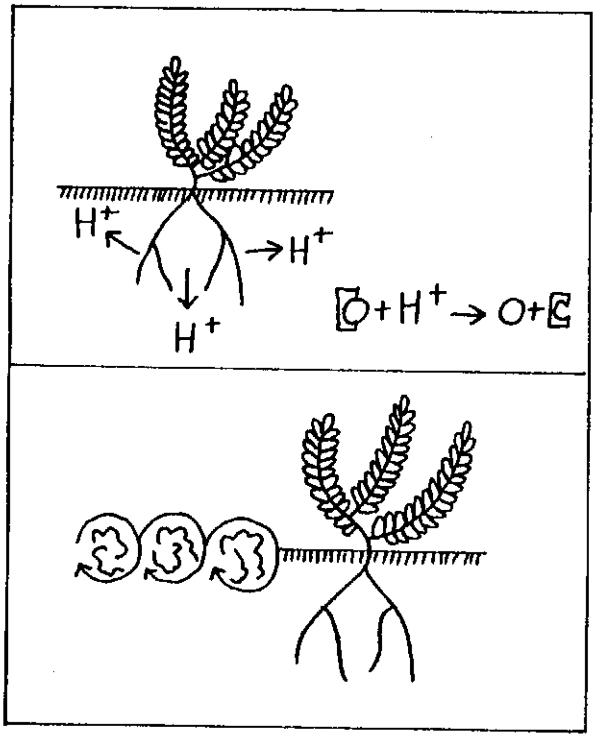


Figure 26: Options for sodic soils.



The last option to reclaim sodic soils is the growth of janter or kallar grass. Janter is a natural supplier of acids (Figure 27). During crop growth, the roots emit acids. These acids dissolve calcium carbonates which will displace the sodium in the soil profile. When janter is ploughed into the soil profile, the reclamation process is accelerated. The organic matter (janter which is ploughed into the soil) helps to improve the soil structure, increases the waterholding capacity of the soil, and makes the soil less vulnerable to crust formation. During fermentation of the organic matter, acids are released; these acids will dissolve more calcium carbonates from the soil profile. Besides, through fermentation, calcium is dissolved; during decomposition of organic matter, calcium is released, since janter absorbs calcium during its growth stages.

Figure 27: Effects of janter on soil structure.



Options for sustained/improved crop production

Under moderately saline-sodic conditions, crops can be grown using special management practices. Under saline or saline-sodic conditions, when the infiltration rates are high, the procedure shown in Figure 28 for the growth of cotton and wheat should be followed. After land preparation, a pre-irrigation should be given before sowing cotton seeds. The pre-irrigation will leach the salts from the upper soil layer and favourable conditions for seed germination are created. During and immediately after boll formation, a high soil moisture should be maintained through frequent irrigation. Wheat should be sowed directly after land preparation. The first irrigation should leach the salts from the upper soil layer, so that the seeds can germinate under low saline conditions. Until the early reproductive stage, wheat is quite sensitive to salinity. High soil moisture content should be maintained until this stage. Preferably, during the sensitive cropping stages, low saline-sodic irrigation water should be used.

Figure 28: Management of wheat and cotton.

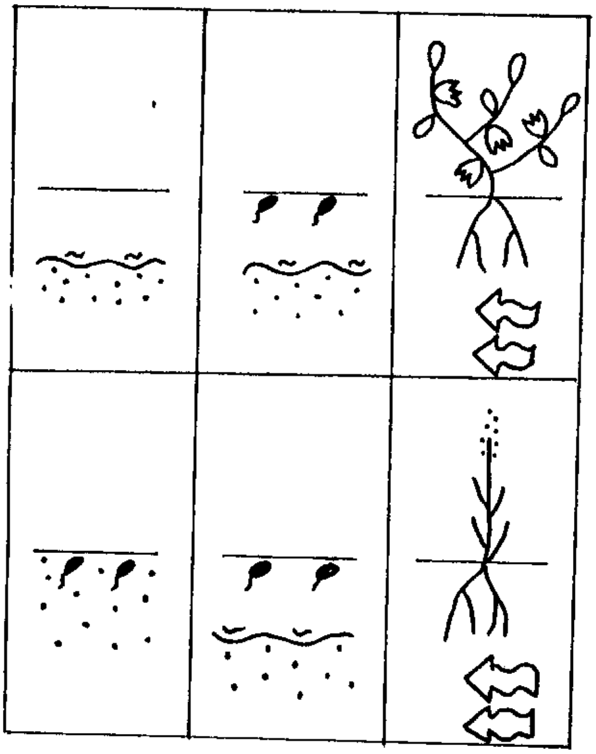
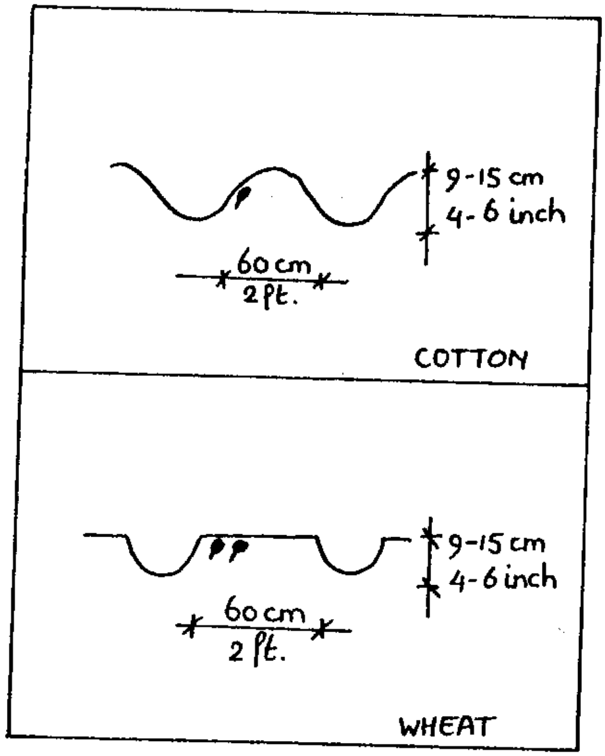


Figure 29: Crop management under sodicity.



Under conditions of low permeability and infiltration rate, furrows (or broad bed and furrows) should be used for the growth of cotton and wheat, respectively (Figure 29), but especially cotton. Varieties that perform best under moderately saline-sodic conditions are SARC1, NIAB63, and Inclab wheat varieties, MNX93 cotton variety, and KS282 rice variety. Under highly saline-sodic conditions where reclamation is not viable, shrubs (atriplex species) or eucalyptus trees can be grown. These crops can be used as firewood, building materials, or can be sold to chipboard, carton or paper industries.

Chapter 4

Results of the Restitution Meeting

Discussions on Experiences, constraints, and Options

Watercourse Fordwah 14-R

The meeting took place in Dera Manzoor Ahmed. About 20-25 farmers attended. Farmers agreed with the analysis that was carried out regarding the quality of their tubewell water and the salinity and sodicity status of their soils.

Farmers have little experience in salinity management. Measures to mitigate the effect of salinity that farmers have undertaken are the removal of top soil and the application of farm yard manure. Farmers were interested in the different options that were mentioned during the meeting. However, farmers face a credit constraint in adopting these methods. When they have difficulty in purchasing fertiliser, how is it possible to purchase gypsum? The farmers also felt that with an improved canal water supply, they will be able to reduce the salinity problems

Perhaps, the location of the meeting (at the head of the watercourse) was not correct, as the salinity problems are occurring towards the middle and the tail. As stated by the staff of the Soil Science Department of the University of Agriculture, Faisalabad, it is extremely difficult to grow crops under highly saline-sodic conditions in combination with high ground water tables. Under these conditions, it might be an option to grow certain salt resistant crops like kallar grass, eucalyptus trees, etc. These options were discussed with the farmers. Since only a few farmers from the tail area were present, these options were not discussed in much detail. Later, a discussion with one of the tail-end farmers disclosed that most cultivators in the tail area are tenants. They like the idea of growing trees, but unfortunately, their lease contracts have a maximum length of a year. This makes the tenants reluctant to invest in long-term measures.

Watercourse Fordwah 130-R

The meeting was announced in the village mosque of Chak 20 Fordwah. About 40-45 farmers attended the meeting, which was held in the Primary School for Boys.

Farmers do not have much experience in reclaiming salinity and sodicity as their soils do not display much indigenous salinity and the soils are moderately coarse (loamy sand to very fine sandy loam). Only recently they been confronted with an increasing sodicity problem and they seem reluctant to invest much in sodicity mitigating/reclamation measures. Farmers also expressed their fears regarding the continuous use of tubewell water. They think that only canal water can save the soils from salinity and sodicity problems. Some were thinking that all other solutions are just temporary solutions. This explains their continued emphasis on an improved canal water supply as a panacea for sodicity problems. During the meeting, farmers were quite vocal about their desire for increased canal water supplies.

A few isolated experiences of farmers were recounted. One farmer had applied a limited amount of gypsum (350 kg) on his field and had found that this amount was not effective in addressing the sodicity problem. Another farmer is trying janter cultivation and was quite positive about using this plant. However, most farmers emphasise the fact that there is very little economic gain to be had in janter cultivation. Also, one farmer had tried sulphuric acid and said that it had an immediate (positive) effect, but this was not sustained and the soil was "destroyed" after one season. Finally, a few farmers claimed that growing crops using furrows was quite helpful in mitigating the effect of sodicity on crop production. Details on these experiments are not available.

Watercourse Azim 111-L

The meeting was attended by 15-20 farmers.

In this watercourse, several farmers have experience in reclaiming saline-sodic lands, due to the presence of indigenous salinity and sodicity (Jhakkar/Adilpur soil series). Some farmers have used gypsum, while others are growing janter. The main constraints related to reclamation are the economics (janter does not give any cash), and the availability of gypsum in the market. They also use fertilisers to mitigate the effect of salinity/sodicity on soils/plants, but state that these fertilisers are often not available or are very costly. In general, farmers complain about the absence of canal water. A minor canal off-taking from Fordwah Distributary has been proposed in order to feed the tail watercourses of Azim Distributary. Farmers have been asked to organise themselves to excavate this minor, but have responded that under the present social context this is impossible. Another constraint the farmers mention is the groundwater quality.

Farmers requested more details on the use of (sulphuric) acid, the ratio, the timing of application, etc. IIMI promised to calculate the requirement for one of the farmers as an example. They also asked for testing of the water of two new tubewells in the area. They would also like to have more detailed information on the quantity of fertilisers to be used and the timing of application.

The discussion on possibilities and constraints to implement certain measures did not focus on the use of indigenous saline-sodic soils. Perhaps, IIMI was not clear enough during the restitution about the different soils in the area. As stated by the staff of the Soil Science Department of the University of Agriculture, Faisalabad, reclamation may not be economical on certain soil types (e.g. where pore density is very low). In certain cases, it might be better to grow certain salt resistant crops (kallar grass, eucalyptus trees, etc.).

Identification of Demand for Action-oriented Research

Watercourse Fordwah 14-R

No clear demand was formulated during the meeting. Two or three farmers were ready to experiment, but did not formulate a clear demand.

Watercourse Fordwah 130-R

A few farmers are interested in trying out a few management options and have offered their land plus some inputs. Notably, they were interested in acid/gypsum application and in janter; perhaps in combination with furrow/bed irrigation methods.

Watercourse Azim 111-L

Farmers stressed that future research should involve field experiments trying the use of janter, eucalyptus, gypsum and sulphuric acid. Farmers suggested that the chisel plough might be a handy tool for mixing the gypsum in the soil profile. They expect that a deeper positive effect of the gypsum on the soil structure will be obtained. A possibility would also be to help farmers in achieving the implementation of the minor canal to deliver canal water to them.

Chapter 5

Conclusions and Recommendations

General Conclusions

- The set-up of this restitution exercise was found to be an excellent method to present and discuss research findings on salinity/sodicity processes at the watercourse level. In this way, as many farmers could be reached as possible.
- Through group discussions with the farmers, a better understanding was gained regarding the severity of the salinity and sodicity problems from the viewpoints of farmers.
- Further insight was obtained in farmers' attempts to solve the problem and in the constraints farmers are facing which restrain them from implementing certain measures.
- Some farmers requested for individual advice on the possibilities for improved salinity/sodicity management. This could not be given in the way this restitution was set-up. Farmers obtained a better understanding of the possible solutions which are technically sound under present conditions.
- Through discussions on the different management options, it became clear that it is site dependent as to which options farmers like and which kind of solutions they are interested in for follow-up research.
- This restitution served three purposes: 1) communicated the research findings to the farmers; 2) validated the research findings; and 3) identified needs for follow-up research. All three purposes were attained in the restitution meetings. Although the restitution meetings were organised quite late in the research program, the experience demonstrated that restitution can be used throughout all phases of research.
- The contact with experts did not only provide relevant information for the restitution meeting, it also provided opportunities to present IIMI's work and to discuss opportunities for future collaborations.

Conclusions by Watercourse

Watercourse 130-R

- Due to the absence of indigenous salinity and sodicity and the light texture of their soils, farmers do not have much experience in salinity and sodicity mitigating/reclamation measures.
- Farmers are confronted with increasing sodicity problems due to the use of poor quality tubewell water. They are mainly interested in an improved canal water supply as a panacea for sodicity problems.
- In a few isolated cases, farmers experimented with sodicity mitigating/reclamation measures, but due to poor implementation, these measures did not always give the desired outcome.
- Credit and the economic feasibility of reclamation/mitigating measures were mentioned as other constraints.
- A few farmers were interested in experiments on the use of acid, gypsum and janter.

Watercourse Azim 111-L

- Due to the presence of indigenous salinity and sodicity, farmers have experience with the use of janter and gypsum to reclaim saline-sodic soils.
- Major constraints for the farmers are the availability of gypsum and the economics of growing janter.
- Farmers have little experience in the use of (sulphuric) acid.
- Future research should involve experiments on the use of janter, eucalyptus, gypsum, and sulphuric acid.
- Assistance could be given to help farmers in achieving implementation of a minor canal to deliver water to them.
- Too little attention was given by IIMI to the limitations and constraints of the use and reclamation of indigenous saline-sodic soils.

Watercourse Fordwah 14-R

- The location for the restitution meeting (at the head of the watercourse) was not correct, as salinity problems are occurring towards the middle and tail.
- Farmers have little experience in using management options to prevent and mitigate salinity problems.
- Farmers were interested in the different options but expressed the difficulty in adopting these methods as they face credit constraints.
- Two or three farmers were ready to experiment but no clear demand was formulated.

General Recommendations

- Sufficient time (minimum of 3 weeks) has to be allocated in the work plan of researchers for the preparation and implementation of a restitution meeting. As the preparation of the way that the message has to be brought to the farmers, the drawing of visual aids like posters, meetings with line-agencies, and the translation from English into Urdu or Punjabi requires considerable time.
- Farmers should be contacted to set the time and place for the meeting. An early announcement of the meeting increases the number of participants. When a site is chosen that is accessible for farmers, the farmers who are supposed to be the beneficiaries of the restitution should be taken into consideration.
- Field staff should be invited to attend the meetings.
- Restitution could be used by researchers at several stages of the research in order to increase the involvement of the farmers and create farmers' interest in the research activities.
- Content of the restitution should be very site specific to attain farmers' interest.
- If line-agencies are considered to be involved in a research project, they should be involved from the start of the research.
- Not only research institutes can be considered for collaboration, but institutes like On-farm Water Management and Extension could be involved in action-oriented research to improve the level of dissemination of the research findings.

Site Specific Recommendations

- The Soil Survey of Pakistan has shown its interest in trials related to soil physics. The Soil Science Department of the University Agriculture, Faisalabad, has expressed its interest in experimenting with trees and shrubs under severe saline-sodic conditions, as well as improved crop management under moderate saline-sodic conditions. These agencies should be involved in the planning and implementation of follow-up research in the three watercourses under consideration.
- In WC 111-L field trials on the use of gypsum, acid and janter should be established. On the indigenous saline-sodic soils, experiments with eucalyptus and atriplex species could be initiated.
- In WC 130-R, some trials on the use of acids, gypsum and janter could be set-up. Since many farmers in this watercourse are still not having proper incentives to make them willing to experiment, only a few interested farmers should be involved in these trials.
- A better identification of the needs for follow-up research should be done at the tail of WC 14-R, as most of the tail farmers (where the most severe salinity problems exist) did not attend the meeting.
- Attempts should be made to involve the Agricultural Department and the Directorate of Land Reclamation in the field trials.
- Most of all, farmers should be involved in the planning, design and implementation of the action-oriented research.

Annex 1

Set-up of Semi-structured Interviews

Depending on the interviewee respectable wording, length of introduction, and phrasing of questions were adjusted.

1. Introduction of interviewers.

2. The following introduction on the restitution exercise was given to the interviewee: 'As you know IIMI has been conducting different researches (e.g. on irrigation practices, farming practices, and salinity and sodicity) in your (and other) watercourses, for last 4 to 5 years. Many times you have been asking for the results of the water and soil samples. Due to circumstances the field assistants were not able to provide you with the results, or to give you any recommendations. For a long time IIMI has planned to change this situation. From last year we have been looking into the possibility to give feed back to the farmers, and to make our research findings more useful for them. In the moment we are planning a restitution of the salinity and sodicity research results. The people who have been working on the salinity and sodicity research component are planning to organise this restitution session on 24 and 25 July. At this moment, we have come to you to find out what your expectations are of the restitution meeting of salinity and sodicity research findings. We want to include your problems and questions concerning salinity and sodicity in the restitution, to make the meeting as useful for you as possible'.

3. At this point the different aspects of the salinity and sodicity research were very briefly explained to the interviewee, which included: purpose of soil sampling, piezometre readings, water sampling, monitoring of warabandi and tubewell operation hours, etc.

4. Then, the interviewee was requested to express his expectations of this restitution meeting. He was asked whether he had any questions related to salinity and sodicity which he would liked to answered during the restitution meeting.

5. Lastly, the organisation of the restitution meeting was discussed with the farmers (time, place, hosting, etc.).

Annex 2

Program of the Restitution Meetings

1. Introduction

    Round of introductions
    Presentation of IIMI and the purpose of the research
    Purpose of the restitution
    Program of the restitution

2. Salinity and sodicity processes and their effects on crop production

    Salinity and sodicity processes
    Discussion
    Salinity and Sodicity problems per watercourse
    Discussion
    Effect of salinity and sodicity on crop production
    Discussion

3. Options for salinity management

    Options for prevention of salinity/reclamation of soils
    Options for sustained/improved crop production
    Discussion on experiences, constraints, (dis-)advantages of different options
    Identification of demand for action-oriented research

IIMI-PAKISTAN PUBLICATIONS

RESEARCH REPORTS

Report #	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
	Crop-Based Irrigation Operations Study in the North West Frontier Province of Pakistan (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
	Crop-Based Irrigation Operations Study in the North West Frontier Province of Pakistan (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	IIMI-Pakistan	March 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- Pulished 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