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 farm systems.
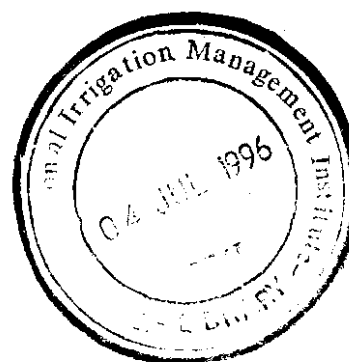
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Summary

This report describes the results of a case study carried out in Watercourse 14-R on the Fordwah distributary in January 1996. It is part of a broader study, entitled: Managing *Irrigation for Environmentally Sustainable Agriculture* in Pakistan. This is a study on farmers' perceptions on salinity and sodicity. Farmers can influence present salinity and sodicity levels through their farming and irrigation practices. It depends on farmers' knowledge of the salinity and sodicity processes, on the global farming objectives, farming strategies, and internal and external constraints of the farming system, as to how a farmer will react to present salinity and sodicity levels or hazards. Only after farmers' perceptions, strategies, and practices related to salinity and sodicity are understood, and the relation between physical environment, farming system, and salinity/sodicity strategies and practices are revealed, will it be possible to anticipate or predict the direction of change in soil salinity and sodicity under different irrigation scenarios.

Starting point for the used conceptual framework was the term sustainability. The definition of sustainability made that salinity and sodicity should be viewed as an environmental degradation process which can be influenced by farmers' action. The agro-ecosystem thinking refined this insight by naming the agents through which nutrients, and thus salts, can enter or leave the ecosystem. Taking the farm as basic unit for analysis, and using the peasant farming system approach as an analytical tool, allowed the placement of all farmers' activities within the context of: a farmer as an individual decision-maker, who tries to achieve his global farming objectives within the possibilities and constraints of his farming system. The use of both theoretical concepts (i.e., agro-ecosystem and peasant farming system concepts) resulted in a concept for explaining the decision-making process of a farmer, that also explains how farmers come to a strategy to deal with salinity and sodicity on their farms. This conceptual framework was a handy tool in trying to understand why farmers deal with salinity and sodicity in a certain way. This placed the salinity and sodicity issue within the global farming objectives, strategies, and constraints. The concept further provided insights into the ways a farmer, as an individual decision-niaker with a personal view on the salinity/sodicity processes, tries to deal with salinity and sodicity for his farming system and how he conies to the definition of a particular strategy.

A mapping exercise was used to obtain insights into the present salinity/sodicity situation. During the mapping exercises, discussions were pursued on the causes of salinity/sodicity, the present situation, and current processes. Though the mapping exercises provided insights about salinity/sodicity situations and actual processes, secondary information was indispensable for understanding farmers language and to cross-check information provided by the farmers. Semi-structured interviews were used for gaining insights into farmers' strategies to cope with salinity and sodicity, and farmers' practices to implement the followed strategies.

The case study revealed that farmers have an excellent knowledge of the present salinity/sodicity situation. A first analysis of the indicators that farmers use to recognise salinity/sodicity phenomena suggested that farmers have a good set of physical and crop appearance indicators to recognise salinity and sodicity. Later analysis showed that what farmers refer to as a black appearance of the soil does not necessarily point to sodicity due to organic matter dispersion. The black soil appearance refers more likely to high salt and sodicity concentrations, since in these soils no crop growth is possible, in contrast to soils having white salts where crop growth is possible.

refer to salinity, sodicity or a combination of both. Further analysis on the basis of soil sample data proved that 'white salinity' refers to salinity, in the majority of the cases without having sodic properties. 'Black and white salinity' combined in one plot seems to refer to saline/sodic soils. Though, due to the small
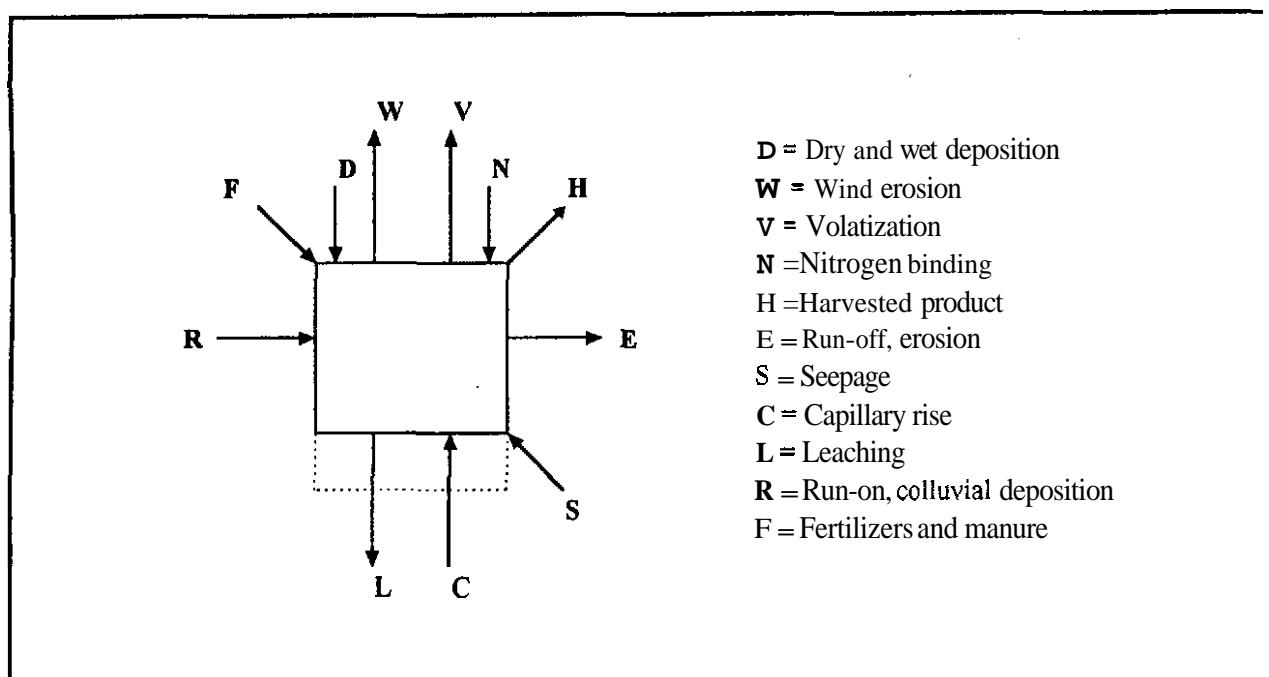
CHAPTER 1

Background and Overview

Introduction

This report describes the results of a case study carried out in Watercourse **14-R** on the Fordwah Distributary in January 1996. This study is part of a broader research project, presently carried out by IIMI-Pakistan in Chistian sub-Division, Punjab. This project tries to develop a research methodology to evaluate the environmental and economic impact of irrigation management interventions (Garin, *el al,* 1996). The outcome of these interventions is a redistribution of (good quality) canal water, with which it is hoped that farmers can better manage salinity and sodicity problems. Allocation and distribution of irrigation water at all levels of the irrigation system has a strong impact on the development of soil salinity and sodicity, and therefore on crop production. Salinity and sodicity processes under different water distribution scenarios can be simulated on the basis of a set of economic and physical "rules". But the actual impact on soil salinity and sodicity at farm and field **level** can only be revealed if farmers' decisions and practices are taken into consideration. Decisions are not only dependent on the physical and economic environment, but depend as well on farmers' perceptions on salinity and sodicity. This case study tries to reveal farmers' perceptions, strategies, and practices to cope with salinity and sodicity in their farming systems.

This chapter describes the general concepts with which aforementioned themes can be studied; an overview of the study objectives, the methodology used, and some background information on the study area will be provided. In the second chapter, the research findings will be presented, which will be done without providing any interpretation of the research findings in order to communicate the way that farmers think about salinity and sodicity to the reader. In the third chapter, the results will be discussed and analysed on basis of secondary data collected by IIMI, and on the basis of relevant literature. In the last chapter, the conclusions drawn from this case study will be presented.

Conceptual Framework

A starting point for this discussion is the term sustainability. In the global objectives of IIMI's research project, under which the work in Chistian sub-Division is carried out, the term sustainability is mentioned several times. This term is used within the context of sustainable use of land and water resources in irrigated agriculture. For this case study, the following definition of sustainability will be used: *The capacity of ihe owners and users d ihe scheme to manage and conserve ihe natural resources, land and water, in such a manner as lo ensure the attainment and coniinued satisfaction d the users needs for present and future generations* (FAO. 1992; Bastiaansen, 1992). In the light of this definition, salinisation and sodification are viewed as environmental degradation processes which can be influenced by the owners and users of the irrigation schemes.

In this case study, the farm is taken as basic unit for analysis. A farm can be regarded as an ecosystem. With regard to soil nutrients (including various salts) a farm can be schematised as follows:

Figure 1: *Agro-ecosystem (Janssen and Beusichem, 1991)*

D = Dry and wet deposition
W = Wind erosion
V = Volatization
N =Nitrogen binding
H =Harvested product
E = Run-off, erosion
S = Seepage
C = Capillary rise
L = Leaching
R = Run-on, colluvial deposition
F = Fertilizers and manure

Nutrients are brought into and removed from the ecosystem through various agents. Winiger (1983) proposes an agro-ecosystem model in which he distinguishes several stages of various levels of human impact on the eco-system. Farmers can influence the quality and quantity of several agents through their farming activities. In terms of salinity and sodicity, this implies that farmers have the capacity, through their farming and irrigation activities, to influence the salinity and sodicity levels in the agro-ecosystem.

Taking a homogeneous physical environment as a starting point, the way and the extent to which farmers' activities will effect the salinity and sodicity situation depends on farming and irrigation practices. These practices are the direct result from the farming goal, and possibilities and constraints imposed on the farming activities. In order to anticipate how the salinity/sodicity situation will develop under different irrigation scenarios, it is indispensable to consider salinity/sodicity management as an integrated part of the farming activities within the context of the peasant farming system.

Using the 'peasant farming system' approach, as described by Ellis (1988), gives an understanding of the reality of farming. This approach sees farms as a system which always consists of a number of activities and processes which are organised in order to achieve fanners' goals. Farmers are considered as individual decision makers who can vary the level and kind of farm inputs and outputs. Further, the peasant farming system approach takes internal and external constraints into consideration. These constraints limit the capacity to vary the organisation of production. Key concepts in understanding present salinity/sodicity management and future developments in the light of the peasant farming system approach are: 1) Farmers' are individual decision makers. Decisions are based on farmers' perceptions and knowledge, and are limited by internal and external farm constraints.; 2) It is recognised that not all farmers will have the same objective (e.g. maximising their farm profits on a long term or short term basis), and in practice, farmers may have many different goals such as family food security, achievement of certain preferences in consumption, fulfilment of community obligations and so on.; 3) Internal and external constraints which limit the capacity to vary the organisation of production, where external constraints are formed by factors from outside the farm (e.g. lack of fertilisers on the market, poor infrastructure, limited water supply, etc.),

and internal constraints are formed by factors peculiar to the farm (e.g. access to credit, number of family members, farm size, etc.).

Figure **2** schematises the peasant farming **system. A** farm is managed by an individual decision maker. The farming goals are set on basis of the household needs. The way this goal is achieved depends on the farmers knowledge and the experience, as well as internal and external farming constraints. The way in which a farmer tries to achieve goals will be referred to as strategy. From this strategy, a number of activities and processes are initiated and implemented

Figure 2: Peasant farming system
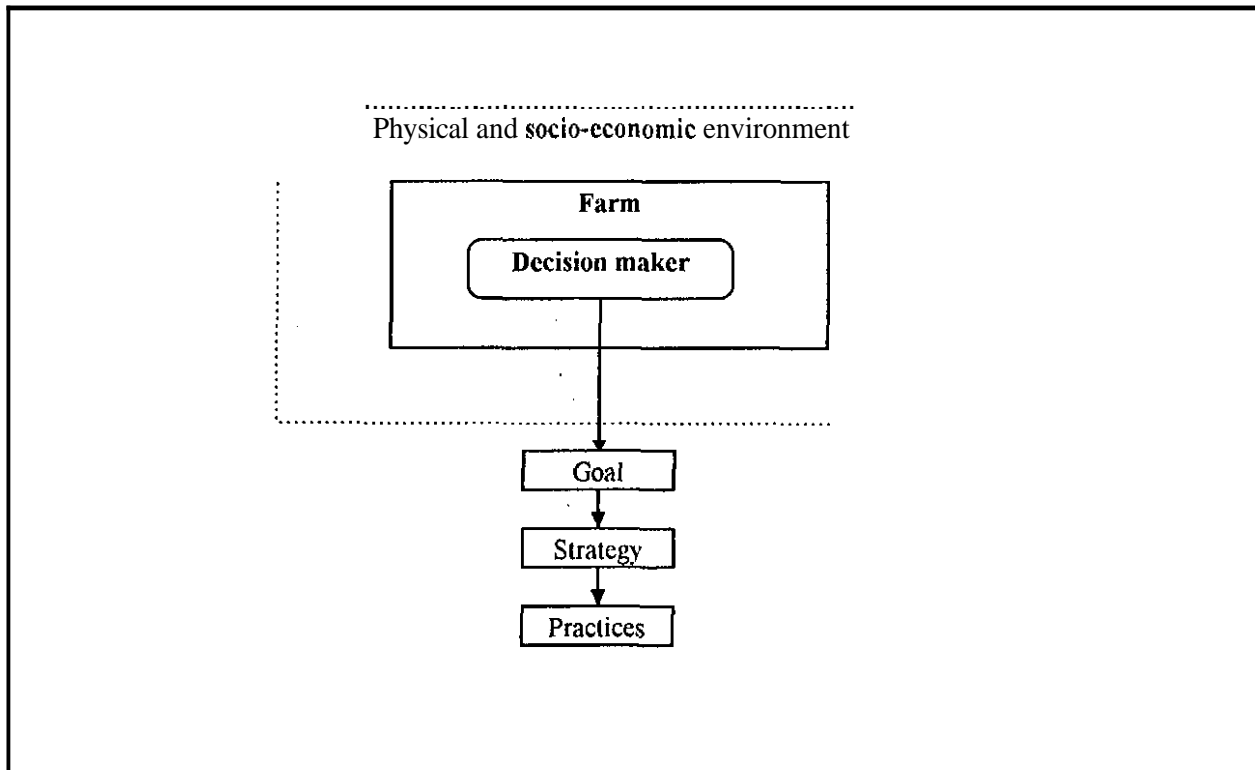
Salinity/sodicity can be regarded as a constraint, or hazard, which limits the achievement of farmers' goals or limits the organisation of production to achieve the farmers' goal. Salinity/sodicity is not an irreversible constraint or inevitable hazard, It depends on farmers' perceptions' whether fanners will adopt some strategies to deal with salinity/sodicity in their farming systems. Therefore, to understand present salinity/sodicity strategies and practices, and to anticipate the direction of change that result from different irrigation scenarios, fanners perceptions, strategies, and practices need to be understood, as well as the relations between the physical environment, farming system, and salinity/sodicity practices.

In trying to understand the influence of farmers' practices on the actual salinity/sodicity levels, and to *reveal* the relation between the farming system and farmers' salinity/sodicity practices, figure 3 could be helpful.

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[1] In tlie remainder of this report, tlie following definition of perception will be used: Perception is the way that a fanner perceives the present soil salinity/sodicity situation. Farmers' perceptions are defined by their understanding of salinity/sodicity processes and the consequences for crop production, and the way they judge the severity of the soil salinity/sodicity for the fulfilment of their fanning objectives in tlie light of the possibilities and constraints of their farming system.

Figure 3: Decision-making process of farmer to define a salinity/sodicity strategy
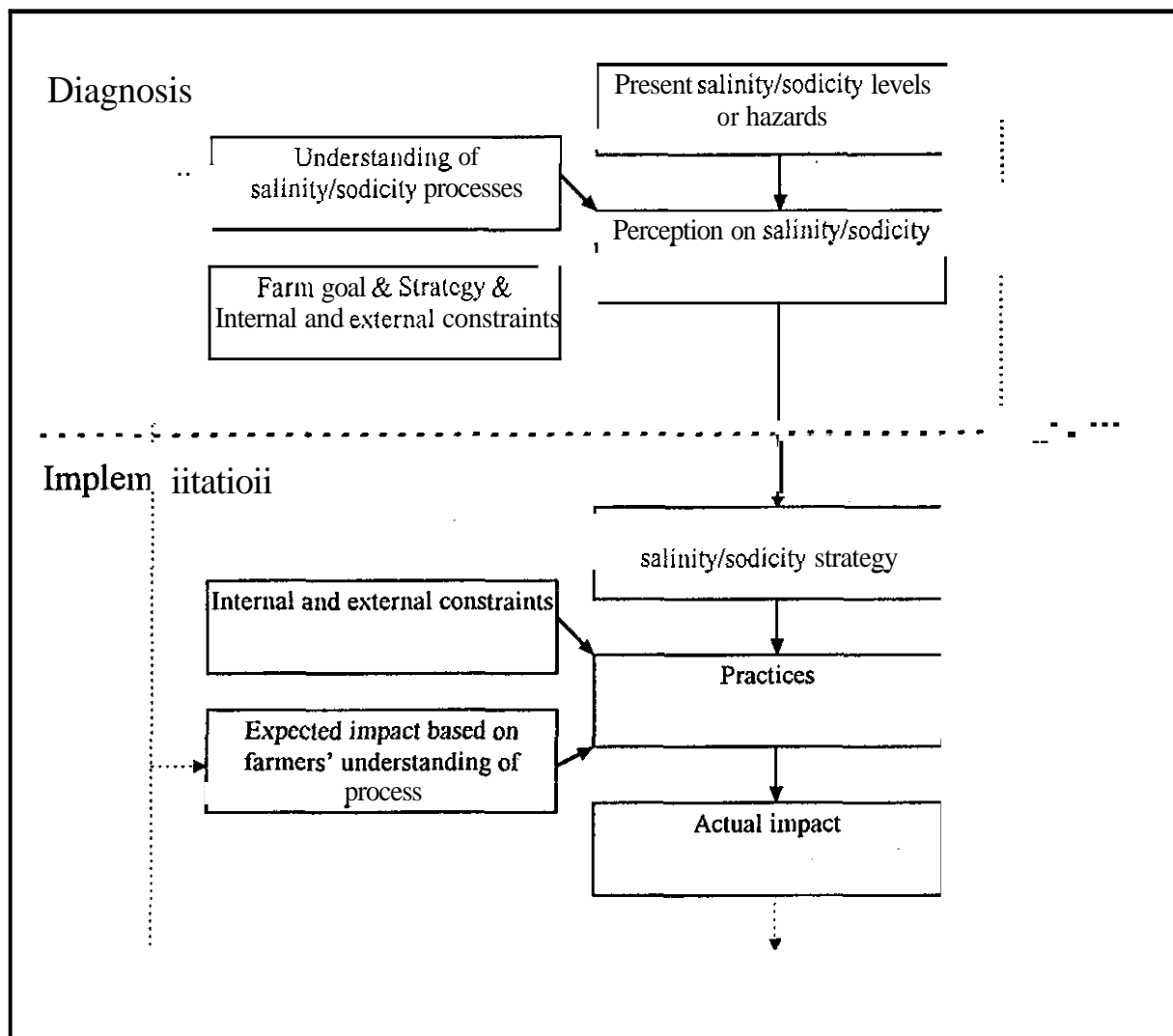
The present soil salinity/sodicity levels or hazards arc taken as a starting point. There are several factors that will influence the way farmers deal with salinity/sodicity, which thus influences the soil salinity/sodicity levels. The first influencing factor is farmers' perceptions on salinity/sodicity. Farmers' perceptions result from their knowledge of salinity/sodicity processes and on their farming goals and internal and external constraints. On the basis of this perception, the farmer defines a strategy to cope with *salinity/sodicity*. Strategies are defined which enables the global fanning goals to be achieved. Based on **the** defined strategy[2], farmers will chose practices' to implement their strategy. Depending on farmers' understanding

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[2] Salinity/sodicity strategies arc the plans that the farmers follow with regard to soil salinity/sodicity, in order to fulfil his forming goals.

[3] Practices are the actual farming activities that farmers undertake to implement their strategies. Practices are chosen on the basis of the expected impact (which depends on fanners' knowledge of salinity/sodicity processes) and the possibilities and constraints of the fanning system.

of the salinity/sodicity process, they will expect a certain impact from a certain measure. On the basis of this expected impact, as well as the limitations set by the internal and external farm constraints, the farmer will select the required practices. The selected practices will have an impact on the soil salinity/sodicity. On the basis of this experience, farmers' understanding of salinity/sodicity processes might change. With this new insight in mind, farmers might change their practices or even their strategies.

Objectives of the Case Study

The objectives of this study were formulated as follows:

1. To assess fanners' knowledge of salinity and sodicity; and

2. To assess farmers' perceptions, strategies and practices to cope with salinity and sodicity, as well as explain the different strategies and practices in the light of the possibilities and constraints of their physical environment and farming system.

Methodology

Site selection

One of the eight sample Watercourses being monitored by IIMI in the Fordwah and Azim distributaries for their research programme, was chosen for this case study. Watercourse **14-R** on Fordwah Distributary was chosen on the basis of its large number of farmers with a great diversity in farm characteristics, the various levels and the spatial distribution of salinity and sodicity, the conjunctive use of irrigation and tubewell water, and the spatial variation in ground water quality and depth.

Data collection techniques

The field data for this case study were collected by making use of two different research techniques: mapping (inspired on mapping exercises used in participatory rural appraisal), and semi-structured interviews.

Mapping was done using a base-map of Watercourse **14-R** that indicated the squares, blocks, *killas*, irrigation canals, villages, and tubewells. On this base-map different salinity/sodicity features could be easily indicated. The objectives of the mapping exercise were to attain insight about farmers' perception on the **causes** of salinity/sodicity, their knowledge on the salinity/sodicity process, and farmers' appraisal of the current salinity/sodicity situation. To fulfil these objectives two different mapping exercises were done in the field. The first exercise was done with a group of three elder farmers. The major aim was to gain insights into the historical development of the soil salinity and sodicity situation along with the changes that took place during the last few decades. The second mapping exercise was executed with a group of eight farmers, coming from different locations within Watercourse **14-R.** With this second group of farmers, the present situation was mapped. Additional information on farmers' perceptions and perspectives regarding

the causes of salinity and sodicity, and the salinisation/sodification processes, was collected during this mapping exercise through discussions by making use of a checklist.

Semi-structured interviews were conducted to obtain insights into fanners' perceptions regarding salinity/sodicity and their strategies and practices for coping with salinity/sodicity. Semi-structured interviews are characterised by a minimum control over the informant's responses. The interviews are based on an interview guide, which was in this case a written list of topics to be covered in a particular order.

Data analysis

On the basis of the information collected by means of the aforementioned techniques, farmers' perceptions, strategies and practices could be described. To obtain further insights into farmers' knowledge and understanding of salinity/sodicity, links were made with secondary data collected by IIMI. In addition famiers' descriptions were evaluated on the basis of literature. Farmers' strategies and practices were evaluated in the light of the possibilities and constraints of the physical environment and the fanning systems. Physical data, along with data **on** farming systems and farm characteristics, were all available within IIMI.

Study limitations

The mapping exercises were found to be an excellent method for quickly attaining insights into the present salinity/sodicity situation. During the mapping exercises, discussions could be held on the causes of salinity/sodicity, the present situation, and current processes. Though mapping exercises can provide quick and detailed insights into salinity/sodicity situations and actual processes, secondary information is indispensable to understand the fanners' language and to cross-check information provided by the famiers. Secondary information that was necessary to come to develop better understanding of the infoniiation provided by the famiers included: soil sample data, water quality analysis, ground water depths, soil maps and theoretical background information on salinity/sodicity. Because this case study was executed after soil sample sites had been selected and piezometers had been installed, some information that was needed to develop a more complete analysis of farmers' understanding of current salinity and sodicity processes, and famiers' interpretation of present salinity and sodicity situations was lacking.

Semi-structured interviews were found to be a good method for obtaining insights into fanners' strategies and practices for coping with salinity and sodicity. Semi-structured interviews leave room to build mutual understanding between interviewer and interviewee. Since semi-structured interviews allow farmers to talk in their own words and at their own pace, one interview might consume a considerable amount of time. Therefore, it is not a good method to quantify relations between strategies, practices, physical circumstances, and fann characteristics. But it does allow a descriptive analysis, through which trends can be discovered[4].

Study location

The study area is located in tlic Fordwah-Eastern Sadiqia Irrigation and Drainage Project area, which is located in the south-east of the Punjab. The area is semi-arid and is served by two main canals (i.e.

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[4] The results of farm interviews and a description of the salinity and sodicity situation per fanner is included in annex 1.

allotted a period of time (Merrey, **1996).** The water is distributed on a weekly rotation basis. During a water turn tlie farmer is entitled to all the water in the Watercourse. This rotational water allocation system is known as *warabandi.*

Fordwah **14-R** has a gross command area of around **200** hectares. **In** 1991/92 this Watercourse

Figure 4: Research location
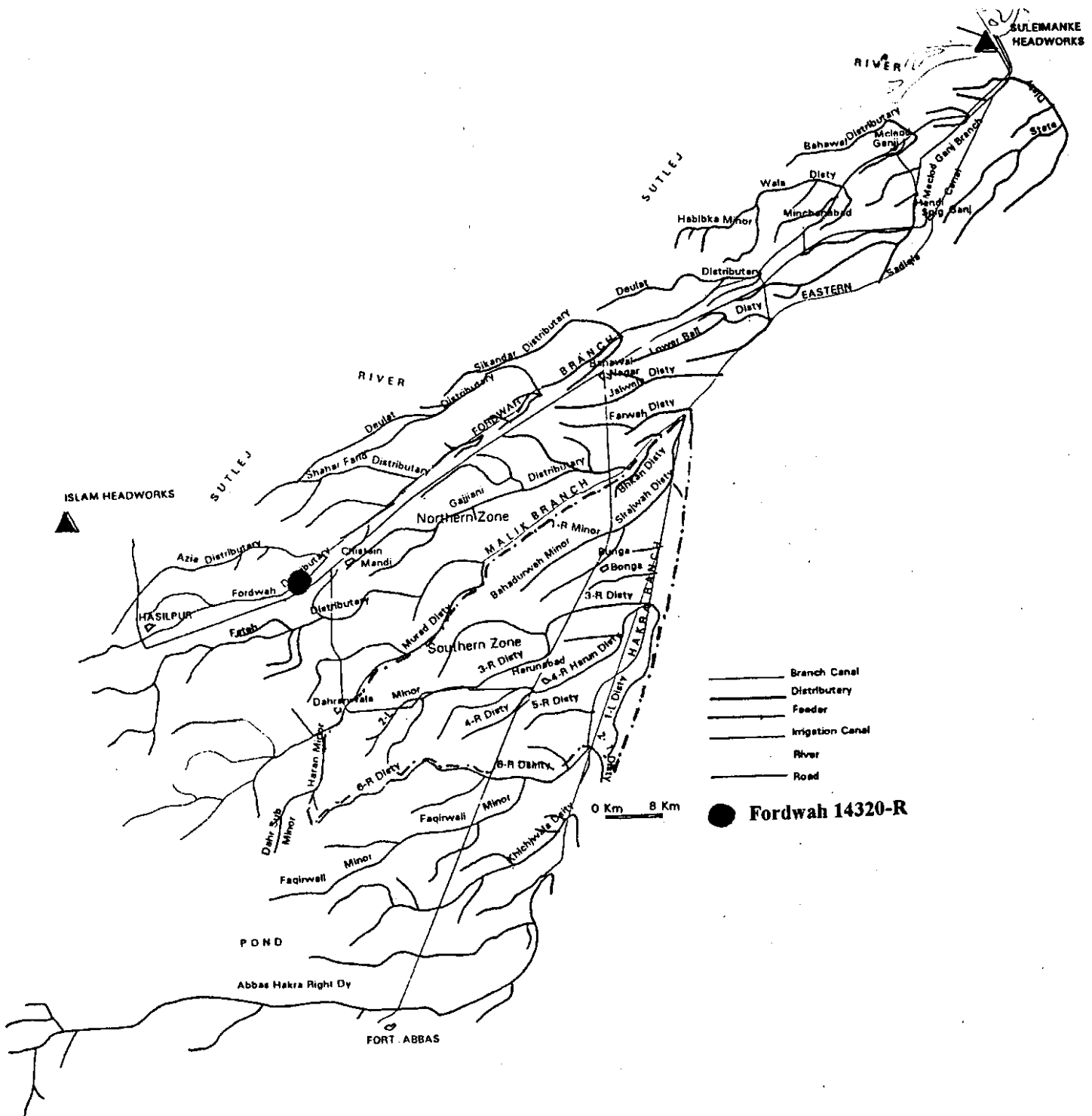
CHAPTER 2

Farmers' Perceptions on Salinity and Sodicity

Farmers' Knowledge of Salinity and Sodicity

Indicators for recognition of saline/sodic soils

Farmers use a number of indicators to recognise problems which are related to salinity and sodicity. These indicators might play an important role in the management of salinity/sodicity. Table 1 shows the indicators. In the second column, farmers' explanations on the use of these indicators is given. A distinction is made between indicators based on the physical appearance of the soil and indicators related to crop performance. Some indicators related to the physical appearance, identify the use of poor quality irrigation water, while others identify soil salinity/sodicity problems.

Table 1: Farmers' Indicators of salinity and sodicity

Indicator	Farmers explanation
Physical *appearance*	
Standing water on the field three to four days after irrigation.	If this phenomenon occurs, and the farmer has used a good quality irrigation water, the soil is having a problem.
Cracks in the soil after irrigation.	If the soil had a a d structure and this phenomenon occurs, the farmer that he has used a poor quality irrigation water and that th il will turn hard.
Sound of walking through a field l ; u g after rig itic	A poor quality irrigation water has been used and a flour-like layer on the il sur , ur der whi a n hard layer, will develop.
Foot prints which ol oily.	This soil has problems with regard to its salinity.
White appearance of soil	This is the first sign of white salinity It might either appear after irrigation with poor quality irrigation water or during an e d period of time in which no irrigation water was applied.
White patches on soil surface.	White salinity on high spots in the fields. This salinity is either caused by the use of poor quality irrigation water or the salts originate from the soil itself.
White soil surface.	White salinity. This is either caused by the use of poor quality irrigation water or the salts origin from the soil itself.
Black colour of the soil.	When the soil is black in colour, the soil has severe salinity problems. Growing crops in black soils is extremely difficult.
Muddy soils but due to a white flour-like surface the soils look dry.	These soils are waterlogged and very saline. Growing crops in them is extremely difficult. Often these soils have black salinity as well.
Crop performance	
Poor germination	Salinity. This indicator is used for a wide range of different salinity levels, both by farmers who have plots with 'some white salinity' as well as farmers who have plots with 'black and white salinity'.
Irregular crop growth	Salinity.
Stunted crop growth	Salts also deeper in the profile. After germination, the crop grows. But when the roots grow too long, they meet the salts and in severe cases the whole crop dies.
Yellow leaf burn	According to the farmers, too many salts in the soils will burn the crop yellow

Salinity/sodicity units

Fanners use the aforementioned indicators, or some of these indicators, to classify different salinity/sodicity units, To get a clear understanding of farmers' perceptions on salinity and sodicity, it is worthwhile to explore the terms which farmers use to indicate certain types of soil salinity and sodicity. During the two mapping exercises, the farmers defined six salinity/salinity units to distinguish between the different types and levels of saline, sodic or waterlogged soils. These distinct salinity/sodicity units will be used throughout this report. The farmers do not use the terms consistently, but in general, most farmers agreed on the following classification:

1. Soils which show a white surface. These soils can have either a good structure underneath the crust, or they can be hard underneath. This type of salinity is referred to as *chitta hlar* (*chitta* means white and *kalar*).
2. Soils which have only some patches of white crust, or where the crust is very thin. Also, this type of salinity is referred to as *chitta kalar.*
3. Soils which have a black appearance and which are hard in the upper soil layer. This phenomenon is called *kala kalar* (*kala* means black).
4. Soils which look good but which are hard deeper in the profile. The hardness is called *kalrafhi.* Sometimes these soils have 'stones' at a depth of one foot. These 'stones' are called *roor*.
5. Soils which have a lot of white salts at the soil surface. They appear to be dry, but under the layer of salts, the soil is muddy. Farmers call this *kalar shoor.* In this type of soil, it is (almost) impossible to grow crops. Some farmers call soils which contain too many salts to grow crops also *kalar shoor.* In this case, the soil does not necessarily has to be muddy.
6. Soils which are waterlogged. Waterlogging is called *sam.*

A variety of combinations of the above mentioned soils exist as well. These combinations are:
1. Hard and white (*kalrathi and chitta kalar*)
2. Black and white (*kala and chitta kalar*)
3. Black, white, and hard (*kala and chitta kalar, and kalrathi*)

Quality of irrigation water

In the same way as farmers use indicators to describe different types of soil salinity/sodicity, they use indicators to describe the quality of irrigation water as well. These indicators are related to the effect that the water has on the soils. The effects are the appearance of a white soil surface, and hardness of soils after irrigation. When farmers talk about a good quality water, it means that the water does not cause a white soil surface nor hardness. In Watercourse 14-R, nineteen tubewells have been installed since 1988. The quality of the tubewells ranges from extremely poor to good quality. In Table 2, fanners' assessments of the quality of different irrigation waters are indicated.

Table 2: Water quality assessment

Water source[5]	Quality[6]
TW64	water causes (hard soil) and white soil surface
TW65 .	water causes hard soil and white soil surface
TW66	water causes hard soil and white soil surface
TW67	water causes hard soil and white soil surface
TW68	water causes white soil surface
TW69	water causes hard soil and (white soil surface)
TW70	water causes hard soil
TW72	water causes hard soil and white soil surface
TW73	water causes hard soil and white soil surface
TW74	water causes (hard soil) and white soil surface
TW75	water causes white soil surface
TW76	good quality[7]
TW77	good quality[6]
TW106	extremely poor quality[8]
TW108	good quality[6]
TW1 10	water causes hard soil and white soil surface
TW132[9]	
TW133	water causes hard soil and white soil surface
TW164	good quality[6]
canal	excellent quality leaches salts and makes soil sol?

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[5] Tubewell numbers correspond with the tubewell identification numbers used by IIMI

[6] Qualities indicated between brackets are disputable. Some farmers have noted this quality of the water while other farmers did not mention it or some farmers mentioned that it only give some white or some hardness.

[7] Although the water is classified as 'good quality', it was incntioned sometimes that the water makes the soil slightly hard or causes a little bit of white crust.

[8] This tubewell was only operated once. Seven days alter irrigation all crops died.

[9] This tubewell had only be operated once during the time of the field data collection.
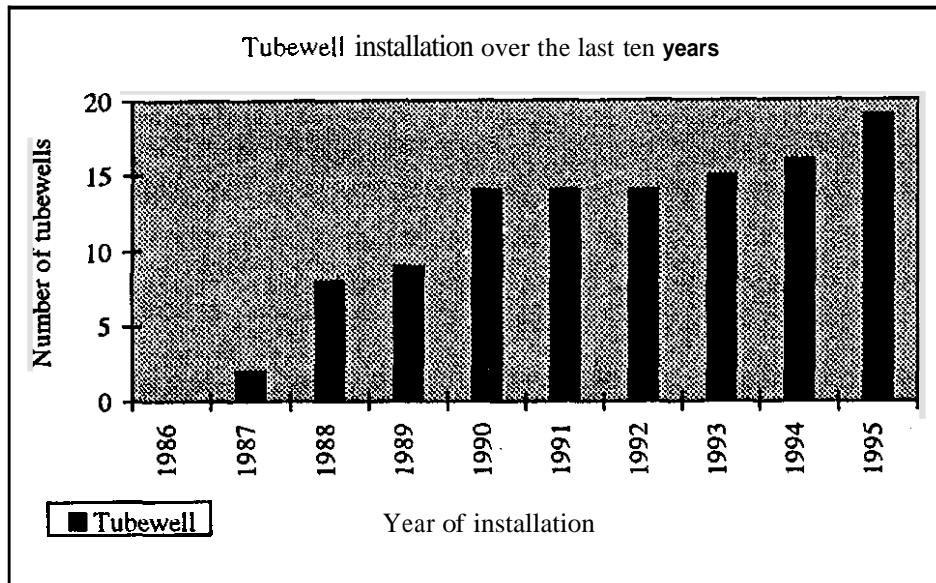
History of salinity/sodicity

The historical description of the soil salinity/sodicity situation is based on a mapping exercise carried out with three elder farmers who have been irrigating in Watercourse **14-R** since the partition of Pakistan and India in **1947,** when they migrated from India to Pakistan. When they first started cultivating in this area they only had temporary land rights, but after **1954** they obtained permanent land rights. Since then, they started levelling the area on a large scale and in this way they brought more land under irrigation.

The time that they started irrigating, the soils were believed to be of good quality. But around **1972,** a drastic change took place. During this period, the area experienced abundant rainfall. Farmers say that it rained for 15 days in a row. Due to this excessive rainfall, the water table rose extremely high. During the succeeding six to seven years, farmers experienced difficult times. Crop production was very low due to waterlogging. Slowly, the water table dropped naturally. A fast drop in the water table level occurred in the period around **1985** to **1987.** These years were 'dry'. After the water table had dropped, the farmers realised that salts had been left behind at the **surface** of their farm lands. Four farmers who were interviewed later in this case study had similar stones about heavy rains around **1972.** One of them said that it left *chitta kallar* (white salinity) at the soil surface and *roor* (stones) a bit deeper in the soil profile.

Map 1 indicates the areas that were left saline/sodic after the excessive rains of **1972.** Two blocks were almost completely waterlogged. In the tail of Watercourse **14-R** a lot of salinity, which is recognised by the farmers **as** a white soil surface, was left behind. Another block, also situated in the tail of Watercourse **14-R,** was classified by the farmers **as** being *kalar* shoor. These soils were too saline to grow any crop and the soils were waterlogged as well. In the middle of Watercourse 14-R, the farmers indicated some smaller areas which were left with white **surfaces.** Some small spots in several blocks were indicated to be black and hard, and white and hard.

Map **2** shows the soil salinity/sodicity situation after it improved naturally due to the dropping ground water table. Many areas which were suffering from white crusts were improving, and the waterlogged areas were getting drier. Simultaneous with the improvements of the soils, the cropping intensities rose. Farmers who, due to limited canal water, left parts of their farms uncultivated started installing tubewells. In **1988,** the first tubewell was installed and operated in this watercourse. Up till now, farmers are still installing tubewells. In **1995,** three new tubewells were installed. Initially, the installation of new tubewells gave a further reduction in the salinity/sodicity problems, and a major reduction in the waterlogging problems was brought about near the head of Watercourse **14-R.** The changes that took place are indicated in map 3. In the tail-end blocks, no major changes have taken place. Since the installation of the tubewells, only the soils, that were said to have white surfaces, improved. The physical characteristics of the other types of saline soils did not change much.

Figure 5: Number of tubewells in Watercourse 14-R

Tubewell installation over the last ten **years**

Present situation

Map **4** shows the present salinity/sodicity situation. This map was compiled from the mapping exercise with eight farmers. The map shows in detail all *killas* which are effected by **a** certain type of salinity/sodicity. It should be stressed that the map is in congruence with fanners' experiences in cultivating these soils. The map is more detailed then the maps made by the elder farmers. One striking similarity between Maps 3 and **4** is the large saline/sodic area in the tail of Watercourse **14-R.** A striking difference between the two maps is the large number of *killas* which were mentioned to have some *chitta kalar* in Map **4** which were not present in Map 3, especially in the middle and tail area of the watercourse.

Farmers' view on salinisation and sodification processes

The farmers who were consulted to map the present salinity/sodicity situation indicated that three. processes play **a** role in the current salinisation process.

1. When farmers do not irrigate their plots for **a** couple of weeks (e.g. due to **a** lack of canal water), the soils turn white in colour. This also happens between the last irrigation event in one cropping season and the first irrigation in the next cropping season. According to the fanners, these salts come from the soil itself. During the farm interviews, it became clear that only farmers who have plots in the tail end, where the water tables are relatively high, confiniicd that this type of process plays **a** role in the salinisation of the soil. In the middle and head, where the water table is deeper, some farmers reported that this type of salinisation occurs, but only when they leave their soils fallow for three to four years.

2. When there is **a** lack of canal water, and fanners have **a** crop in their field, they use tubewell water to prevent wilting. Water from most tubewells causes **a** white crust on the soil surfaces and makes the soils hard.

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3. For some farmers, waterlogging is indicated to be the major problem. The cause of the problem is rainfall. Not only abundant rainfall, but all rainy seasons cause an increase in the waterlogging problcms. **This** problem was indicated to occur in several *killas* in the tail of Watercourse **14-R.**

Farmers see the different stages in *salinisation* as follows: 1) All the soils which become saline **start** to show a white soil surface and become hard as well (in white salinity, it is still possible to grow crops); **2)** If the *salinisation* process continues, the soils become more and more white and harder; and 3) Finally, they turn black and no crop is able to grow in these soils anymore (in this stage, the soils are called *kalar shoor*).

SALINITY SODICITY AFTER RAINS OF 1972
WATERCOURSE 14-R

IIII While **surface** (Chilla *Kalar)*
≣ *Water logged* **(Sam)**
▦ Hard, black and while *mostly waterlogged (kalar* shwr)
▨ White and Had *(Chitla kalar* and Kalmlhi)
■ Blackand *Hard (Kala kalar* and *Kalralhi)*
∧ *Watercourse*
∿ *Distributary*
★ *Tubewell*
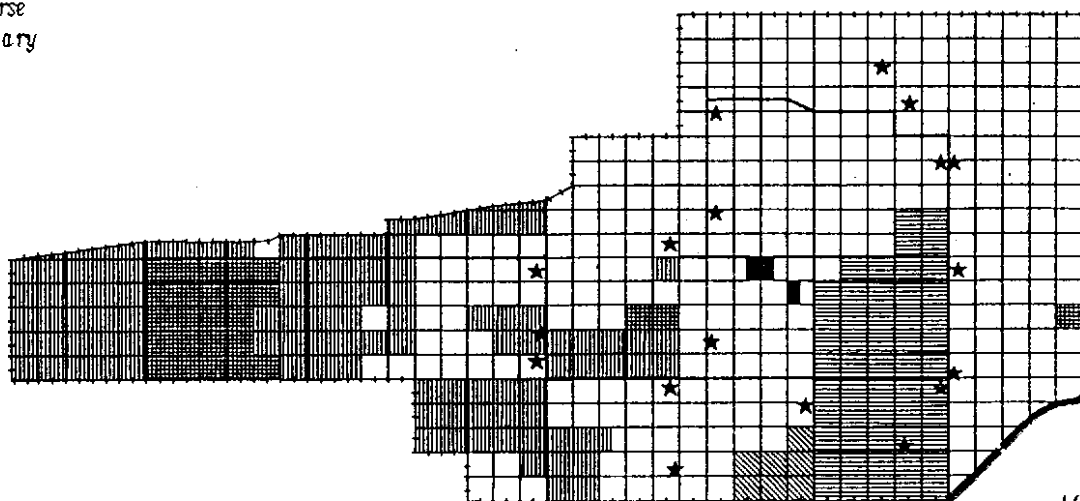
Map 1

SALINITY SODICITY BEFORE INSTALLATION OF TUBEWELLS 1587
WATERCOURSE 14-R

IIII While surface *(Chilla Kalar)*
⊟ *Improving* While Surface
⊟ *Improving* Water *Logged* Soils
▦ *Hard,* Mack and while *mostly waterlogged (kalar* shwr)
▨ While and Hard (Chitla *kalar* and Kalmlhi)
▨ While. **Blackand** *Hard (Chilla, Kala kalar and Kalralhi)*
∧ *Watercourse*
∿ *Distributary*
* *Tubewell*
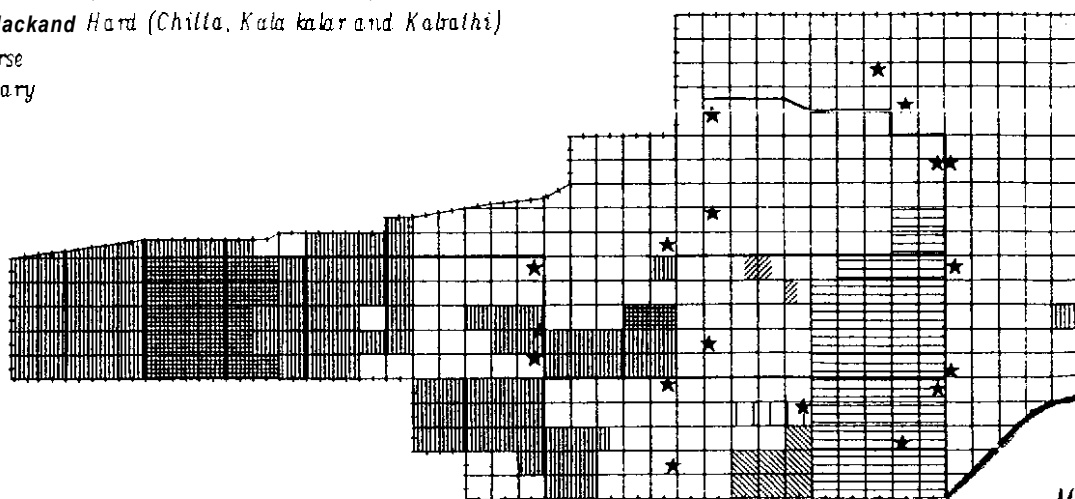
Map 2

SALINITY SODICITY AFTER INSTALLATION OF TUBEWELLS OF 1987/95
WATERCOURSE **14-R**

▦ *While surface (Chitta Kalar)*
▢ *Improving While Surface*
▓ *Hard. Mack and white mostly waterlogged (kalar shoor)*
▨ *White* and *Had (Chitla hlor and Kalrathi)*
■ *Block and Hard (Kah kalar and Kalrathi)*
𝑁 *Watercourse*
⚡ *Distributary*
★ *Tubewell*
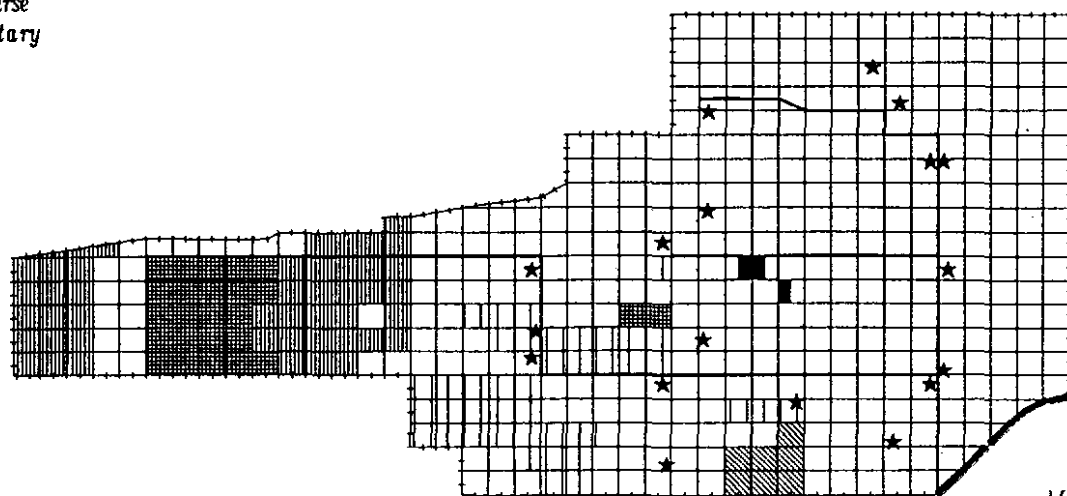
Map 3

SALINITY SODICITY PRESENT SITUATION
WATERCOURSE 14-R

▦ *While surface (Chitla Kalar)*
▥ *Some While at surface*
▦ *Black Soils (Kala kalar)*
▓ *Hard, block and while mostly waterlogged (kalar shoor)*
⊠ *Black and While (Kah and Chitla kalar)*
▨ *Chile and Had (Chitta kalar and Kalrathi)*
▨ *While. Black and Hard (Chitla, Kala kalar and Kalrathi)*
⊠ *Some Khile and Black (Some Chitla and Kala kalar)*
𝑁 *Watercourse*
⚡ *Dislnbulay*
★ *Tubewell*
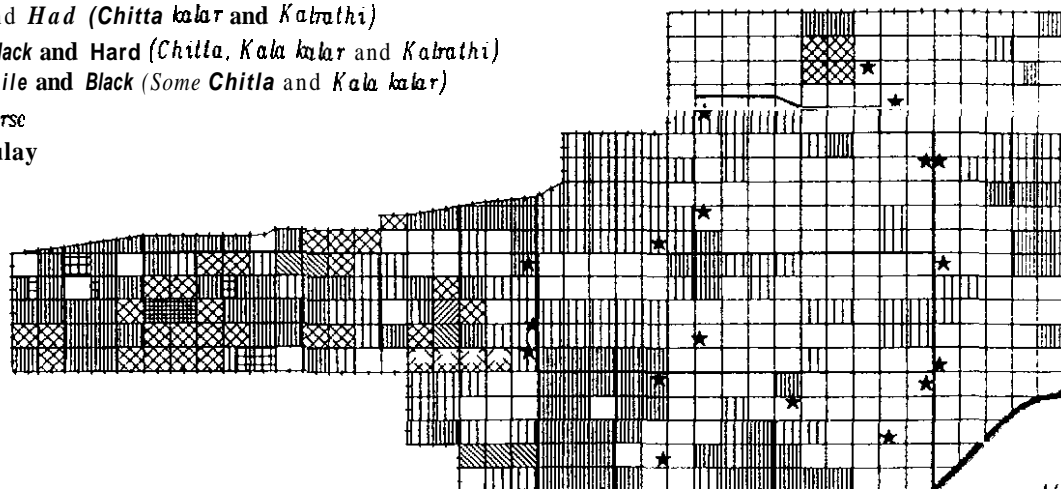
Map 4

Farmers' Strategies to Cope with Salinity/Sodicity

During the semi-structured interviews, it appeared that not all farmers follow the **same** strategies to cope with the current salinity/sodicity situation. It is not obvious that all farmers try to reduce or prevent salinity (e.g. some farmers indicated that they allow an increase in salinity/sodicity). There are basically four strategies that farmers apply:

1. Reduce salinity/sodicity levels;
2. Prevent an increase in salinity/sodicity;
3. Allow increase in salinity/sodicity; and
4. Mitigate the effects of salinity/sodicity on crop growth.

These strategies can be combined or used separately. Sometimes, one strategy is applied in one part of the farm, while in other **parts** of the farm other strategies are applied. Some farmers do not have any strategy at all. In these cases, farmers often indicated that they are not interested in salinity issues since they themselves, or family members have employment outside the farm. To find a job outside the fann could form a strategy in itself again.

Farmers' Practices *to* Cope with Salinity/Sodicity and the Expected Impact

In order to Fulfil their strategies to prevent, reduce or mitigate the effect of salinity/sodicity, farmers have many practices at their disposal. From the semi-structured interviews, a list of practices could be abstracted. In the following table on the next page, the measures are grouped according to the strategy they serve. One group contains the measures that serve the goal to prevent or reduce the soil salinity/sodicity. These two strategies are taken together because it depends on the practical implementation in the field whether the measure will achieve a reduction in soil salinity/sodicity, or whether it only prevents an increase in soil salinity/sodicity. The second group is the measures that mitigate the effect of salinity/sodicity on crop growth. These measures are not meant to reduce the soil salinity/sodicity, but they are meant to prevent yield reductions or financial losses. Further, the practices are grouped according to the type of measure. Some practices involve an adjustment in irrigation management, while others are related to crop choice, chemical or biological amendments, or mechanical improvements.

Farmers implement the measures with certain expectations regarding the impact these practices will have on the salinity/sodicity levels. In the second column of the table farmers' perceptions on the impact of the practices are given.

Table 3: Salinity measures and their expected impact

Measures	Expected impact
IRRIGATION	
Reduce/prevent salinity/sodicity	
Use canal water as much as possible	Leaches the salts and makes hard soils soft.
Use as little tubewell water as possible	Prevents an increase in salinity problems.
Chose best quality tubewell	Limits the problems induced by the use of tubewell water.
Mix canal water with tubewell water	Increases the quantity of 'relatively' good quality water.
Priority canal water used on saline plots	Prevents good soils to become saline by using tubewell water.
Mitigate the effect of salinity/sodicity	
Use tubewell water if canal water shortage	Prevents crop from wilting in case of canal water shortage.
Timing of irrigation	Since crops are more drought sensitive in saline plots, this practice prevents crops from wilting.
Priority canal water used on wheat and cotton	Increases the yields since wheat and cotton are saline sensitive.
Priority canal water used on fodder	Prevents crop failure, increases yields in saline plots.
Irrigate after land preparation and sowing	Prevents mixing the salts in the soil profile. In this way seeds germinate better since they do not get in contact with the salts.
CROP CHOICE	
Reduce/prevent salinity/sodicity	
Fodder and sugarcane planted in saline plots	These crops can grow under saline conditions, and they reduce salinity since they need a lot of water.
Jnnter gross production	Jnnter production reduces the salinity levels. After ploughing it in the profile it improves the soil structure as well. In some cases it is the
Plant eucalyptus in saline/sodic areas	It is not clear whether the farmer expects a reduction in soil salinity and sodicity or, whether he grows these trees to use the plots is o useful manner since other crops are not financially attractive to grow.
Mitigate effect of salinity/sodicity	
Fodder grown in less saline areas	Farmer does not want to buy fodder. He wants to have good fodder yields.
Wheat and cotton grown in less saline plots	These crops are salt sensitive in less saline plots they give higher yield.
Oil seeds grown in saline plots	Seeds are cheap. If the crop fails financial losses are limited.
MECHANICAL	
Reduce/prevent salinity/sodicity	
Land levelling	Prevents high spots in the plot to become white.
Reduce/prevent and/or mitigate effect of salinity/sodicity	
Remove top soil	Removes salt crust and lowers the level of the plot. In this way larger quantities of canal water can reach the plots.
Ploughing to dry the soil	Create favourable conditions for crop growth.
Adding a 'fresh' layer of sand	Creates a good layer for seed germination, effect last 1 or 2 seasons.
AMENVMENTS	
Reduce/prevent salinity/sodicity	
Application of farm yard manure (FYM)	Reduces salinity a bit (in combination with irrigation),fertilises the soil.
Ploughing cotton steins into the soil	Improves the soil quality.
Application of gypsum	Reduces the salinity problems.
Application of fertilisers	Certain fertilisers help to reduce the salinity and soften the soil.
OTHER	
Reduce/prevent salinity/sodicity	
Prevent fallow periods	Prevents the salts from rising by capillary action.
Leave part of the farm fallow to increase water availability for a smaller area	In this way, more canal water is available for a smaller area. Thus, the salinity level can be kept lower on this small area.
Mitigate effect of salinity/sodicity	
Leave saline/sodic plots fallow	Prevent financial losses due to poor yields or complete crop failures.

There were **a** few practices nicntioncd during the farm interviews that were not meant to be anti-salinity/sodicity measures but which influence the soil salinity/sodicity. Therefore they are mentioned here.

1. **Plots** are left fallow. Some fanners did not give a reason for it but others mentioned it in connection with **a** lack of canal water.
2. One fanner only irrigated his cotton crop twice during seven to eight months. The soil salinity/sodicity increased during this period.

Some fanners mentioned explicitly that they do not have funds to **use** biological or chemical amendments.

CHAPTER 3

Discussion on Farmers' Perceptions

Farmers' Understanding of Salinity/Sodicity

Farmers and scientists often use different languages to describe the same phenomena. This already becomes clear from the preceding paragraphs. Farmers talk about *chitta kalar, kala kalar* and *kalrathi* while scientists talk about salinity and sodicity. Fanners classify soil salinity/sodicity on the basis of the physical appearance of the soil and the effect of the salinity/sodicity on crop growth, irrigation and land cultivation, while scientists' will classify soil salinity/sodicity mainly on the basis of EC, SAR_e, ESP, and pH. The same applies for the evaluation of the quality of irrigation water. For this case study, it is interesting to evaluate farmers' knowledge about the salinity/sodicity process and the causes of salinity/sodicity, soil classification, salinity/sodicity indicators, and irrigation water quality valuation on the basis of soil sample data, water quality data, ground water table data, and literature. In this way, farmers' understanding of salinity/sodicity can be better revealed. This is **also a** helpful expedient in understanding farmers' strategies and practices to cope with salinity/sodicity problems.

Indicator for soil salinity/sodicity

Smedema and Rycroft (1983) have mentioned six indicators based on soil appearance to **assess** salinity/sodicity. They **also** mention that many salt-affected soils have a normal field appearance. The actual salt content may be quite high before salinity becomes observable in the field and before crops show any salinity symptoms. The six indicators they mention are:
1. efflorescence phenomena: powdcry, crystalline salt deposits on soil surfaces (especially high spots), side slopes of ditches, etc.;
2. damp, oily looking soil surface (due to hygroscopy of salts, especially $CaCl_2$);
3. mycelia in soil profile: salt precipitated in the fine pores, forming **a** pattern of thin white veins (usually carbonates);
4. crystals, clustered or scattered (especially with gypsum crystals);
5. crusts: concentration of crystalline salts at certain depths (near or on the soil surface) leading to the formation of **a** cemented layer: and
6. dark film on the soil surface, left by evaporating soil moisture containing dispersed organic matter (especially in the presence of Na_2CO_3).

The following phenomena were mentioned by the farmers and have similarities with the phenomena described by Smedema and Rycroft, and thus might refer to the same phenomena:

1. efflorescence phenomena: farmers describe this as a flour like layer, also the white appearance of the field might be the first symptoms of the efflorescence phenomena;
2. damp, oily looking **surface:** famiers recognise this if their footprints look oily;
3. mycelia: not mentioned by famiers;
4. crystals; not mentioned by famiers:
5. soil crust: the first sign of crust formation is the sound of walking through a field, later the crusts become visible in the field (white in colour); and
6. dark film on soil surface: soils which are really badly affected by salinity/sodicity have a black appearance, according to the farmers.

The first five features mainly indicate a high salt content in the soil, although the ESP **may** be high **as** well. Feature six indicates sodicity (high ESP and especially high pH). Poor soil physical conditions are also related to high sodicity levels. Poor soil physical conditions are expressed by the farmers through: soils drying slowly after irrigation; cracks; and hardness of soil. Salinity symptoms in crops mentioned by farmers are: irregular germination and stunted crop growth.

On the basis of some of these indicators it is already possible to relate farmers' soil types to salinity related problems (Table **4).**

Table 4: Anticipated salinity problem

Soil types	Indicator	Problem
Chitta kalar	efflorescence phenomenon; crust	Salinity[10]
Some chitta kalar	efflorescence phenomenon; white appearance	Salinity
Kala kalar	black appearance/no crop growth	Sodicity
Kalrathi	poor soil physical conditions	Sodicity
Kalar shoor	black, crust, poor soil physical conditions, muddy	Salinity/sodicity/waterlogging

Soil salinity and sodicity units evaluated

The aforementioned evaluation is completely based on indicators, which does not really provide evidence for the anticipated relations between salinity/sodicity and salinity/sodicity types as defined by the farmers. In order to obtain more evidence for these anticipated relations, it is interesting to compare salinity types with EC and SAR values for the soil samples. A set of **56** soil samples have been taken in **'94** and **'95.** Table **5** summarises the soil sample results for Kharif **'95.** The samples were grouped according to the classification

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[10] From the indicator given hy the farmers, it is for sure that the soils which have been appraised as being *chitta kalar* have saline properties. Farmers mentioned often that soils being *chitta* kalar were hard as well, hut not hard enough to he classified as being *kalrathi*. It is not clear whether the hardness associated with *chitta kalar* refers to sodic characteristics or to cemented layers caused by concentrations of crystalline salts. Nevertheless, some of the soils classified as *chitta kolar* could be sodic as well.

of the farmers. For every soil type, the average and standard deviation per depth is calculated, as well as the average and standard deviation for the average of the whole profile.

From Table 5, it can be concluded that the range of EC values for the soils being classified as 'non-saline/sodic' is small (small standard deviation). For soils classified as having 'some white salinity', the range for the top soil (0-6 inches) is small. The EC levels further down in the profile vary more. The range of EC for 'white salinity' varies more. This can be explained by the fact that farmers do not classify their soils as white, more white, and extremely white. Also, the SAR values for white soils vary quite a lot. This was mentioned by the fanners themselves, 'white' soils might be 'hard', but they will only be classified as being 'hard' if it is a pronounced feature in comparison to the 'white salinity'. The sample size for soils classified as 'black and white' is too small for drawing conclusions. Though, it can be observed that the average EC and SAR values are higher than the values classified as white salinity. No samples were taken from the classification groups 'black', 'white and hard', 'hard' and 'kalar shoor'. Anticipated relations between these units and saline/sodic properties rely on indicators used by the farmers.

Table 5: EC and SAR of soil samples (Kharif '95)

SAR Depth (inch)	No (# samples 24)		Some White (# samples 10)		White (# samples 15)		Black & White (# 2)[11]	
	Avg	Stdev	Avg	Stdev	Avg	Stdev	Avg	Stdev
6	2.7	2.0	2.6	1.6	5.9	4.5	9.2	4.6
12	3.2	2.1	3.5	1.2	6.9	4.4	12.7	6.9
24	3.6	2.5	6.9	2.3	8.1	5.7	10.1	1.9
36	4.7	3.7	6.5	3.8	7.3	5.6	13.5	1.6
Avg.	3.6	2.1	4.7	3.7	7.0	3.4	11.4	3.8
EC								
6	1.2	0.5	1.8	0.7	4.7	2.8	5.5	3.6
12	1.1	0.6	1.6	0.9	4.8	2.1	7.7	5.9
24	1.2	0.8	2.6	1.9	4.7	2.3	5.9	3.2
36	1.5	1.0	2.6	1.6	4.2	2.0	5.4	2.6
Avg.	1.4	0.6	2.1	1.2	4.6	1.6	6.1	3.8

The next step is to classify the soils on basis of the chemical composition of the saturation extract. Them classification system used here is derived from Richards (1954).

Table 6 USDA soil salinity/sodicity classification

	ECe < 4 dS/m	ECe > 4 dS/m
ESP ≤ 15%	non-saline; non-sodic soils	saline soils
ESP > 15%	sodic soils	saline; sodic soils

The relation between the farmers classification and the classification system of USDA, 1954 is presented in table 7. This table is based on the sample data for kharif '95. This is the most recent sample set. Since fanners were ask to classify their soils on basis of the present situation, this seems to be the most appropriate data set to be used. Perhaps farmers judge their soils based on features over a couple of seasons, but the sample size is too small to analyse them in a historical perspective (sample data from '92 for Watercourse 14-R are available for 15 plots only). The values indicated between brackets are the

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[11] Sample size is too small to draw conclusions The data are used here to indicate a trend

ranges. Thus, farmers talking about *chitta kalar* soils can refer to saline, non-sodic soils as well as to saline, non-sodic and saline, sodic soils. The percentages behind the classification units are tlic percentages of samples falling within this classification class.

Table 7: Farmers classification compared with USDA classification

	USDA-Classification[12]
No salinity/sodicit	li non-sodic *100%*
Some *Chitta kalar*	non-saline, non-sodic 90% (saline, non-sodic *10%*)
Chitta kalar	saline; non-sodic *60%* (non-saline, non-scdic *33%*; saline, sodic 7%)
Chitta kalar & Kala kalar	saline; sodic ?

Irrigation water quality in relation to salinity/sodicity hazards

The classification systems for evaluating the quality of water for irrigation purposes used here. is the FAO classification system (Ayers and Westcot, 1985). The system appraises the salinity hazard on the basis of an increased EC-value in irrigation water. The systems defines three classes (i.e. none, slight to moderate, and severe salinity hazards). With respect to the sodicity hazards. the hazards decrease when the total EC of the irrigation water increases. The statement is made that infiltration rates generally decease with decreasing salinity or increasing sodium content relative to calcium and magnesium. Table 8 and 9 can be used for the appraisal of irrigation water as promoted by the FAO.

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[12] In this classification system the ESP value to classify sodic soils is 15%. It is assumed that as long as exchangeable Na does not exceed 15% on the cation exchange complex the effects of sodium are negligible. Recently Sumner, 1993 has shown evidence that the negative effects of Na on the physical soil conditions might be manifested at levels far below those previous used lo define sodic soils

Table 8: FAO classification system for salinity hazards (adapted from the University of California Committee of Consultants, 1974)

Salinity hazards	
C1 (EC_e < 0.7 dS/m)	None
C2 (0.7 > EC. < 3.0 dS/m)	Slight to Moderate
C3 (EC_e > 3.0 dS/m)	Severe

Table 9: FAO classification system for sodicity hazards (adapted from the University d California Committee d Consultants, 1974)

SAR.	EC_s (dS/m)		
	None (S1)	Slight to Moderate (S2)	Severe (S3)
0 - 3	> 0.7	0.7 - 0.2	< 0.2
3 - 6	> 1.2	1.3 - 0.3	< 0.3
6 - 12	> 1.9	1.9 - 0.5	< 0.5
12 - 20	> 2.9	2.9 - 1.3	< 1.3
20 - 40	> 5.0	5.0 - 2.9	< 2.9

Fanners' classification related to the aforementioned classification system are combined in Table 10. The FAO system classification are based on measured EC and SAR values.
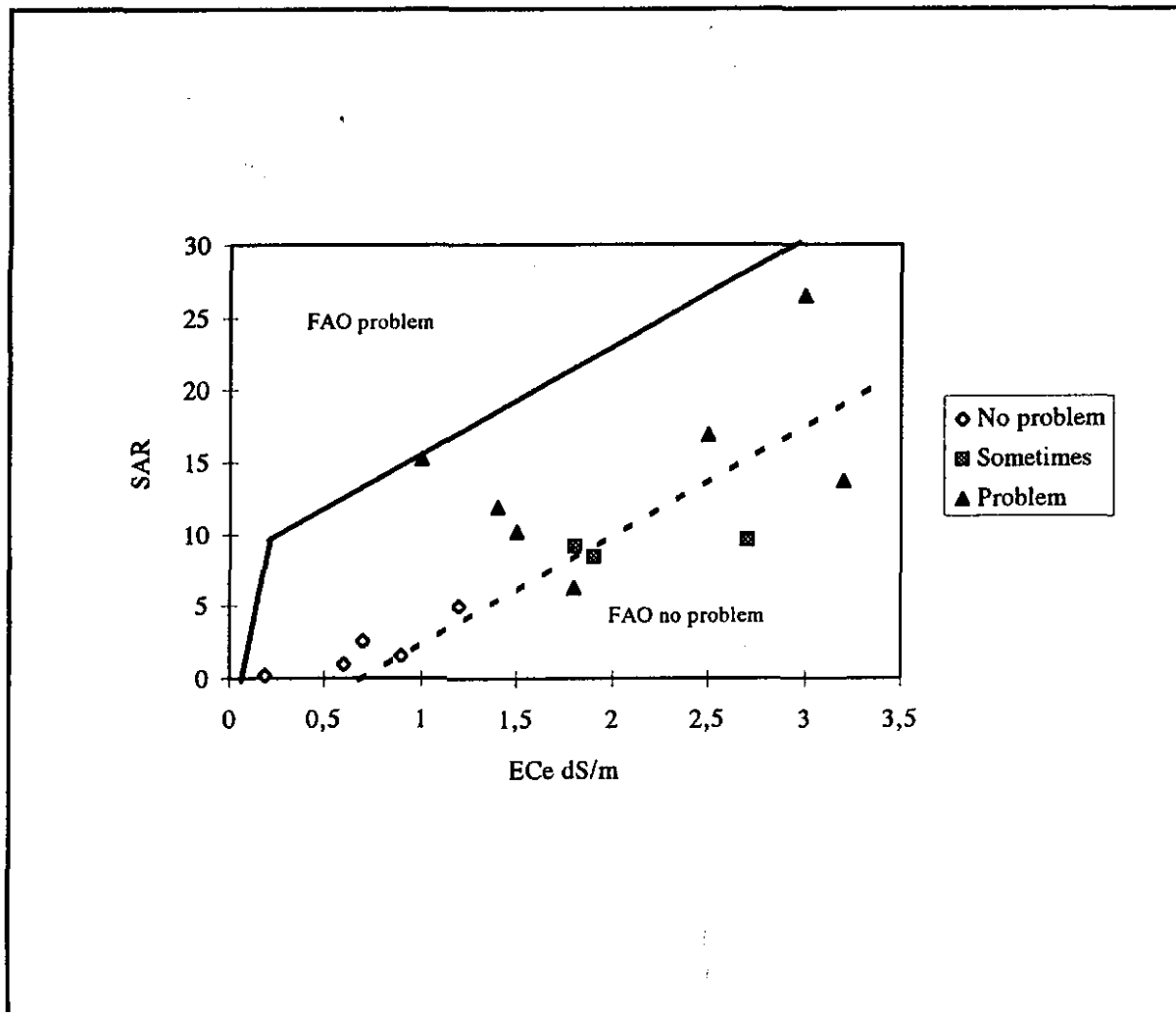
Table 10: Farmers classification system compared with FAO classification system

TW no.	Farmers classification	EC dS/m	SAR	FAO
64	(hard) + white crust	2.7	9.54	C2 - S1
65	hard + white crust	3.2	13.62	C3 - S1
66	hard (black) + white crust	1.4	11.85	C2 - S2
67	hard + white crust	2.5	16.85	C2 - S2
68	white crust + (hard)	1.9	8.42	C2 - S2
69	hard + (white crust)	1.9		C2
70	hard	1.8	6.24	C2 - S1
110	hard + white crust	1.5	10.10	C2 - S2
72	hard + white crust	3.0	26.43	C3 - S2
73	hard + white crust	1.0	15.24	C2 - S3
74	(hard) + white crust	1.8	9.09	C2 - S2
75	white crust	1.2	4.97	C2 - S2
76	good quality	0.7	2.55	C1 - S2
77	good quality	0.9	1.53	C2 - S1
106	extremely poor quality			
108	good quality	0.6	0.95	C1 - S2
133	hard + white crust	0.7		c 2
164	good quality			
canal	excellent quality	0.19	10.22	C1 - S2

The classification of salinity hazards is in congruence with the classification systems. Water classified by farmers as having a good quality was mentioned to increase problems when used for a long time period.

At first sight, there does not seem to be a clear relation between the FAO classification system for sodicity hazards and farmers appraisal of sodicity hazards. To get a better picture of farmers sodicity hazard assessment, the FAO classification system and the farmers classification systems are plotted in Figure 6. For comparative reasons, another sodicity classification system is included as well. This classification system was published by FAO (1989) and adapted from Rhoades (1977) and Oster & Sclioer (1979) in which the relative rate of infiltration as affected by salinity and sodium adsorption ratio, is assessed.

Figure 6: Farmers appraisal of sodicity hazards compared with FAO classification systems

By comparing tlic FAO classification systems and tlic farmers' classification system in this graphical way, the argument could bc made that the classification system as promoted by the FAO underestimates the problems induced by the use of high SAR, low ECe water. The quality of canal water is the only water which cannot be explained by the theoretical reasoning which forms the basis of the two 'FAO classification systems'. According to farmers' experiences, the use of canal water 'softens' soils which have 'hard' properties. Research has shown that alternating irrigation with waters of different SAR values result in very

low infiltration rates (Kijne and Kuper, 1995). Farmers seem to attribute this effect solely to the use of low quality ground water.

Farmers' perceptions on the salinity/sodicity process

Salinity in irrigated agriculture is often linked with waterlogging. Recent research in Manawala, Pir Mahal, Fordwah and Arim distributaries has shown that the reduced waterlogging, due to the installation of tubewells, did not result in a subsequent reduction in salinity problems. This results from irrigating with low quality ground water (Kijne, Kuper, 1995). This trend in the relation between salinity and waterlogging, and salinity and the use of low quality ground water, can be found on a small scale in Watercourse 14-R.

Due to high ground water tables, salinity/sodicity problems evolved over the past years. Farmers claim that excessive rainfall around 1972 were the cause of present salinity/sodicity problems. The rainfall data from Bahawalpur meteorological station (Figure 8) confirms that heavy rainfall occurred in 1973. The rainfall in this year was almost five times as high as the average rainfall in the foregoing years. From 1980, the rainfall was average again. In 1984 and 1985, the rainfall was 40 mm below the average rainfall. Farmers say that the water table dropped naturally and between 1985 and 1987 a fast drop occurred due to a drought. These rainfall data do not show evidence for a dry spell which occurred around 1985-1987.

Figure 7: Rainfall data for Bahawalpur meteorological station
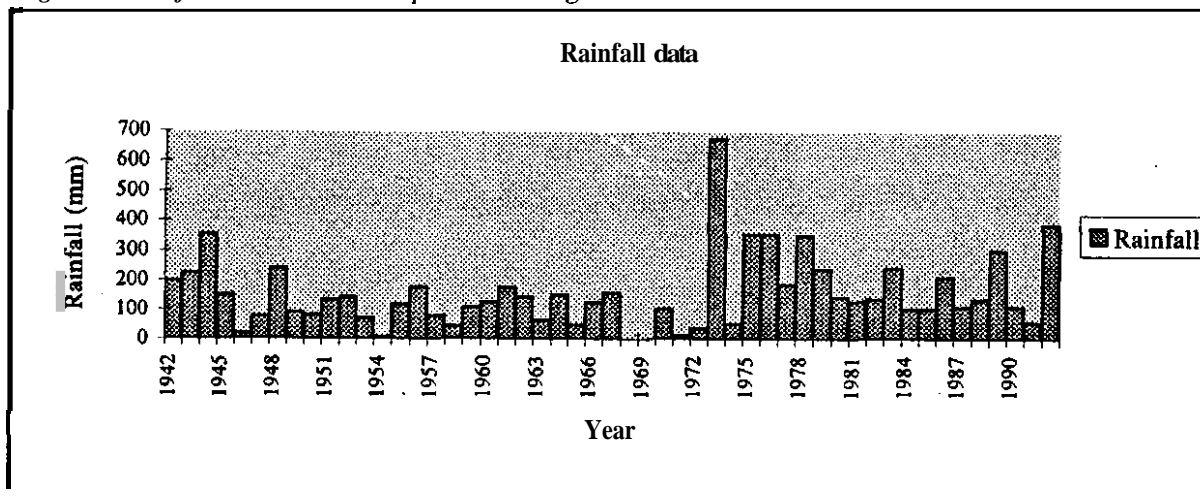

From 1988, tubewells have been installed in Watercourse 14-R. This resulted in a further reduction in salinity/sodicity problems, but this was only of temporary duration. The use of low quality tubewell water caused salinity problems in areas which were not saline before, or which had declining problems. In the tail of Watercourse 14-R, no tubewells have been installed up till now. Therefore, the water table did not drop as much as in the middle and head of Watercourse 14-R. The piezometer readings, as well as stories told by the farmers, confirm higher ground water tables in the tail of Watercourse 14-R in comparison with the depth of ground water in the middle and head of Watercourse 14-R (Figure 9).

As a result, the soil salinity/sodicity did not improve significantly over the last years, and in some of the plots the soil salinity might have increased. Initially, the introduction of tubewells improved the soil quality in the middle and tail areas of Watercourse 14-R. But continued irrigation with tubewell water, often of low quality, has caused development of salinity in many *killas* which were not effected by salinity before (Maps 3 and 4). Comparing farmers' perception on the causes of salinity/sodicity with processes based on

theoretical explanations, it can be concluded that farmers' understanding of soil salinity and sodicity processes strokes with expected theoretical soil salinity and sodicity processes.

Figure 8 Ground water depth in Watercourse 14-R. during 1995
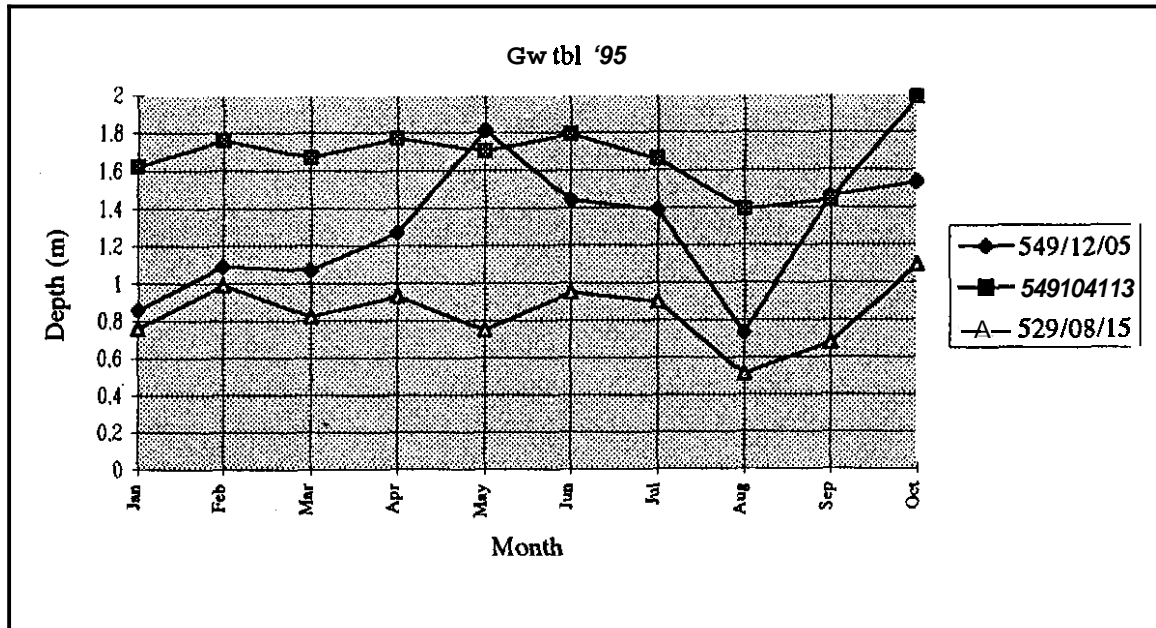
Soil sodicity hazards are largely related to the Exchangeable Sodiuni Percentage (ESP) of the soil and the EC of the infiltration water. High ESP-values cause expansion of the electrical double layer. A high salt concentration in the soil moisture compresses the layer, while the layer expands when the salt concentration decreases. Dispersion problems generally increase with higher ESP-values. Irrigation with high salinity and high sodicity tubewell water increases the ESP of the soil and subsequently increases the sodicity risks. If these soils are irrigated with low salinity irrigation water afterwards, or during rainy seasons, the hydraulic conductivity and permeability should decrease theoretically. In relation to the irrigation water classification, farmers relate sodicity problems to the use of low quality tubewell water. Farmers think that the tubewell water directly reduces the hydraulic conductivity and permeability of the soils, but whether they associate the problem with applying low EC canal water following tubewell irrigation is not certain.

In trying to attain insights regarding fanners understanding about the salinisation and sodification process, it is useful to reflect upon their understanding in the light from the results of the Soil Survey of Pakistan. Their study included soil maps for the eight sample water courses and the identification and delineation of the areas subject to present and potential salinity/sodicity and drainage problems. The mapping units present in the Watercourse 14-R area include the Harunabad, Rasulpur, Bagh, and Malti series. All soils in Watercouse 14-R arc good agricultural lands except for the saline-alkali variant and dune land complex of the of the Rasulpur fine sandy loam series. This mapping unit is 90% barren and is therefore not considered. The whole of Watercourse 14-R has a shallow ground water table, W1 (90 - 150 cm). Which is interpreted by the Soil Survey of Pakistan as imperfectly drained soils, which causes restrictions on the agricultural potentials of the soils. With regard to salinity and sodicity, several mapping units of the Harunabad, Rasulpur, and Malti series have been indicated to have a saline sodic crust. The crusts arc caused by the use of low quality tubewell water. These soils can theoretically bc improved by restricting the use of low quality tubewell water, as well as organic matter application. The Rasulpur series has a variant with a saline-sodic phase. These soils are some what more difficult to reclaim, but not impossible. Options are the cultivation of janter grass for a couple of seasons. Afterwards, salinity/sodicity

can be reduced by avoiding the **use** of low quality tubewell water, adding organic matter, and irrigating in small precise levelled fields.

Soils classified by the farmers having black and white salinity, fall largely within the boundaries of the Rasilpur fine sandy loam with saline-sodic surface (10-20 cm), water table at 90-150 cni. Smaller areas having white and black salinity occur in and around **die** Bagh and Malti mapping units. The Bagh series **has** been developed in the level parts of the flood plains. The Malti series in tbe basins. This physiographic unit refers to the lowest parts of the land form. The occurrence of black and white salinity might therefore be related to the water table depth. Soils classified by farmers having white salinity, or some white salinity do not correspond with thepepri" indicated by the soil survey. This could be explained **the** fast changing appearance and disappearance of the *pepri* due to intermittent irrigation and irrigation with different qualities of irrigation waters.

According to the farmers 'white salinity' is easily leached by the use of good quality canal water, while the 'black and white saline plots' need much more effort to be reclaimed. This corresponds with the reconimendations of the Soil Survey of Pakistan.

Expected theoretical impact of farmers' practices on salinity/sodicity levels

In this section the practices used by the farmers to achieve certain strategies will be discussed from a theoretical viewpoint. Comparing the theorctical impact of certain measures with farmers expectations, provides insights about farmers knowledge on the impact of their practices. A short theoretical review of crop sensitivity to salinity and sodicity is presented in Annex 2.

Irrigation practices

Use of canal water **as** much **as** possible. Canal water has an **EC** of 0.19 dS/m, and a SAR of 0.22. According to the USSL classification, this water is classified **as** CI-SI: Low salinity • Low sodium hazard water. In the FAO classification system, this water would be classified **as** CI-S2, which means that the **use** of this water **docs** not give salinity hazards but slight to moderate sodicity hazards. By making use of canal water **as** much **as** possible. farmers prevent their soils from developing saline/sodic properties. Once the soils are saline, the watcr has the capability to leach the salts from the root zone. This capacity of canal water was also ascribed by the farmers to the water. Theoretically, the use of this water on saline/sodic soils will reduce the hydraulic conductivity of the soil due to its low salinity, and will leach the calcium salts from the profile. In this way, the use of low salinity canal watcr will increase die sodicity related problems. Farmers do not agree under all circumstances with last the mentioned characteristic of canal irrigation watcr. Farmers mention that canal water has the capacity to make the soils 'soft' again. This might stroke with the cases where tlic Soil Survey of Pakistan talks about *pepri* or saline/sodic surface, or where according to Dr. Ramzan (1996) the SAR is below 13. These soils can easily be improved by the use of good quality canal watcr.

Use of tubcwcll water in case of canal watcr shortage. Most tubewells have a high EC as well **as** a high SAR. The **use** of most tubewells increases the salinity and sodicity of the soils. Farmers **use** tubewells to avoid yield reduction due to watcr dcficicncy. Some farmers recognise that crops grown on saline plots are more sensitive to water shortage (delayed irrigation) than crops grown on non-saline plots. Many fanners, though, try to minimise the use of tubcwcll water in order to ration the amounts of salts brought onto their

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[13] 'Pepri' is a thin salt crust (1-3 mm) at the soil surface.

fields. Access to canal water will determine if this practice has a positive or negative effect. If tlic canal water supply is sufficient to leach tlic salts during the following irrigation event, it is good to limit the amounts of salts and especially the amount of sodium brought into the profile. But, if the access to **canal** water is low, tlic salts will just build up in the soil profile and tlic hazards of secondary salinisation increases.

Select best quality tubewell water. Four tubewells, out of the nineteen, were classified by the farmers as having good quality water. This was confirmed by tlic water sample analysis. Theoretically, the use of this water gives none to slight salinity hazard. Only in the case of under-irrigation. or when the leaching fraction will be very small, can this water increase root zone salinity. The use of tliis water does not increase the soil sodicity, but the use of this low salinity water on sodic soils might reduce the hydraulic conductivity of tlie soil. In general the believe by the fanners is that all tubewell waters increase the salinity problems. Therefore they might limit tlie quantity used and thus increase the salinity problem.

Sometimes, faniicrs prefer one tubewell with low quality water over another tubewell with low quality water (e.g. TW 74 (**EC 1.X: SAR 9.1**) over TW 64 (**EC** 2.7; **SAR** 9.5)). If both tubewells arc used in limited amounts, then TW 74 causes less salinity problems (or the root zone salinity build up is slower) than when TW 64 **was** used.

Mix canal water with tubewell water. and tubewell with tubewell water. By mixing canal water with tubewell water, a larger area can be irrigated with "fair" quality irrigation water, instead of some areas being irrigated with "good" quality **canal** water and other areas with "poor" quality tubewell water. This "fair" quality actually depends on tlie quantities of tlie canal water and tubewell water used. Theoretically the following effects result from blending water resources: the hazard of tlie canal water to reduce the hydraulic conductivity of tlic soil will be lowered (mixture will liave a higher **EC** value compared with the **EC** of canal water); tlic salinity liazard of tlic tubewell water is lowered (mixture will have a lower **EC** value compared with tlic **EC** of tubewell water); the sodicity hazards are reduced (**SAR** of the mixture will reduce by the square root of **tlic** dilution factor). One farmer mixes TW 65 with TW 66. TW 66 has a better quality than TW 65, which seems to be true when comparing **EC** and **SAR** values. (TW 65: **EC 3, SAR 14;** TW 66: **EC** l, **SAR** 12).

Priority canal water used on saline plots. When **low** salinity, low sodicity canal water is allocated to saline/sodic fields. the following things might happen:
1. Salts arc leached from the root zone which gives a reduction in soil moisture salinity.
2. Reduction of hydraulic coiiductivity due to lowering of concentration of electrolytes in tlie soil moisture which favours dispersion of soil particles and swelling of clay minerals.
3. Salinity levels in the soil moisture are reduced due to dilution. This reduces the osmotic pressure of the soil moisture and **makes** tlic water more easily available for root adsorption.

Timing of irrigation. Salinity decreases **tlic** osmotic potential in the soil moisture. **Also** a reduction soil moisture content gives **a** decrease in osmotic potential of the soil moisture. When tlic osmotic potential of tlie soil moisture decreases and reaches a certain thresliold value in comparison to the osmotic potential of tlie plant's cells, the roots arc not able to absorb enough water for assimilation processes and the plant will suffer from water stress. By increasing tlic frequency of irrigation. tlic soil nioisture content of tlie soil is kept high, **thus** a high osmotic potential is kept in tho soil nioisture. This prevents tlic plants from suffering from water stress and subsequently prevents yield reduction.

Irrigation after land preparation and sowing. When salinity levels arc highest in tlie top soil, this practice seems to make sense. During ploughing the upper soil profile is turned upside down. The most saline layer is brought deeper in the profile. The seeds arc **sown** in a relative **low** salinity top soil. **With** the first

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