farmers attitudes | salinity | sodic soils | farming systems
soil properties | soil management | soil classification

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REPORT NO. R-

Farmers' Ability to Cope with Salinity and Sodicity

Farmers' perceptions, strategies and practices for dealing with salinity and sodicity in their farming systems.

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Summary

This report describes tlie results of a study carried out in eight sample watercourses on tlic Fordwah and Azim Distributaries in Chistian Sub-division, Punjab. This study is part of a broader research project which trics to evaluate tlic economic and environmental impact of changes in irrigation management, through tlic development of an 'intcgratcd approach'. This study relates farmers' perceptions on salinity and sodicity, their strategies and practices, to tlie possibilitics and constraints of the physical environment and to the farm characteristics. In this way, fanners' abilities for improving salinity and sodicity management under management interventions at higher levels of tlie irrigation system are revealed.

The starting point for the conceptual framework was the term sustainability. The definition of sustainability infers that salinity and sodicity should bc viewed as an cnvironmcntal degradation process which can be influenced by farmers' actions. The agro-ecosystem thinking refined this insight by naming the agents through which nutrients, and thus salts, can enter or leave the ecosystem. For the evaluation of soil salinity and sodicity, and the impact of irrigation water on salinity and sodicity, parameters like EC. EC/SAR, and RSC wcre suggested. Taking tlic farm as a 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 dccision-maker, who trics to achieve his global farming objcctivcs within tlic possibilities and constraints of his farming system. The use of these theoretical concepts (i.e., agro-ecosystem and peasant fanning system conccpts), resulted in a concept for explaining tlic decision-making process used by a farmer, that also explains liow fanners develops a strategy for dealing with salinity and sodicity on their farms. The conceptual framework was a handy tool in trying to understand farmers' perceptions on salinity and sodicity and why farmers deal with salinity and sodicity in certain ways. Ihis concept placed the salinity and sodicity issue within the global farming objectives, strategies, and constraints. This also provided further insights into the ways a farmer, as an individual decision-maker with a personal view on the salinity/sodicity processes, trics to deal with salinity and sodicity for his farming system and how he arrives at tlic definition of a particular strategy.

The field data for this stndy were collected by making use of three different techniques: 1) structured interviews with open questions; 2) discussions: and 3) mapping (inspired by mapping exercises used in participatory rural appraisal). On tlie basis of tlie information collected by means of tlic aforementioned techniques, farmers' perceptions, strategies and practices could be described. To obtain further insights into farmers' hiowledge and understanding of salinity/sodicity, links were made with secondary data collected by IIMI. Farmers' strategies and practices were evaluated in the light of the possibilities and constraints of the physical environment and tlie farming systems. Physical data, along with data on fanning systems and farm characteristics, wcrc all available within IIMI.

The study took place in eight sample watercourses (tertiary units) located in Fordwah and Azim distributaries at the tail of Fordwah Branch canal, where IIMI has been conducting research for a few years. The study learned that the present salinity and sodicity status in the Indus Basin is caused by different processes, some of which occur as combined processes. Four watercourses were selected to illustrate these cffects. In essence, tlic four watercourses represent tlic following processes:

1. lndigcnous salinity and sodicity originating from watcr action (Azim I I I-L)
2. Salinisation and sodification due to the use of poor quality tubewell water (Fordwah 130-R)
3. Salinisation and sodification due to capillary rise from high ground water tables (Fordwah **14-R)**
4. Rcducing salinity and sodicity problcm duc to the usc of good quality irrigation watcr.

Farmers use indicators based on the physical appearance of soils and crops to recognise problcnis which are rclated to salinity and sodicity. Thcsc indicators. or some of these indicators, are used by tlic farmers to classify different salinity/sodicity units. Farmers defined six salinity/salinity units to distinguish between tlic different types and levels of saline, sodic or waterlogged soils.

Comparing famiers' salinitykodicity classification system with the USSL soil classification system showcd that saline-sodic propcrtics occur under conditions classified by tlic USSL as non-salinc and non-sodic. New parameters were explored to explain farmers classification of saline-sodic soil properties. The ratio EC_e/SAR can bc used to dcfine an indicative valuc below which soils start showing propcrtics of hardness. The height of the value differs per textural group, with coarser textured soils having a lower valnc than finer textured soils. The EC. is a good measure for the occurrence of salinity. The levels above which salinity becomes visible for faniicrs arc not rclatcd to soil tcxture.

An evaluation of farniers' irrigation water classification system showed that the total salinity level measured by the **EC** of the irrigation water is a good parameter to predict soil salinity problems. The **EC/SAR** ratio can be used to predict infiltration problcnis, while tlic residual sodium carbonatc (RSC) in combination with the **EC** level in the irrigation watcr gives a good indication of the hazards of reduced hydraulic conductivity.

Farmers' strategies are in the first place related to the physical environment under which tlic farnicrs opcratc. Undcr conditions where farmers can largely influcncc the dcvclopmcnt of salinity and sodicity, farm characteristics determine the salinitykodicity stratcgy. Farmers with high investments in their farms try to prevent an increase, or even to reduce tlie salinity and sodicity. Under conditions where land is not a major constraint and lack of credit prevents farnicrs to have intcnsivc farming, farnicrs tend not to have plans to control the salinity and sodicity. Under most saline/sodic conditions. farmers mitigate tlic effects of salinity/sodicity **on** crop growth. Only the large mechanised farms do not have special measures to mitigate the effects; they give all plots the same treatment.

The practices that farmers implement arc in the first place a result of tlic physical conditions **under** which they cultivate. Secondly, they are in line with the salinity/sodicity strategy and tlic possibilities and constraints set by tlic farm characteristics.

At present, farmers in many areas are able to cope witli salinity and sodicity. These are mostly farnicrs with good access to canal water, or canal water supplemented by good quality tubewell water. In places where the use of tubewell watcr might cause salinity/sodicity problems, mostly the fanners with good investment capacity are able to control salinity/sodicity and mitigate tlic effects on crop growth. Farmcrs with limited farm resources would benefit **the most** from improved canal watcr supplies.

1. **Indigcnous** salinity **and** sodicity originating froni watcr action (Azini 1 I I-L)
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3. Salinisatioii and sodification due to capillary **risc from high** ground watcr tables (Fordwali 14-R)
4. **Rcducing** salinity and sodicity **problem** due to tlic **usc of good** quality irrigation water.

Farniers use indicators based on the physical **appearance** of soils and crops to rccognise problems wliicli are **rclated** to salinity **and** sodicity. **These** indicators, or **some** o f **these** indicators, arc used by tlie farnicrs to classify different salinitylsodicity units. Farnicrs defined six **salinity/salinity units** to distinguish between tlic different types and levels o f saline, sodic or **watcrlogged** soils.

Comparing farnicrs' salinitylsodicity classification **systcm** with the USSL soil classification **systcm showcd** that **saline-sodic** propcrtics occur under conditions classified by **thc** USSL as non-saline and non-sodic. **Ncw parametcrs were** explored to **explain** fanners classification of saline-sodic soil properties. Tlic ratio **EC_e/SAR** can be **uscd** to **dcfine an** indicative **valuc bclow** which soils start showing propcrtics o f hardness. Tlic hciglit o f **the** value differs **pcr** textural group, with coarser textured soils having a **lowcr valuc than** finer tcxturcd soils. The EC. is a good **mcasure** for tlic occurrence o f salinity. Tlic **levels** above **which** salinity bccoiiics visible for **farmcrs** are not related to soil texture.

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Farnicrs' **stratcgics** arc in the first **placc** rclatcd to **tlie** physical **cnvironment undcr** which **thc** farnicrs **operatc**. Undcr conditions whcrc fariiicrs **can largely influcnce the** dcvclopmcnt o f salinity and sodicity. **farm characteristics determinc** tlic **salinity/sodicity** strategy. **Farmers** with **high** invcstnicnts in **their farms** try to prcvcnt **an increasc**, or **even** to rcducc **the** salinity and sodicity. **Undcr** conditions **where land** is **not** a **major** constraint and lack o f **credit** prevents farmers to have **intensive** fanning, farnicrs **tend** not to **havc** plans to control **thc** salinity and sodicity. Under **most** salinelsodic conditioiis. farnicrs **mitigatc the effects** o f salinitylsodicity **on** crop growth. Only tlic large **mechanised** farms do not **havc special measures** to **mitigate** the effects; they give **all** plots the **same** treatment.

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Chapter 1

Background and Overview

Ihtroduction

This report describes the results of a study carried out in eight snmplc watercourses on the Fordwah and Azim Distributaries in Chistian Sub-division, Punjab. This study is part of a broader research project which is evaluating the economic and environmental impact of changes in irrigation management, through the development of an 'integrated approach'. Research, which started in 1989, showed that salinity could bc disassociated from waterlogging and that there was an emerging threat of sodification through the use of poor quality groundwater. The underlying hypothesis of the research is that through better distribution of good quality canal water, farmers are better armed to deal with salinity and sodicity. The research aims to evaluate the impact of interventions in canal irrigation management on salinitylsodicity and agricultural production (Garin *el al*, 1996).

Salinity and sodicity processes under different irrigation 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 the farm and field level can only be revealed if fanners' decisions and practices are taken into consideration. A case study conducted in January 1996 showed that farmers deal differently with salinitylsodicity depending on the physical and irrigation environment, farm goals and characteristics, and their knowledge and perceptions on salinity and sodicity (Kielen, 1996). This study tries to relate farmers' perceptions on salinity and sodicity, their strategies and practices, to the possibilities and constraints of the physical environment and to the farm characteristics.

Conceptual Framework

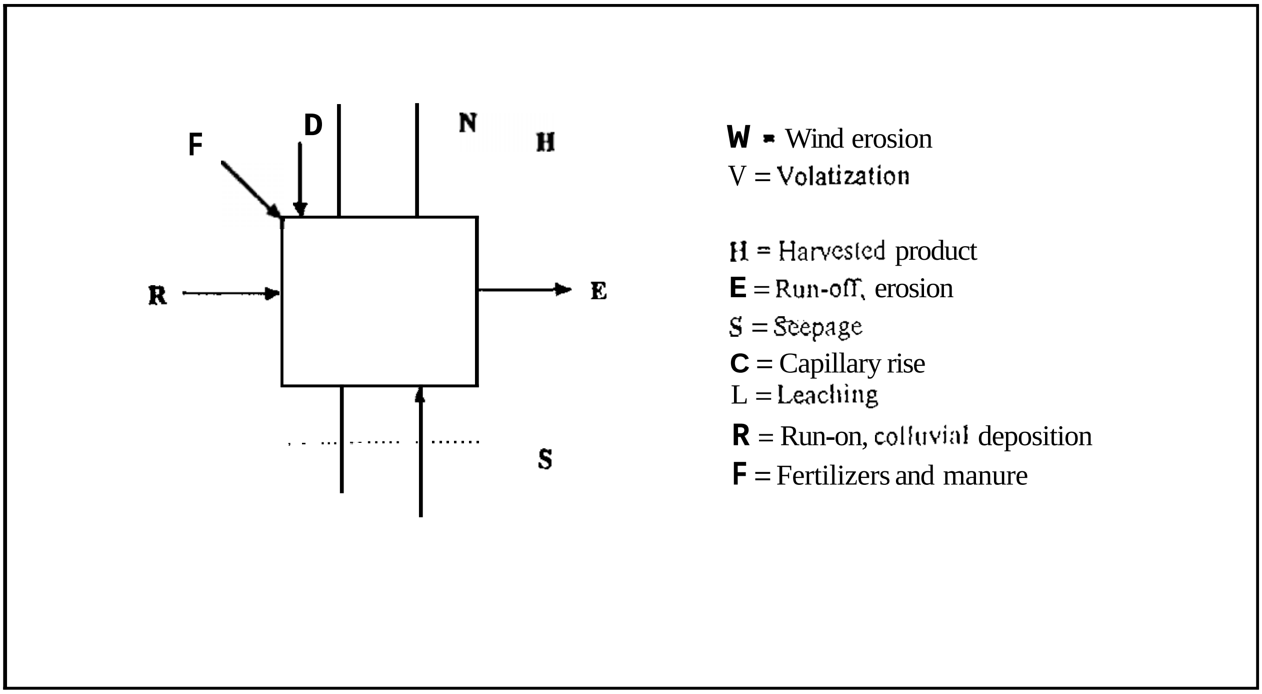
Sustainability of agro-ecosystems

A starting point for this discussion is the term sustainability. In the global objectives of IIMI's research program, 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 ease study, the following definition of sustainability will be used: ***rhu capacity of the owners and users of the scheme to manage and conserve the natural resources, land and water. in such a manner as to ensure the attainment and continued satisfaction of the users needs for present ond future generarions*** (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 a 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 presented in figure I Nutrients are brought into and removed from the ecosystem tlirougli various agents. Winiger (1983) proposes an agro-ecosystem model in which he distinguishes several stages of human impact on tlie eco-systeni. Farmers can influence the quality and quantity of several agents through their farming activities. In terms of salinity and sodicity, this implies that fanners have the capacity, tlirougli their farming and irrigation activitics. to influence tlic salinity and sodicity levels in tlic agro-ecosystem.

In the following scctions. some theoretical background will be given on soil salinity and sodicity, water quality for irrigation. and decision-making processes of farniers to arrive at a salinity and sodicity strategy.

Figure I: Agro-ecosystem (Janssen and Beusichem, 1991).



Soil salinity and sodicity

The most commonly used soil salinity and sodicity classification system is the system as proposed by the US Salinity Laboratory (USSL) Staff, 1954. They distinct four types of soils with rcsyect to salinity and sodicity. which are presented in Table I.

	EC. < 4 dS/m	$EC_e \geq$ 4 dS/m
ESP < 15 %	non-saline, non-sodic (pH < *8.5)*	saline (pH < *8.5)*
ESP ≥ 15 %	sodic (pH > *8.5)*	saline, sodic (pH ≈ *8.5)*

Physical properties of saline soils are described by USSL (1954) as: ***Owing** to the presence of excess salts ond the ohsencc of significant amounts of exchangeable sodium, these soils generally are flocculated; and, as a consequence, the permeability is equal to or higher than that of similar non-saline soils. Saline soils ore rccognised by the presence of white crusts of salts on the surface.*
Saline-alkaline soils are described as: When ***excess salts ore present, the appearance and properties of the soil ore generally similor to those of saline soils. If excess soluble salts ore leached downword. rhc properties of these soils may change markedly and become similar to those of non saline-sodic soils.***
General characteristics of non saline-sodic soils are: ***As the proportion of exchangeable sodium increases, /he soil tends to become more dispersed. The soils have low permeability and ore difficult to till. Due to a high pH reading, dispersed and dissolved organic matter present in rhe soil solution moy he deposited on the soil surface, causing darkening.***

The total salt concentration in the soils affects crop production. Not all plants respond in a similar manner to soil salinity. Some crops are better able to make the needed osmotic adjustments allowing tlicm to extract more water from a saline soil. Therefore the suitability of saline soils for crop production depends largely on the crops grown and the water availability. Normal saline soils arc not susccptiblc to structural degradation aiid arc easily reclaimed by leaching the salts from the soil profile.

Saline-sodic and sodic soils arc susceptible to structural degradation. Tlic sodification aiid degradation processes are complex, and reclamation of sodicity affected soils is difficult aiid requires a lot of inputs and time.

The threshold value for **ESP** of **15%** (USSL Staff, 1954) is used to define a sodic soil, which is tlie level at which clay particles spontaneously disperse aiid above which the soil structure is adversely affected. The USSL Staff (1954) did **not** take soil structure and tlie total cation concentration (TCC) of the leaching water into consideration. The influence of texture was rccogniscd by Grecne *et al.* in 1978. Shaiiiberg *et al.* (1989) stressed importance **on** tlie TCC of the leaching water used to establish a threshold value above which the soil structure will be adversely effected. Some investigations have suggested that this threshold value need reconsideration because soil degradation can take place even at low **ESP** in dilute solutions. Crescimanno *el al.* (I 995) investigated aggregate stability, rating of soil shrink-swell potential. and both sturated and unsaturated hydraulic conductivity on two soil types under ESP values up to IS. at low cation concentration. They found an almost linear relationship between the investigated soil properties aiid **ESP.** This. according to tlic researchers, indicates that **no** critical **ESP** value exists and that soil quality degradation can be forecasted even in a 2 to 5 **ESP** range at low cation concentrations.

In his rcccnt review paper **on** new perspectives about sodic soils, Sumner (1995) shows that soil physical degradation, due to the presence of sodium, are manifested at very low **ESP** levels, far below those previously used to define sodic soils. ***The primary processes responsible for physical degradation are swelling or relatively high levels and cloy dispersion throughout the range of ESP. J'rovided that the TCC is below a critical flocculation concentration (CFC), clays will disperse spontaneously at high ESP values, whereas or lower ESP levels, inputs of energy ore required for dispersion. The TCC of the ambient solution. because of its effects in promoting clay flocculation, is crucial in determining soil physical behaviour.*** Rengasamy *et al.* (1995) state that the boundary **(ESP - TCC)** between stable and unstable conditions varies **from** one soil to the next. In addition, the stability boundary for water entry into the soil (infiltration) is different from water movement through tlic soil (hydraulic conductivity).

Soil hydraulic conductivity (*K*) depends both **on** the **ESP** (or **SAR** of the soil solution) and tlic salinity of tlic **soil** solution. The higher the SAR and tlie lower the salinity, the larger the reduction in *K*. Though, cacli soil responds differently to the same combination of salinity and **SAR** because of differences in clay content, clay mineralogy, iron and aluminium oxide content, and organic matter content. The influence of these variable factors on soil hydraulic properties have been investigated by many researchers during recent decades.

In cultivated soils from semi-arid regions, sealing is a major determinant affecting the infiltration rate (IR). Seal formation at the soil surface is due to two processes: 1) physical disintegration of soil aggregates and soil compaction caused by the impact of water, especially water drops; and 2) chemical dispersion and movement of clay particles and the resultant plugging of conducting pores. Both processes act simultaneously, with the first enhancing the second (Agassi *et al.*, 1981). Infiltration rates are especially affected by the SAR and EC of irrigation water, because of the mechanical and stirring action of falling water drops, overland water flow, and relative freedom of particle movement at the soil surface (Rengasamy *et al.*, 1984). Oster and Schoer (1979) obtained considerably better correlation of IR to the SAR and EC of the applied irrigation water than to the SAR and EC of the soil solution averaged over the entire column length.

Surface sealing. and subsequent waterlogging at the surface, are followed by high initial rates of evaporation. However, if the hydraulic conductivity of the soil is low and unable to match the rate of water loss, the surface will dry rapidly followed by shrinkage and a breaking away of the dry surface into crusts. In loamy soils with high contents of sand and silt, drying may extend to a considerable depth resulting in a hard setting soil (So and Aylmore. 1993). Rengasamy and Olsson (1991) found a linear relationship between ESP and the strength of two hard setting soils. An important point from the relationship is that, for a given soil. ESP is a good indicator of its hard setting behaviour. The effect of increasing ESP on modules of soil rupture (MOR) is mediated through the effects of ESP on the dispersion of clay (So and Aylmore, 1993). The effects observed are similar to the effects observed on illite dominated soils (Rengasamy and Olsson, 1991). However, ESP by itself is not a good indicator of physical behaviour across a group of soils (So and Aylmore, 1993).

From the above discussion, it can be concluded that for the evaluation of present soil conditions the following indicators could be used:

Indicator per soil type	Phenomena
ECe	Soil salinity
ESP (or SAR)	Hard setting
ECe/SAR	Hydraulic properties
EC/SAR	Infiltration rates

Evaluation of Water Quality for Irrigation

The suitability of a saline water for irrigation depends upon the conditions of use, including crop. climate, soil, irrigation method, and management. A commonly used irrigation classification system is the classification system promoted by the FAO (Ayers and Westcot, 1985). The system appraises the salinity hazards on the basis of an increased EC-value in the irrigation water. With respect to the sodicity hazards, the hazards decrease with decreasing salinity or increasing sodium content relative to calcium and magnesium. The statement is made that infiltration rates generally decrease with decreasing salinity or increasing sodium content relative to calcium and magnesium. Table 2 can be used for the appraisal of the suitability of water for irrigation.

Table 3: Water quality for irrigation[1].

		None	Slight - Moderate	Severe
Salinity problems				
	EC (dS/m)	< 0.7	0.7 - 3.0	> 3.0
Sodicity problems				
SAR 0 - 3	**EC (dS/m)**	> 0.7	0.7 - 0.2	< 0.2
3 - 6		> 1.2	1.2 - 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

3 Rlioadcs (1982) suggcstcd a classification systcm using thc total salt concentration. which is tlic major quality factor gencrally limiting tlic use of salinc watcrs for crop production. In Chistian Sub-division. not only the total salt concentration fornis a threat to sustained crop production, but sodicity due to the usc of highly sodic tubewcll watcr far irrigation fonns a threat, if not a bigger threat, to sustainable agriculture. Rengasamy and other researchers (1984) recognised that thc infiltration rates are mainly affected by tlic EC and SAR of the irrigation watcr. Oster and Schoer (1979) obtained considerably better correlation of IR to SAR and EC of tlic applicd irrigation watcr than to tlic SAR and EC of the soil solution avcragc ovcr thc entire column Icngtli.

Rcsearch has documentcd many instances in which swclling, aggregate failure. and dispersion increases as salinity decreases cven if tlie ESP is far less than 15%. Research in Australia showed that the use of high SAR irrigation water, irrespective of the ionic strcngtli (or EC value), led to rapid salinisation and sodification of soil profilcs (Mchanni and Chalmcrs, 1986; Rcngasamy and Mchanni, 1088). tlic lcvcl depcnding on the salinity and SAR of applicd water (high EC - high SAR water giving the largest incrcment in EC. and ESP: low EC - low SAR watcr giving thc least incrcmcnt in EC, and ESP, ovcr a rcscarcli period of 4 years). Mnrlet (1996), stressed tlie importance of the Residual Sodium Carbonate (RSC) and Calcite kesidual Alkalinity (CRA) of used irrigation watcr, in the sodification process. The RSC and CRA are calculated as follows:

CRA = $(HCO_3^- + CO_3^{2-}) - Ca^{2+}$ [meq/l] and RSC = $(HCO_3^- + CO_3^{2-}) - (Ca^{2+} + Mg^{2+})$ [meq/l]

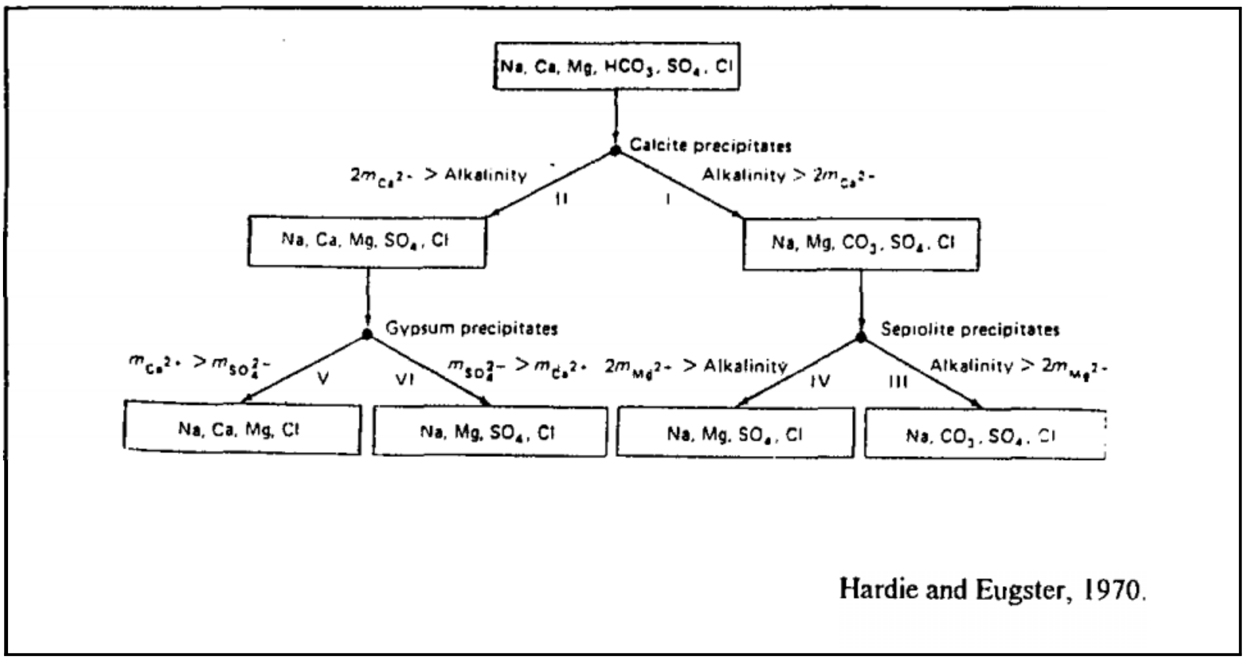
Upon the concentration of water in the soil profile due to evapo(transpi)ration, precipitation will occur. Calcium, in the fonii of calcite, is thc first salt to precipitate. If the solution further concentrates, magnesium salts will precipitate as well. The concentration of Ca, or Ca plus Mg, relative to the concentration of CO_3 and HCO_3 in the soil solution or used irrigation water, defines whether sodification of the soils occurs, and at which rate this occurs. Figure 2 explains the possible pathways for precipitation of salts upon concentration. Based on tlic possible pathways, Marlct (1996) proposed thc following irrigation water quality evaluation system:

[1] Adapted from University of California Committee of Consultants 1974

Table 4: Irrigation water quality evaluation system.

• RSC > 0	• Sodicity hazards (even if the EC is low)
• RSC < 0 and CRA > 0	• Sodicity hazards when EC levels are high • Minimum sodicity hazards when EC levels are low enough
• CRA < 0	• No sodicity hazards (even if the EC is high).

Figure 2: Possible pathways for evaporation of natural waters.



From this framework, the following indicators could be used to assess the impact of irrigation water on salinity and sodicity related problems:

Table 5: Indicators for the assessment of irrigation water quality.

• EC	• Salinity problems
• EC and EC/SAR ratio	• Assess (short term) sodicity hazards of reduced IR
• EC, and RSC and/or CRA	• Assess (long term) sodicity hazards of reduced *K*

Farmers' decision-making process

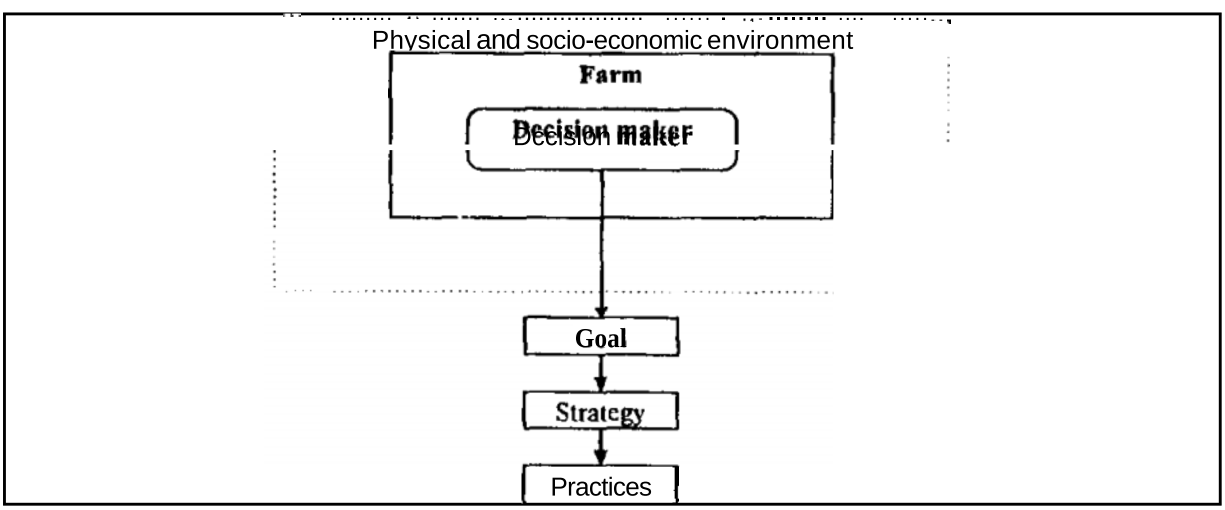
Taking a homogeneous physical environment as a starting point, the way and the extent to which farmers' activities will affect the salinity and sodicity situation depends on farming and irrigation practices. These practices are the direct result from the farming goal, and possibilities and constraints 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 farmers' goals. Farnicrs are considered as individual decision makers who can vary the level and kind of fanii inputs and outputs. Further, the peasant fanning system approach takes internal and external constraitits into consideration. These constraints limit tlic capacity to vary the organisation of productioii. Key concepts in understanding present salinity/sodicity management and future dcvclopments in tlic light of tlic peasant farming system approach arc: I) Farnicrs' are individual decision makers, where decisions are based on farmers' perceptions and knowledge, and arc limited by internal and external farni constraints; *2)* it is recognised that not all farniers will have tlic same objective (e.g. maximising their farm profits on a long-tenii or short-ten11 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; and 3) internal and external constraints which limit the capacity to vary the organisation of production. wlicrc external constraints arc foriiicd by factors from outside the farm (e.g. lack of fcrtilisers on the market, poor infrastructure, limited water supply. ctc.). and internal constraints are formed by factors peculiar to tlic farm (c.g. access to credit, number of family members, farni site, etc.).

Figure 3 schematises tlic peasant farniing system. A farm is managed by an individual decision maker. The farming goals are set on the basis of the household needs. Tlic way this goal is achieved depends on the farmers knowlcdgc and experience, as well as internal and external farming constraints. The way in which a fariner tries to achieve goals will be rcfcrrcd to as strategy. From this stratcgy. a number of activities and processes are initiated and implemented.

Salinity/sodicity can be regarded as a constraint. or hazard, which limits the achievement of fanners' goals or limits the organisation of production to achieve tlic fanners' goal. Salinity/sodicity is not an irreversible constraint or inevitable hazard. It depends on farmers' perceptions' whether farmers will

Figure 3: Peasant farming system.



[2] In the remainder of this report, the following definition of perception will be used: Perception is the way that a farmer understands 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 farming objectives in the light of the possibilities and constraints of their farming system.

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 cliange that result from different irrigation scenarios, **farmers** perceptions, strategies, and practices need to be understood, as well as **the** relations **between** tlic pliysical environment, fanning system, and salinitylsodicity practices. In trying to understand tlie influence of farmers' practices on **the** actual salinitykodicity levels, and to reveal the relation between tlie fanning system and farmers' **salinity/sodicity** practices. **Figure** 4 could **be helpful**

Tlie present soil salinitylsodicity **levels** or **hazards** arc **taken as a** starting point. Tlicre arc **several** factors that will influence tlie way fanners deal with **salinity/sodicity,** which **thus influences the** soil **salinity/sodicity** Icvels. **The** first influencing factor is farmers' perceptions on salinitykodicity. Farmers' perceptions result from their knowledge of ***salinity/sodicity*** proccsscs and on tlicir farming **goals *and*** internal and ***external*** constraints. On tlie 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', **farmers** will **choose practices**[4] to **implement** tlicir strategy, **Depending** on farmers' understanding of tlic salinitylsodicity process. **they** will expect a **certain** impact **from** a certain measure. **On** tlie basis of this expcctcd impact, **as well as** tlie limitations set by tlie intcnial and external **farm** constraints, **the farmer** will **select** tlic required practices. **The** sclccted practices will **have an impact** on tlie soil **salinity/sodicity**. **On the** basis **of this** experience, farniers' understanding of salinitylsodicity processes **might** change. **With** this **new** insight in **mind,** farmers **might change their** practices or **even their** strategies.

Objectives

The case study carried out in Watcrcoiirsc Fordwali **14-R (Kielen,** 1996) **showed that** farnicrs **deal** differently with salinity and sodicity **depending** on tlie physical environnient. **farm** objectives and **strategies,** fanners' knowledge **on** salinity **and** sodicity proccsscs, and **on** tlic constraints **set** by tlic farming systcni. **Since the** study **area** only consisted of **one sample** watercourse, only a **limited number** of **environmental** characteristics **as well as different** fanning systems were included in tlie case study. This study is **supplementary** to **the case** study. **The** objectives of this study **were formulated** as follows:

1. To **assess farmers'** perceptions. strategies, and practices in tlie light **of the** possibilities and constraints of thcir pliysical environinent and fanning system; and
2. Identify **whether** management interventions at higher levels of tlie irrigation system would facilitate improved farmers' **management** of salinity and sodicity.

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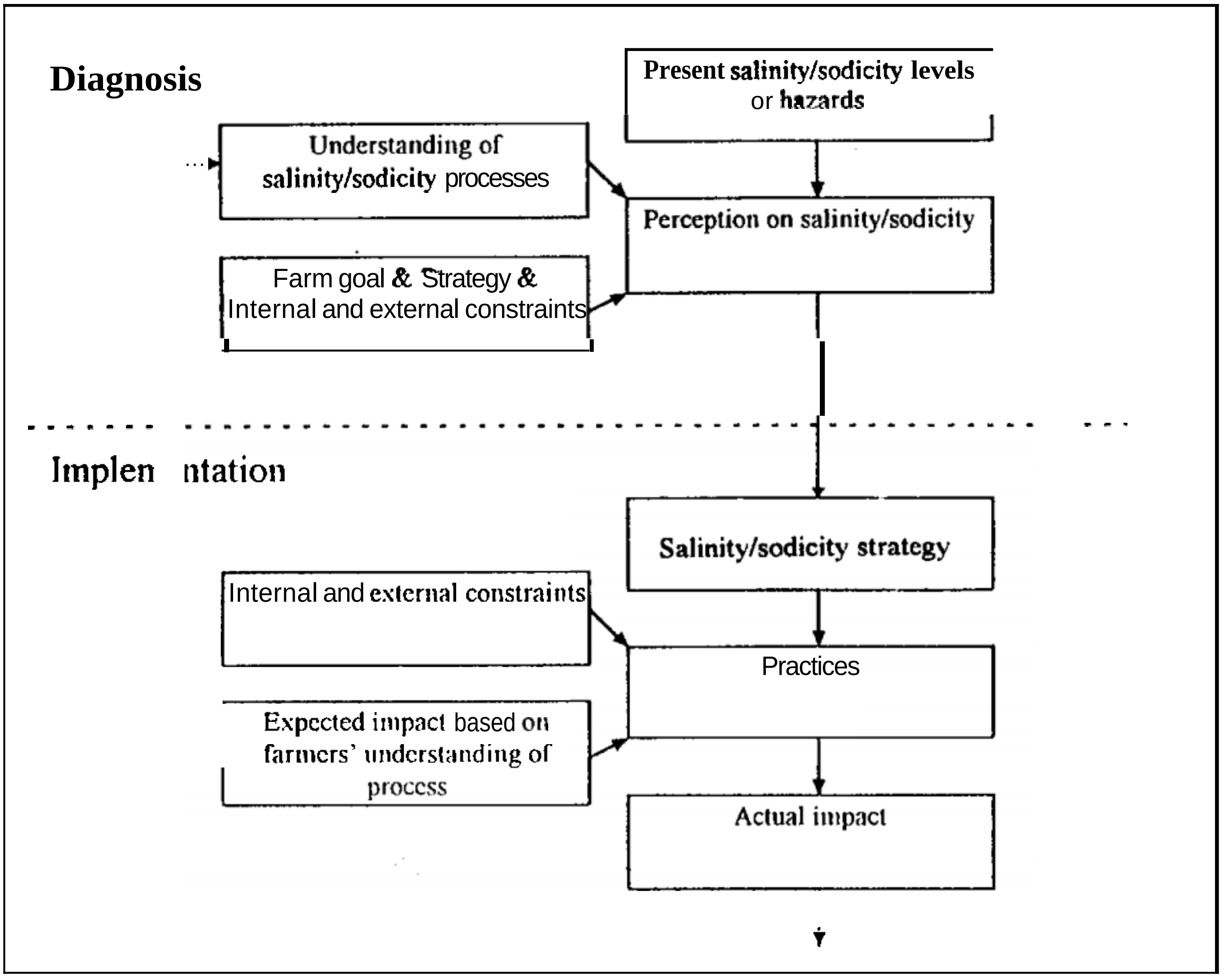
[3] **Salinity/sodicity strategies are the plans that the farmers follow with regard to soil salinity/sodicity, in order to fulfil his farming goals.**

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

Figure 4: Decision-making process of farmers for defining a salinity/sodicity strategy.



Methodology

The methodology for this study is based on the same methodology used the case study which was conducted during January 1996. Major conclusions on this same mcthodology were that niapping esercises arc an excellent mctliod to obtain quick insights into the salinity and sodicity processes. But, secondary information is indispensable for understanding fanners' language and to cross-clicck information provided by tlic farmers. Information on fanners' strategies and practices to cope with salinity in their farming systems were obtained through scnii-structured interviews. Since this type of interviews allows farmers to talk at tlicir own pace and in tlicir own wordings, one interview can take quite a lot of time. Therefore, it was found not to be a good method for developing quantitative relations between strategies. practices. physical circumstances, and farm characteristics. Based on these cxpcricnccs, the following approach had been adopted.

Site *selection*

All o f tlie eight **sample** watercourses **on** the Fordwali and Azim distributaries at the tail o f **Fordwah** Branch canal in which **IIMI** is conducting rescarch. were included in this study, in **order** to include as **many** physical and irrigation environments as possible, and all farming systems as they were **identified** by Rinaudo (1994).

Data collection techniques

The **field** data for **this** case study were collcctcd by **making use of three** diffcrcnt research **techniques**: **structured** interviews with opcii questions, discussions, and **mapping (inspired** by niapping exercises **used** in participatory **rural** appraisal).

The study was **started** by visiting tubewell owners **and/or** tubewell users and farms from which soil samples **were** taken. **The effect** o f the **use** o f **tubewell water** for irrigation **on** different soil **types,** and **the** quality o f soil from the ***killas*** where **soil samples** werc **taken** from, were discussed in unstructured interviews. Tlicsc discussions did not only **give** insight into farnicrs' pcrccptions **on** soil salinity and sodicity and **the impact** o f the **use** of different qualities o f tubewell water, but **also provided** the opportunity to visit **the watercourse** and get a first **impression** o f the extent and severity o f the salinity and sodicity problems. This **insight** provided a **framework** for the selection o f farmers to be interviewed.

Interviews were conducted to obtain insights into farmers' perceptions regarding **salinity/sodicity** and tbcir strategies and practices for coping with salinitylsodicity. Since the **sample** size o f farmers to **be interviewed was** larger than the **number** intervicwcd in tlie previous case study, and the case study had **learned** wliich questions **were** important to bc discussed, **a** questionnaire with open questions was developed. **During the** interviews, **there** was **plenty** o f **room** for discussions with the fanners, but **the** questionnaire helped in covering all topics. **The farmers** were selected on tlie basis o f tlie fanning system group **they** belonged to. **their** location in the **watercourse**, and **the** probability o f salinity and **sodicity problems**.

Initially. niapping exercises wcrc not **included** in **the research** proposal. But during **tlie** analysis **of** collcctcd field data and secondary data **available** in **IIMI**, it was **realised** that the approach being used did not provide insight into the history o f salinity and sodicity. **Knowledge** o f the history helps in understanding farmers reactions to salinity and sodicity. **Therefore**, it **was** decided to execute mapping **exercises** in four **watercourses where the most** distinct types of salinity **and** sodicity processes are **present**. **Mapping was done** using a **base-map** o f tlie watercourses that indicated **the** ***killas*** (acres). irrigation canals, villages. and **tubewells**. On this **base-map**, diffcrcnt **salinity/sodicity features** could **be easily** indicntcd. **The exercise was** done **with** a group o f faniicrs **with a** lot o f knowledge about the history o f the **area** and extensive experience **with** fanning.

Data analysis

On tlie basis o f the infomiation **collected** by **means** o f **the aforementioned** tccliniqucs. fanners' pcrccptions. stratcgics and practices could **be described**. To obtain **further** insights into farnicrs' knowlcdgc and understanding o f **salinity/sodicity**, links werc **made** with secondary **data** collcctcd **by IIMI**. **Farmers'** strategies and practiccs **were evaluated** in **tlie light** o f **the** possibilities and constraints o f **the** physical cnvironmcnt and **the farming systems**. Physical data, along **with** data on farming systems and **farm** characteristics. were **all** available within **IIMI.**

Chapter 2

Description of the Physical and Social Environment

This study took place in IIMI's eight sample watercourses. The study learned that the present salinity and sodicity status in the Indus Basin is caused by different processes, some of which occur as combined processes. For this introductory chapter, four watercourses were selected to illustrate these effects. In essence, the four watercourses represent the following processes:

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

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

Watercourse Fordwah 14-R

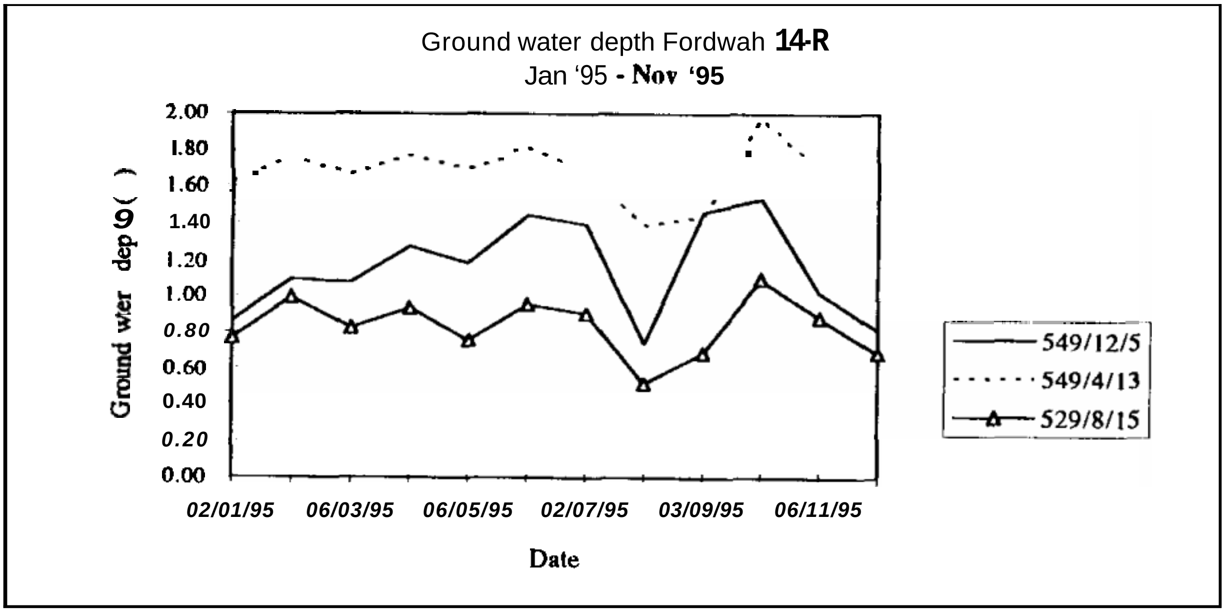
Soils

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. Fouteen 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 5 presents the water table depths as they were measured in 1995, along with the position of tlic observation wells. The dcepcst ground water lcvcls were observed in tlie middle of Watercourse 14-R. At this place. tlic watcr table fluctuates bctwccn 2.00 m (October) and 1.40 m measured in August. In tlic tail area, the most shallow water table lcvcls are observed fluctuating between 0.5 m (August) and 1.05 m (October).

Figure 5**: **Water table depths** in **Watercourse Fordwah 14-R.

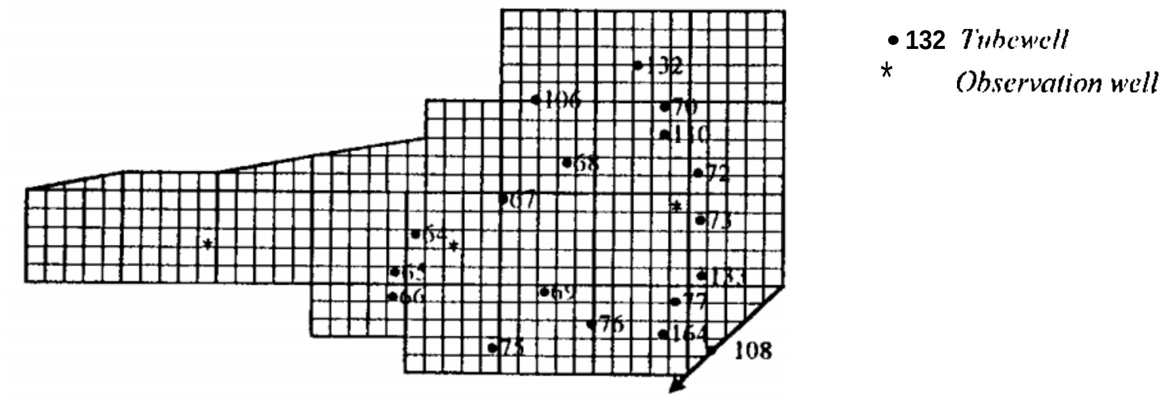


An indication of tlie quality of the ground watcr can bc obtained from the tubcwcll samples. Tubewells in the head of Watercourse 14-R have an approximate EC of 1 dS/m, SAR 1.5, and an RSC-value of -3. The quality of ground water decreases with the distance from the distributary. The quality of the tubewells in tlie middle of Watercourse 14-R are approximate: EC 3 dS/m, SAR 11, and RSC -6. No tubewells arc present in the tail of Watcrcourse 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 arc plotted.

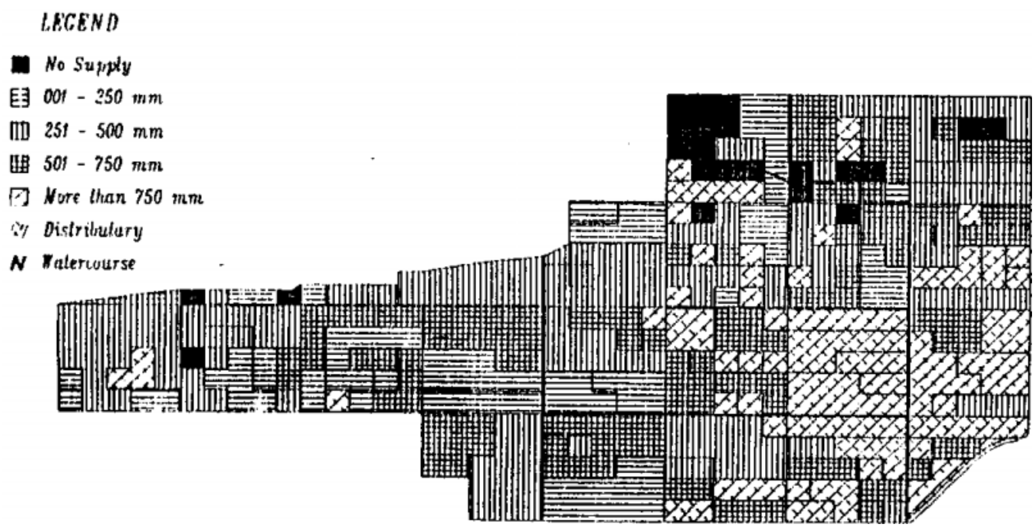
Crops and cropping intensities

Major crops during Rabi (winter season) arc wheat and foddcr. During Kliarif (summer mansoon season) tlic main crops arc cotton, sugarcane and foddcr. Sugarcane is grown by several fanners in tlie head and middle of the watercourse. Average yearly cropping intcnsitics arc 130 percent. The average cropping intcnsitics in Rabi and Kharif are 65 percent. The cropping intensities differ greatly per farm and especially per location in tlic watcrcoursc. Farmers at the head of tlic watcrcoursc have yearly cropping intcnsitics ranging bctwccn 140 and 200 percent; while in the tail of tlic watcrcoursc, tlic yearly cropping intcnsitics do not exceed 90 percent. In Kharif. the cropping intensities in the tail of the watercourse are very low (around 30 pcrccnt).

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



Map 3: Canal water distribution in Watercourse Fordwah 14-R



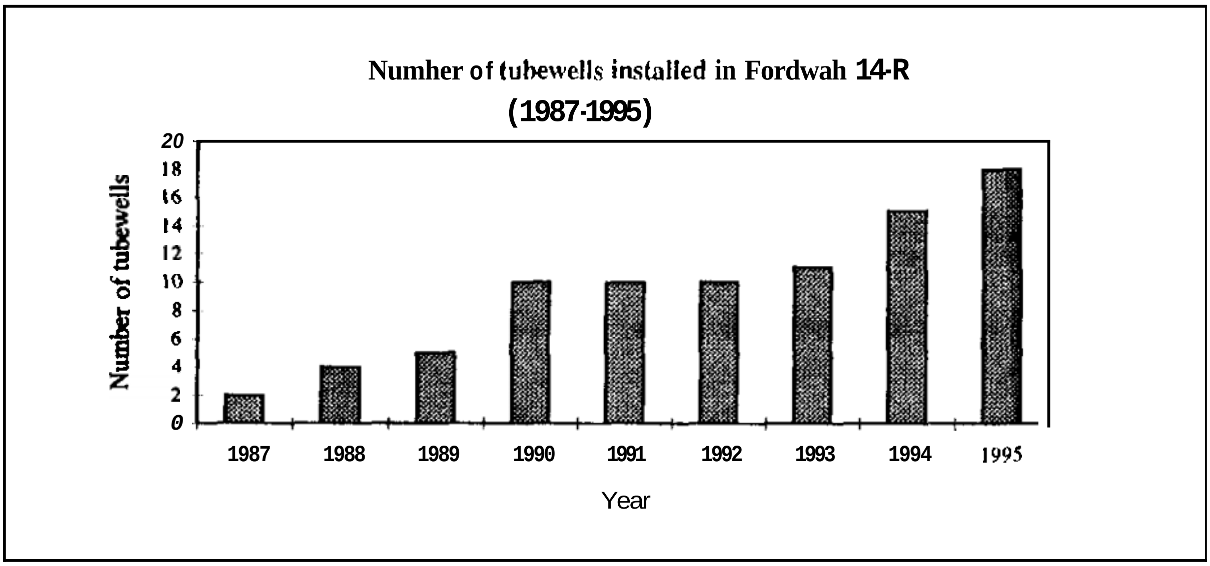
Canal water supply and distribution

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 (Map 3). However, there is a large spatial variability in the tail area. The highest canal water supplies can be observed in the head of the watercourse (Asif and Ashraf, 1996). In this area, the highest cropping intensities can be observed.

Tubewell use and quality

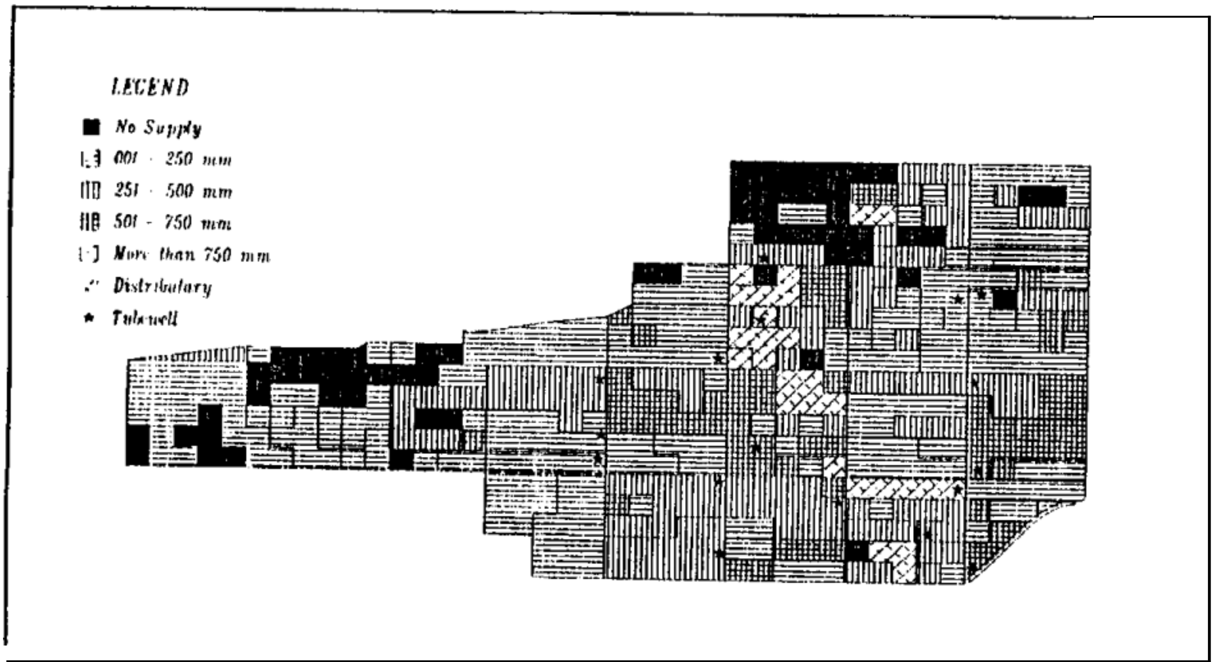
In 1987 the first tubewell was installed in Watercourse 14-R. Since that time, the number has steadily increased to a total number of 21 (Figure 6). Most tubewells are located in the head and middle of Watercourse 14-R. As discussed before, the best quality tubewells are found near the Fordwah Distributary. 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 6).

Figure 6: Total number of tubewells installed in Watercourse Fordwah 14-R.



Map 4 shows the spatial distribution of tubewell water use. 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 (Map 5).

Map 4: Spatial distribution of tubewell water use in Watercourse Fordwah 14-R.



Map 5: Total water supply in Watercourse Fordwah 14-R.

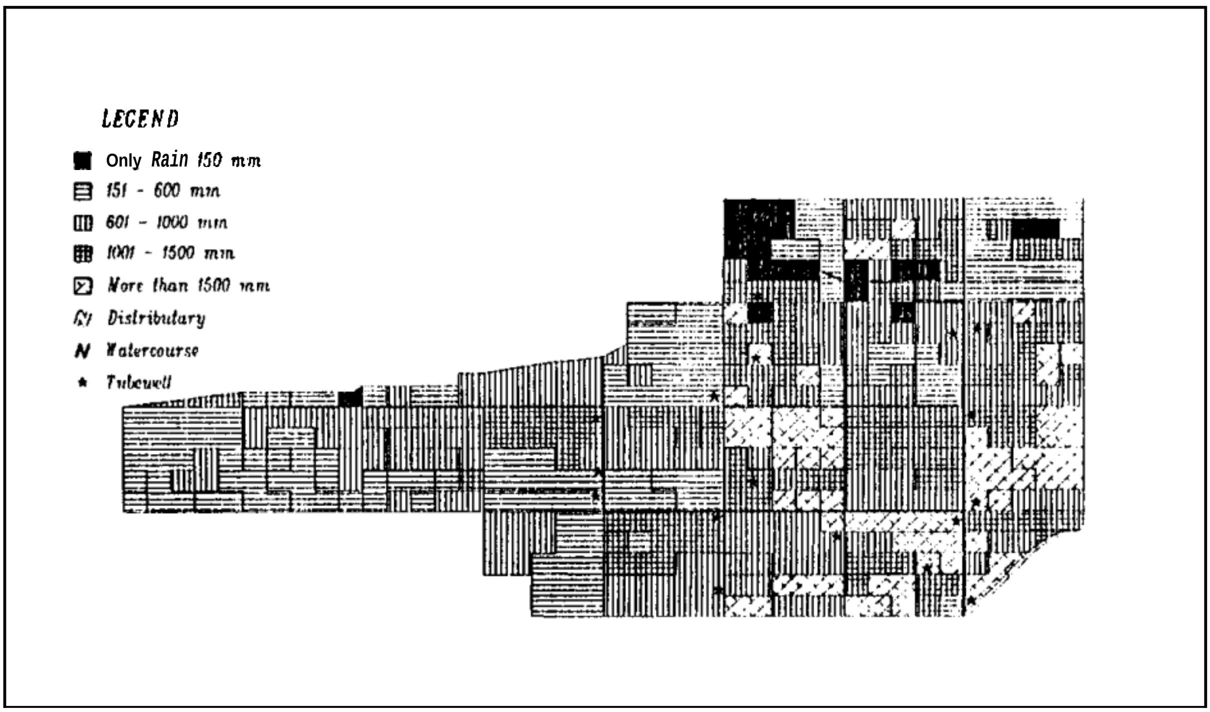


Table 6: Tubewell water qualities of watercourse Fordwah 14-R.

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

History of the salinity and sodicity

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

Tlic time that they started irrigntiiig, tlic soils were bclicvcd to bc of good quality. But around 1972, a drastic change took plncc. 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 tlic succeeding six to seven years, fariiicrs cxpcriciiccd difficult times. Crop productioii was very low due to waterlogging. Slowly. tlic wntcr table di-oppcd naturally. A fast drop in the water table level occurred iii the period arouiid 1985 to 1987. Tlicsc ycnrs were 'dry'. After the water table had dropped, the farmers realised that salts had bccii left behind at tlic surface of their farm lands.

Map 6 indicates tlic areas tlint 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 tlic farmers as a white soil surface, was left bcliiiid. Another block, also situated in the tail of Watercourse 14-R, was classified by the farmers as being *kalar shoor*. Tlicsc soils were too saline to grow any crop and tlic soils were waterlogged as well. In the middle of Watercourse 14-R. the fariiicrs iiidicatcd 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 liard. Map 7 shows tlic soil salinity/sodicity situation after it improved naturally due to the falling grouiid wntcr table. Many areas which were suffering froiii white crusts were improving, and the waterlogged areas were getting drier. Simultaneous with tlic improvements of the soils, tlic cropping intensities rose. Farmers who, due to limited canal wntcr, left parts of their farms uncultivated started installing tubewells. In 1988, tlic first tubewell was installed and operated in this wntcrcoursc. Up till now, farmers are still installing tubewells. In 1995, three new tubcwclls were installed. Initially, tlic installation of new tubcwclls gnvc a further reduction in the salinity/sodicity problems. aiid a iiinjor reduction in tlic waterlogging problciiis was brought about near the head of Watercourse 14-R. Tlic changes that took place arc indicated iii Map 8. In tlic tail-end blocks. no iiinjor changes have taken place. Since tlic installation of the tubewells, only the soils that were said to have white surfaces improved. The physical characteristics of tlic other types of saline soils did not change much.

Present salinity and sodicity status

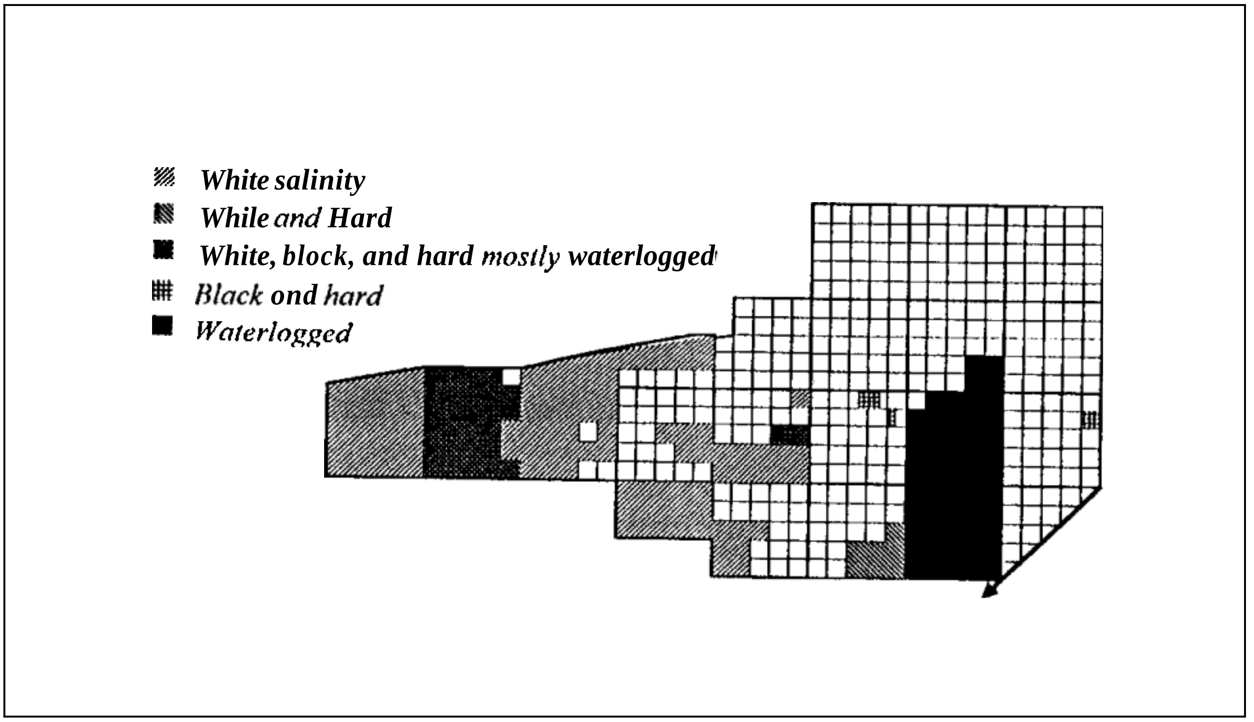
Two causes for tlic present snliiiity and sodicity can be identified: 1) salinisation-sodification due to the use of poor quality tubewell water. especially in the middle of the watcrcoursc: niid 2) salinisation-sodification due to capillary rise from high saline-sodic ground water tablcs, especially in tlic tail of llic watcrcoursc. Due to the saline nature of the groundwater in the area, soil degradation due to sodification is not n major concern. Map 9 shows tlic present salinity/sodicity situation according to farmers' perceptions. Tlic map shows in detail all *killas* which arc affected by a certain type of salinity/sodicity. It should be stressed that the map is in congruence with fnriiicrs' cspcriciiccs in cultivating these soils.

Farm characteristics

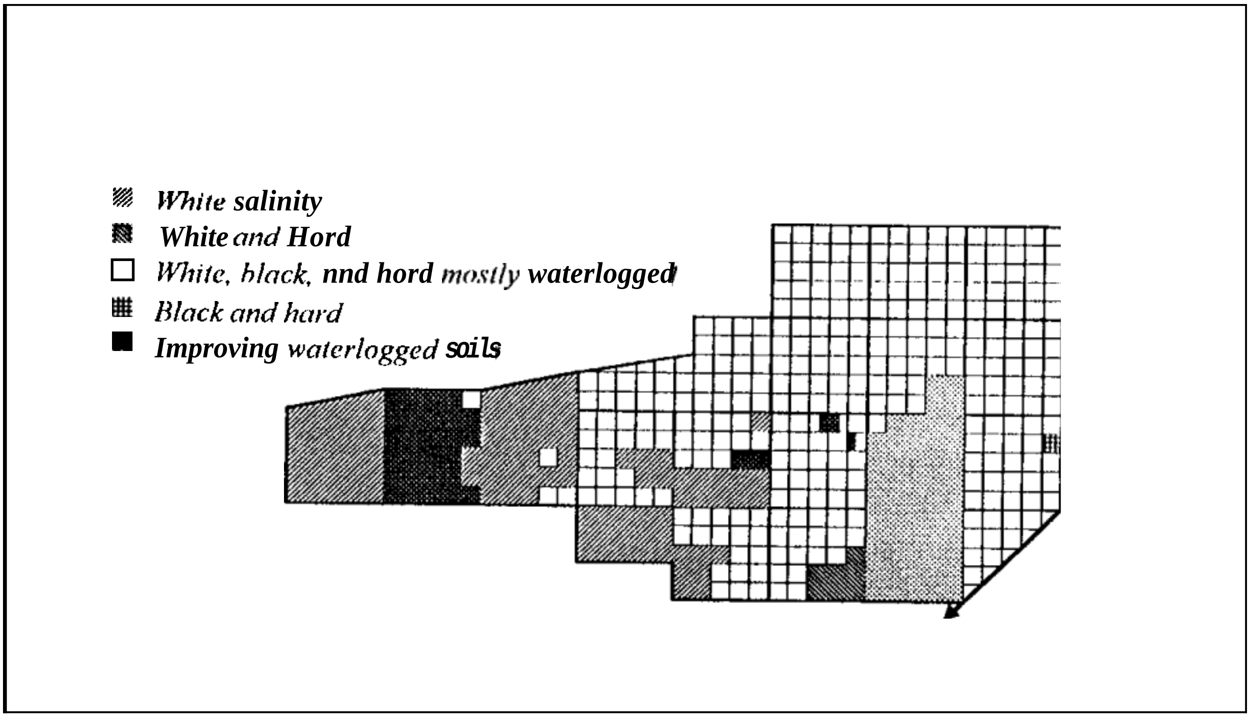
Tlic two major groups of fnriiicrs represented in Watercourse 14-R arc: 1) Farmers with a rather small total operated area (average 4.5 ha), low level of capital, adequate aiid reliable wntcr supply, and high percentage of total operated area under sugarcane: aiid 2) Fnriiicrs with large families, a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

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

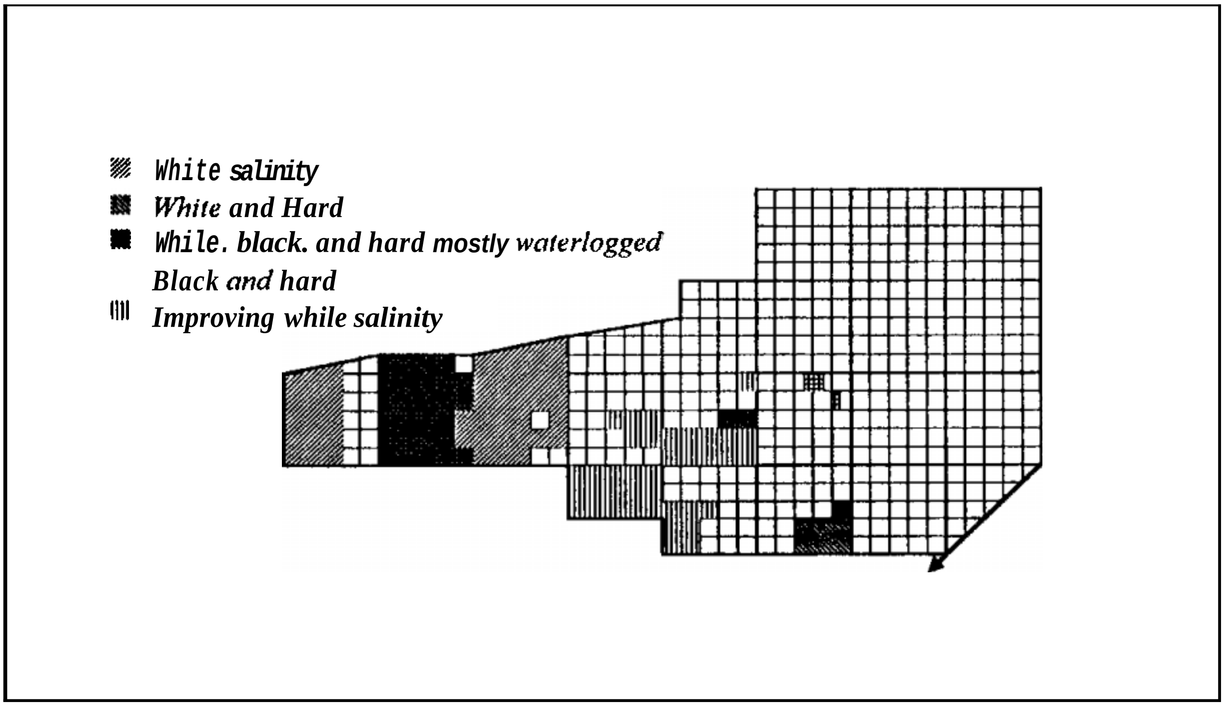
Map 6: Salinity and sodicity after the rains of 1972 in Watercourse Fordwah 14-R.



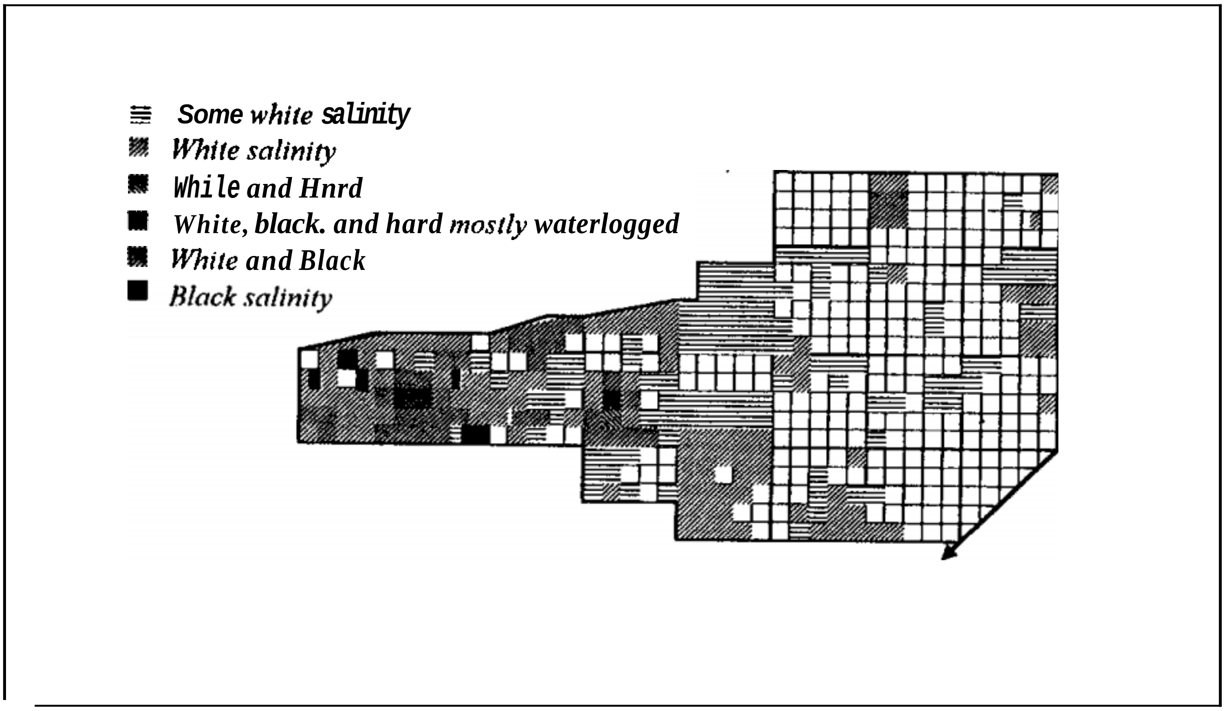
Map 7: Salinity and sodicity before installation of tubewells in 1987 in Watercourse Fordwah 14-R.



Map 8: Salinity and sodicity after the installation of tubewells(1987-96) in Watercourse Fordwah 14-R.



Map 9: Salinity and sodicity present situation in Watercourse Fordwah 14-R



Watercourse Fordwah 130-R

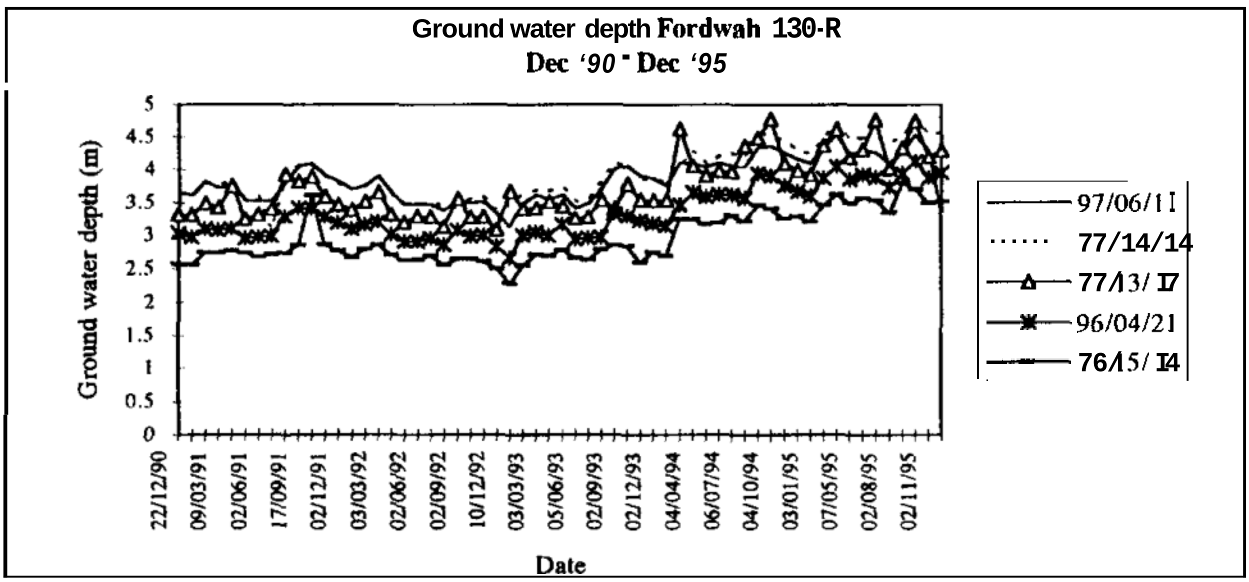
Soils

Map 10 presents the soil map for Watercourse Fordwah 130-R. The watercourse coiiiniand is located in tlic Rasulpur terrace. comprising soils which dcvclopcd in subreccnt 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 tlie command area is covered by level plains. The Harunabad soil scrics 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. Tlic Rasulpur soil series are somewhat excessively drained and have a moderate rapid to rapid pcrnieability. Tlic Jhang scrics are cxccssivcly drained and have a rapid permeability. The remaining 30 pcrccnt in this command area is covered by nearly levelled gently undulating levees. Thirty percent dcvclopcd on more loamy soils and are therefore classified as belonging to tlic Rasilpur soil scrics. The remaining area is covered by Jhang soil series. It should be noted that 62 percent of the soils wcrc 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 liave any saline-sodic properties.

Groundwater table depth mid quality

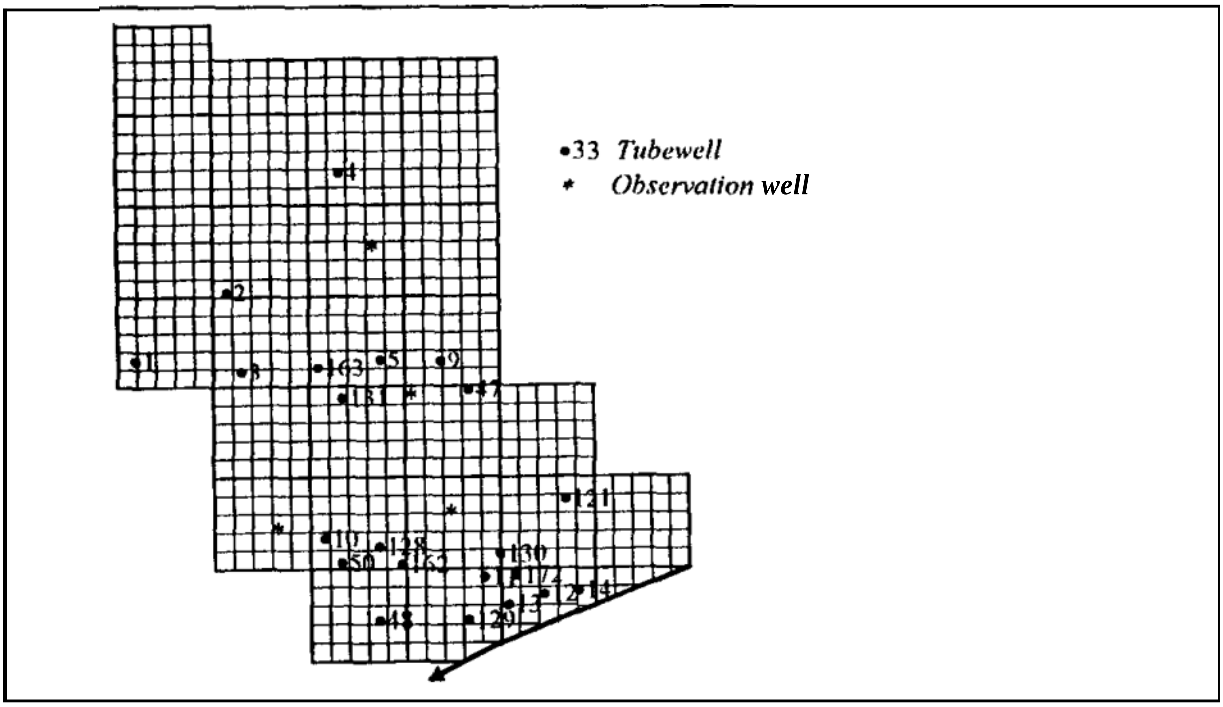
Since 1990, the water table deptli in this watercourse has dropped by approximately one metre (Figure 7).

Figure 7: Water table depths in Watercourse Fordwah 130-R.



The difference in water table depth bctwccn the head of tlic watercourse. where most tubewells arc installed, and tlie 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 tlic water table depth fluctuates between 4.2 m (February) and 4.X m (October). Tlie quality of ground water differs per location

Map II: *Location of observation* wells **ond** *tubewells* **in** *Watercourse Fordwah 130-R.*



and is not related to tlic *distance from* **the** *watercourse.* Tlic EC values, **as** measured in the different tubewell waters, range between **0.8** and **1.5** dS/m, tlic SAR between 3.6 and 17.2 and **the** RSC-value between 0.8 arid **S.7**meq/l. Map **II** shows tlic locations of tlic 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 tlie farmers. During Kharif. **94%** of the farmers grow cotton. **84 %** fodder, and 30% sugarcane. Tlie cropping intensities are not related to a specific location within tlic irrigation scheme. Tlic average cropping intensities during Rabi are 78% (ranging between 0 and **100%)** and tlic average cropping intensity during Kharif is X1% (ranging bctwccn 10 and 100%). Tlic average yearly cropping intensity is 159%.

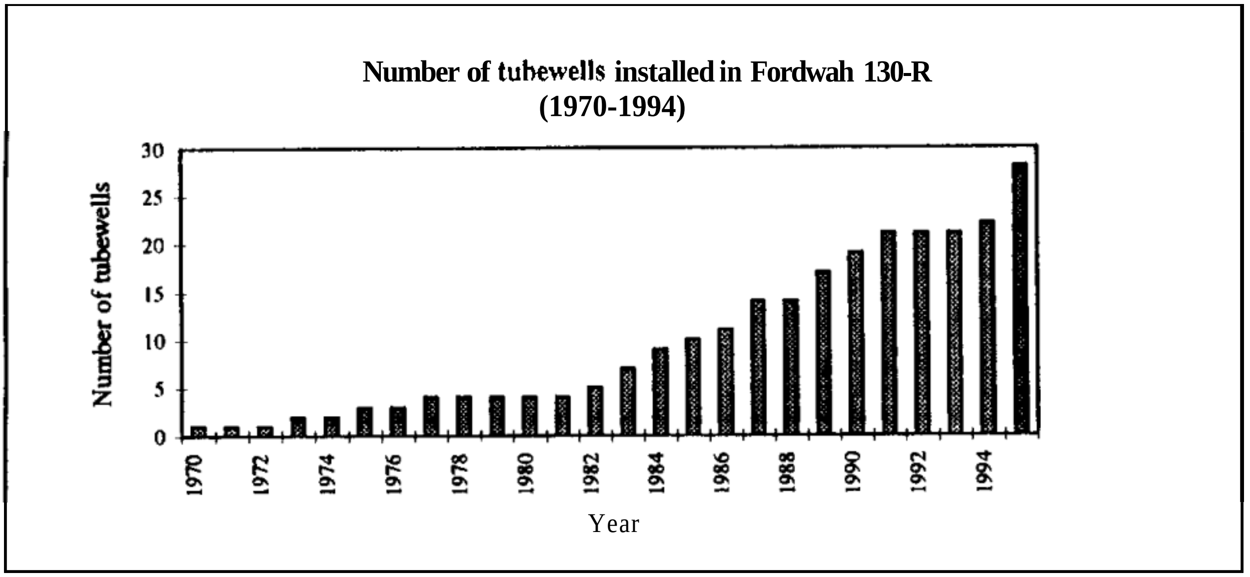
Canal water supply and distribution

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

Tubewell use and quality

In 1970, tlic fist tubewell was installed in Watercourse 130-R. From 1982, a rapid *incline in* tlic *number of* tubewells **can** be observed (Figure 8).

Figure 8: Total number of tubewells installed in Watercourse Fordwah 130-R



The quality of the tubcwells in this watcrcourse is generally poor. The actual quality differs from location to location and from bore dcpth to borc depth. Table 7 gives an overview of the tubcwell water qualities. All tubewell waters have slight to moderate salinity lcvcls and tlic SAR levels range from low to high. A prominent characteristic for the tubcwell wntcr quality in this wntcrcoursc is tlic high RSC lcvcls found in tlic majority of tubcwell water. See Map 11 for the location of tlic tubewells.

History of salinity and sodicity

The history and prcscnt salinity and sodicity situation was discussed with several experienced fanners. They gnvc tlic following explanation on the origin of the salinity and sodicity. The first tubewell was installed 20 years ago. For the last 12 to 13 years, the use of tubewell water for irrigation has increased dramatically. Before the tubcwells were installed, the soils were very good. As long as farnicrs can remember there has been salinity in the head of the watercourse (Map 12). This salinity only occurred in the areas which were not cultivated by the farmers. The type of salinity was white salinity and it could be removed with canal water. Several plots were reclaimed by the farmers (Map 13).

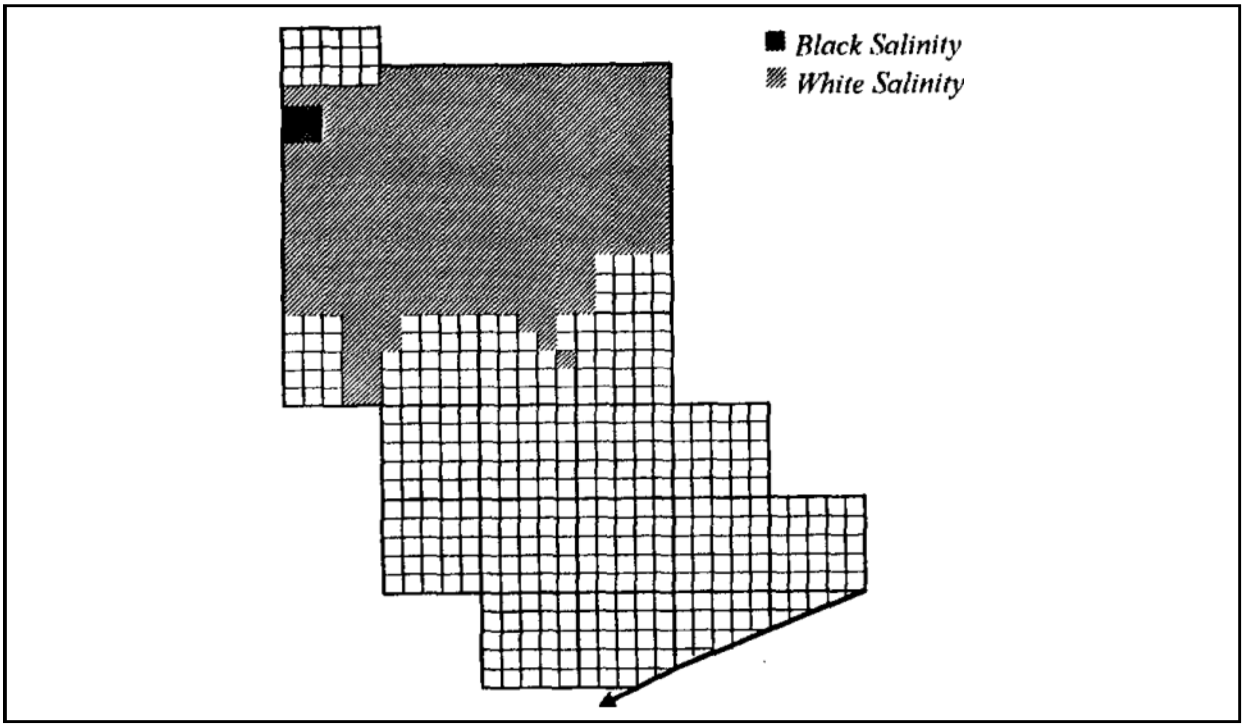
Table 7. Tubewell water qualities of Watercourse Fordwah 130-R.

TW NMR	Depth (Foot)	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

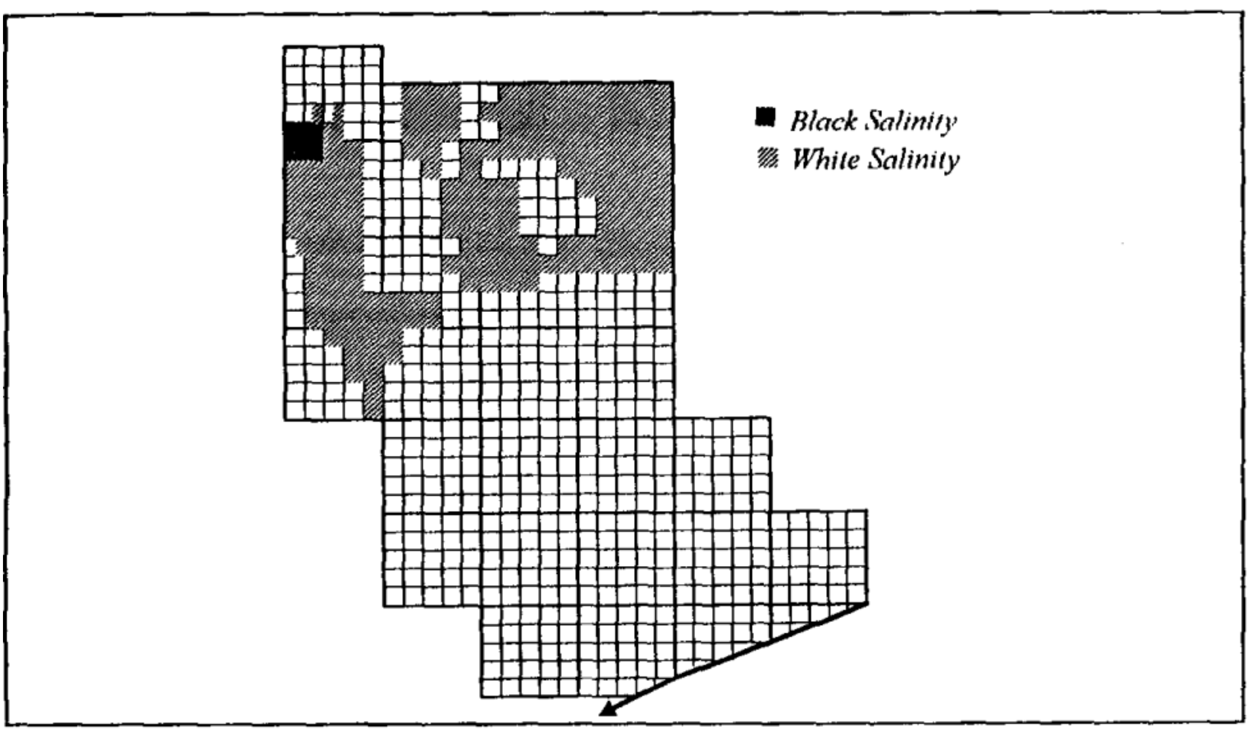
Present salinity and sodicity situation

Since canal water supply for 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. Conversations with farmers learned that salinity and sodicity is an increasing problem since the installation of the first tubewells. A major concern in this watercourse is physical soil degradation due to the use of highly sodic tubewell water. According to the farmers, the salinity which was present in the past was not the same type of salinity that farmers are facing now. The

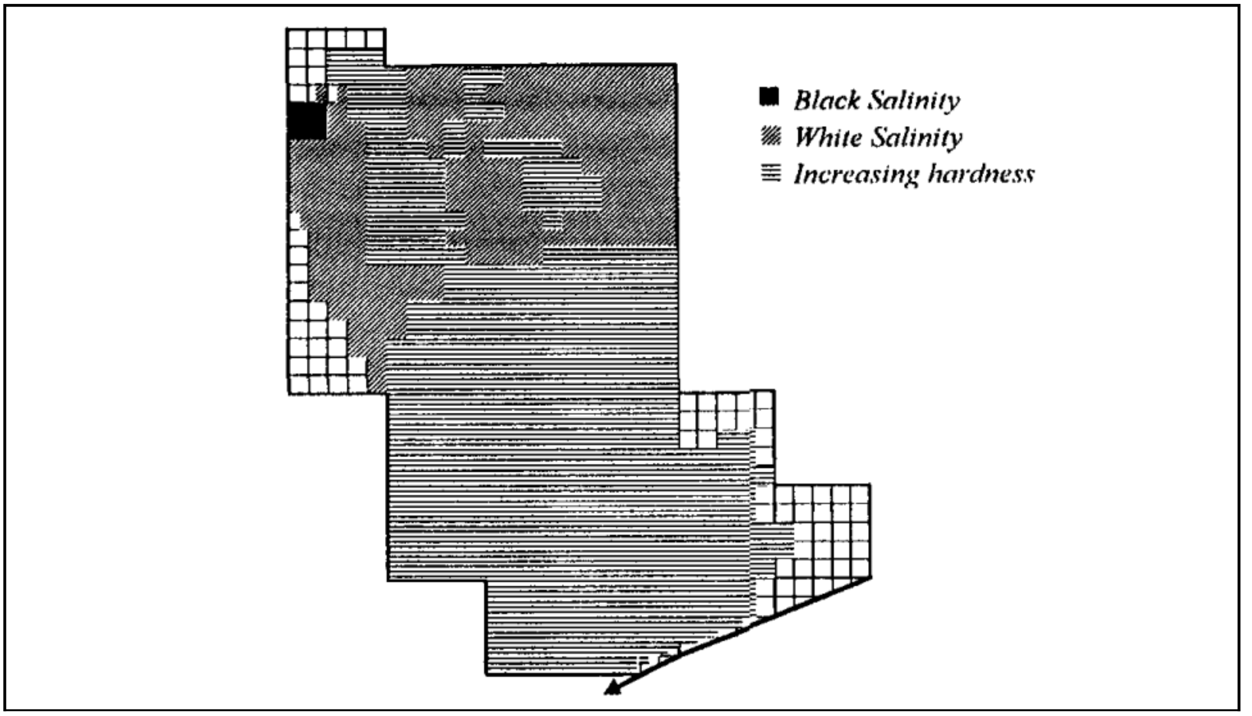
Map 12: Salinity and sodicity situation around 1950 in Watercourse Fordwah 130-R



Map 13: Salinity/sodicity situation before tubewell installation (1982) in Watercourse Fordwah 130-R.



Map 14: Present salinity and sodicity status in Watercourse Fordwah130-R.



salinity in the past made the soil soft. The present salinity. caused by the use of poor quality tubewell water. makes the soil hard. At tlic moment, almost all of tlic farm land is becoming hard (Map 14). According to the farmers, tlic hardness varies with the quality of tubewells that the different farniers are using. There arc three places in tlic wntercoursc where hardness is not an increasing problem. In these areas, farmers receive good quality watcr from their tubewells.

Farm characteristics

Three major farni groups arc present in this watercourse: I) farmers with a small total operated area, low level of capitalisation, low and unreliable water supply. high cropping intensities, high use of inputs, high farni output. and high purchase of tubewell water: 2) fariiicrs 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, bettcr canal water supply than most farmers in tlic watcrcoursc, high farm outputs.

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

Watercourse Azim 111-L

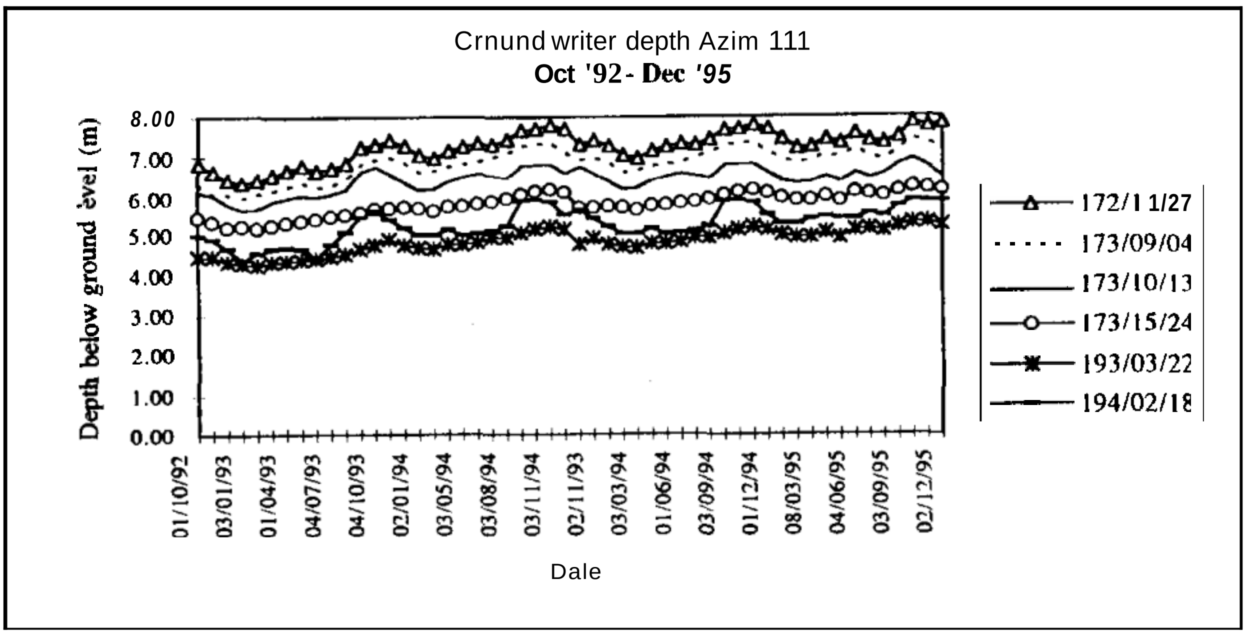
Soils

Map 15 presents tlic soil map for Watercourse Azim I I I-L. The watercourse comprises soils which dcvclopcd in subrecent flood plains. The different physiographic units of this land form identified in Watercourse 1I I-L arc lcvcl plains and basin margins. Fifty thrcc percent of the soils in this watercourse have dcvclopcd in tlic lcvcl plains. The soils scrics in this unit are Sultanpur and Nabipur loam. These soils arc medium textured. arc well drained. and have a moderate permeability. Twenty nine pcrcciit of the plots in these soil series have a saline-alkaline crust. On the slightly raised parts of this physiographic unit, the Jliakkar and Grandhra loam series dcvclopcd. They comprise 25 percent of tlic command area. They arc medium textured, well drained. and arc 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 arc 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. V c n small areas arc covered by Adilpur loam and Sodrha loam, which dcvclopcd in basin margins and covered sand bars. respectively

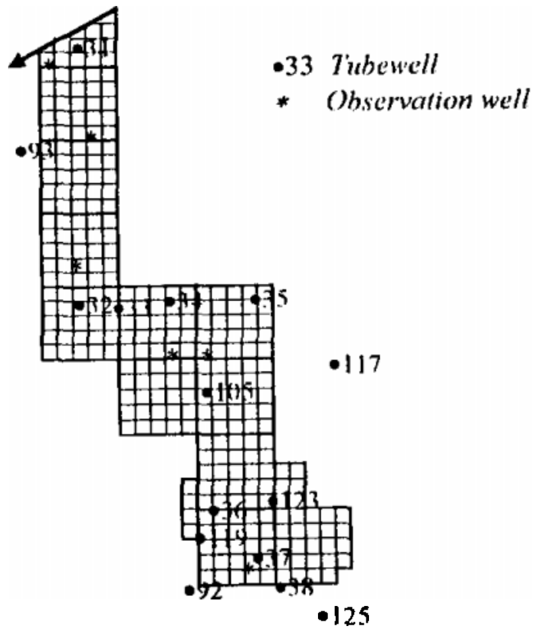
Groundwater table depth and quality

The water table depth at tlic head of tlic watercourse is two to thrcc meters dccpcr than tlic depth at tlic tail of the watercourse. Since 1992, a decline in water table depth can be observed (*Figure 9*). *For 1995 the* dccpcst ground water table occurrcd in April. At the head. the water table depth was 7.2 m and at tlic tail *S.2* m. The highest ground water tables occurred in October. At the head, the depth was 7.9 m and at tlic tail 5.8 m. For tlic location of the observation wells see Map 9

Figure 9: Water table depths in Watercourse Azim 111-L.



Map 16: Location of observation wells and tubewells in Watercourse Azim 111-L.



The best quality ground water is found at tlic head of the watercoursc (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 arc wheat and fodder. **Wlicat** is grown by 100 percent of the farnicrs. while fodder is grown by 70 percent of **tlic** farmers. Average cropping intensity for wheat is 62 percent, The average croppiiig intensity for fodder in the Rnbi season is 10 pcrcciit. The major crops grown during the Klinrif season are cotton. rice and fodder. Sixty five percent of the farnicrs grow cotton, with an average croppiiig intensity of 57 pcrcciit (ranging between 30 and 97%). Rice is grown by 70 percent of all farmers. Average cropping intensity of rice is I7 percent (ranging between I and 38%). Fodder in Kharif is grown by 65 percent of tlic farnicrs with an **average** croppiiig intensity of 26 percent. Average yearly cropping intensities arc 146 percent ***(90-*** 200%). The average cropping intensity during Rabi is 73 percent (37 - 100 %) and during Kharif 73 pcrcciit (20 - 100%). Cropping intensities arc not related to the location within **tlic** water coiirsc.

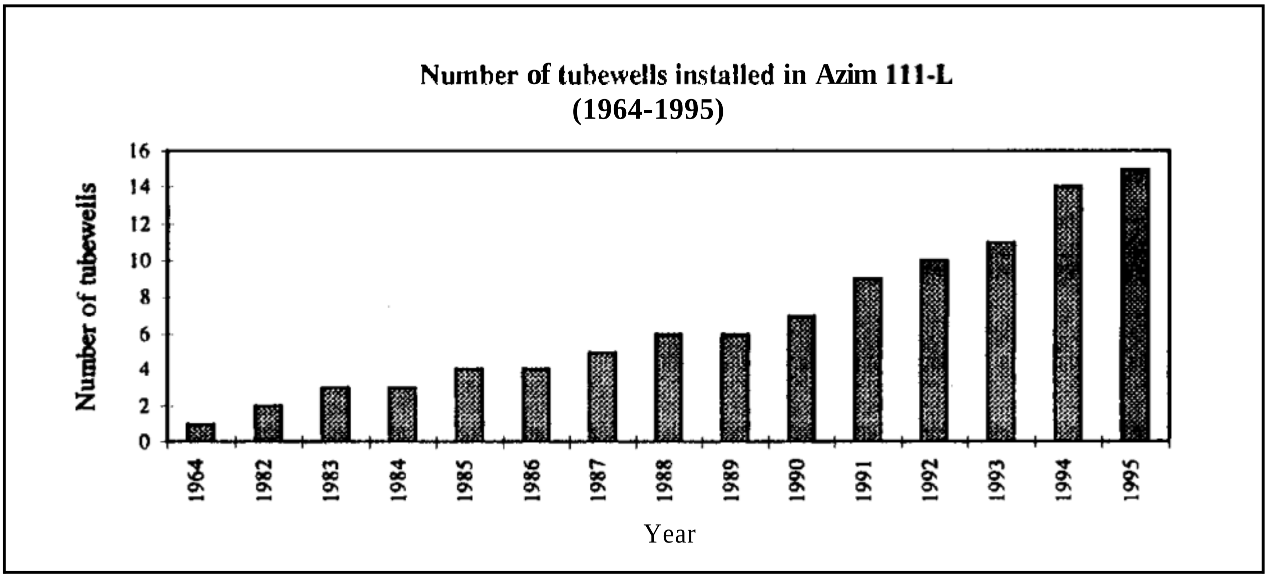
Canal water supply turd *distribution*

No **canal** water reaches this watercourse. Farmers complctcly rely on tubcwcll water supply

Tubewell use and quality

The first tubewell was installed in 1964. The second tubcwcll was installed 18 years later. Since then, **a** steady increase in tlic number of installcd tubewells can be observed (Figure 10).

Figure 10: Total number of tubewells installed in Watercourse Azim 111-L.



The quality differs significantly from one location to the other and with depth Table *8* gives an overview of tlic quality of the different tubewclls, along with the bore depth. The location of the tubewells arc plotted on **Map 16**

History of salinity and sodicity

The history of the salinity situation was discussed with some experienced fanners. They gave the following explanation on the origin of the prcscnt salinity arid sodicity problems. The first tubcwcll was installed around 1956. The second tubewell was installed in 1964. At this time, there was no effect from tlic tubcwclls **on** the salinity since farmers were using both canal and tubewell water. Round this time, **all** tlic cultivated area had good soils. Only tlic barren land, which was never cultivatcd or not cultivatcd for a long time, was having salinity. **At** this time, the land prcssurc was less and fanners did not reclaim **all** barren land, and land was often left fallow. The salinity **was** white salinity, but **at** places where **there was** too much salinity. tlic salinity turned into black salinity **(Map** 17). Since 1982, the number of tubcwclls increased rapidly. For the last 10-12 years, tlie tail end farmers have not received any, or very little, canal water. Since that tinie, tlic tail area has become **hard** and has cxpcrienced a ‘declining fertility‘ (Map **18).**

Table 8: Tubewell water qualities of Watercourse Azim 111-L

TW NMR	Depth (foot)	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

Present salinity and sodicity status

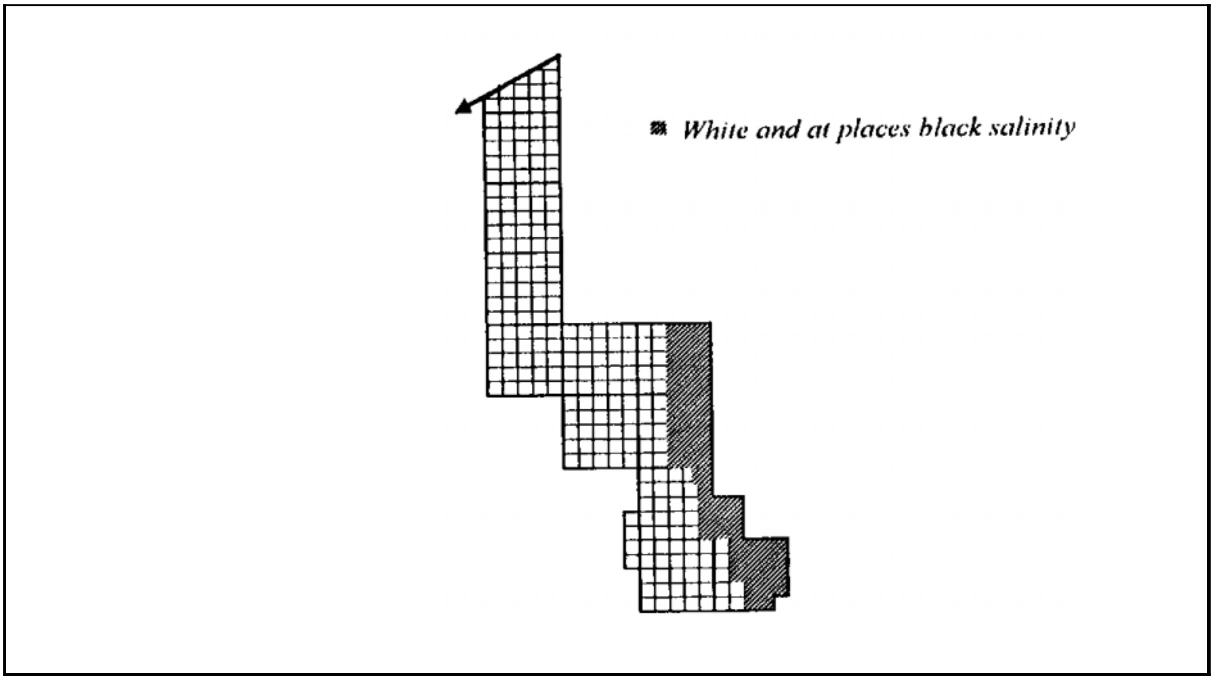
Quite large arcas within this watcrcoursc arc covered by saline-sodic soils. Since the water table is deep and canal water docs not reach this watercourse, recent developments in salinity and sodicity arc related to the use of different qualities of tubewell water and on the salinity and sodicity management practices of tlic farmers. According to tlic farmers, tlic head of the watercourse has rcccivcd more canal water for a longer time period then the tail area. But. during recent years, this area also has hardly rcccivcd any canal water In general, the quality of the tubewells is better at the head of the watercourse. Therefore. the head is experiencing fcwcr problems, although some arcas are becoming affected (Map 19).

Farm characteristics

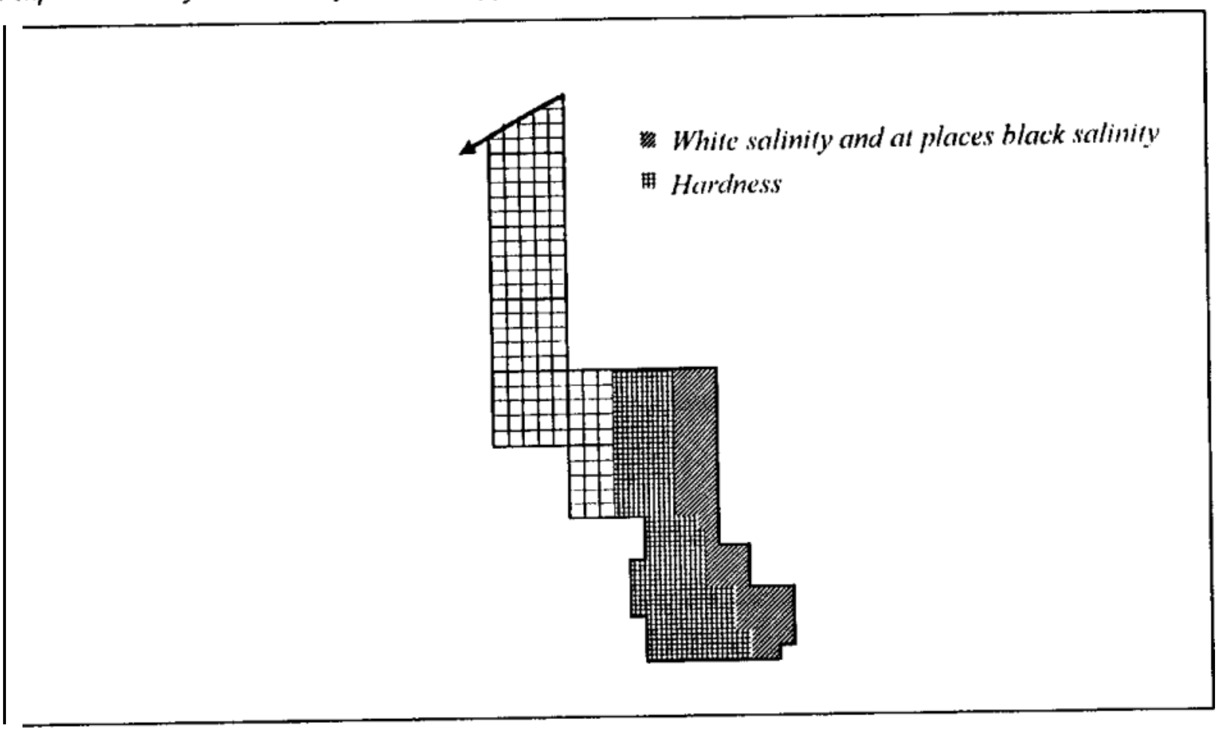
The majority of tlic farmers in this watercourse can be categorised in two groups: 1) large investment capacity. liigli percentage of tubewell owners, and intensive cultivation; and 2) small total operated area, high percentage of tubewell owners, intensive cotton cultivation, liigli cotton outputs.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

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

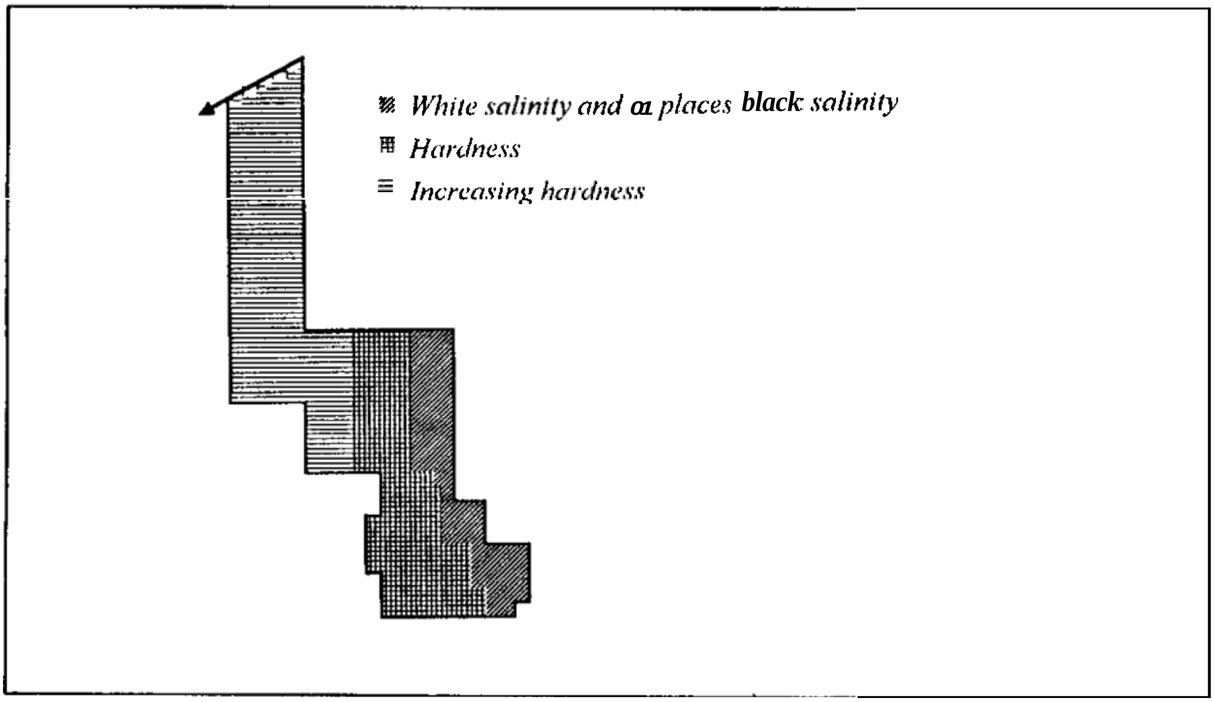
Map 17: Salinity and sodicity situation around 1950 in Watercourse Azim 111-L.



Map 18: Salinity and sodicity between, approximately, 1985 and 1993 in Watercourse Azim 111-L.



Map 19: Present salinity and sodicity status in Watercourse Azim 111-L.



Watercourse Azim 20-L

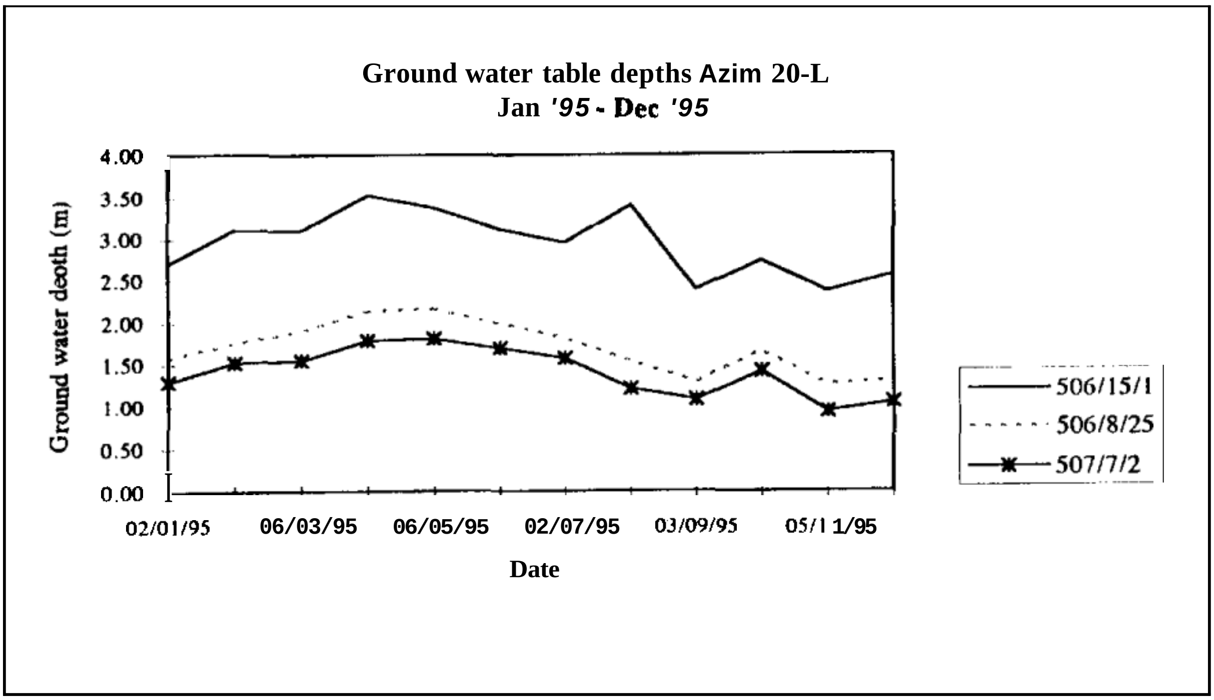
Soils

Map 20 presents tlic soil map for Watercourse Azim 20-L. The watercourse comprises soils which developed in subrcccnt flood plains. The diffcrcnt physiographic units of this land form idciitificd in Watercourse 20-L arc level plains. basins, levecs, covered sand bars, and sand bars. Characteristic for this watercourse is the large waterlogged area which covers 9 pcrceiit of the total area. The waterlogged area is surrounded by subrecent sand bars in tlic north (Sochra scrics) which cover *22* pcrcciit of tlic area. a subrcccnt basin in the south-west (Satgarah series) which cover 10 percent, and a levelled levee in the south and south-west (Rasulpur series) covering 10 percent. Tlic Sultanpur subrcceiit level plain cover 33 percent in tlic head of tlic watercourse. The soils round the waterlogged area are imperfectly to poorly drained. Tlic soils further away from this arca are well draiiicd. The soils dcvclopcd on the subrcceiit level plains have a moderate to moderate slow permeability. Tlic other soils have a moderate rapid to rapid permeability. Most soils directly bounding tlic watcrloggcd arca liavc a saline-sodic profile.

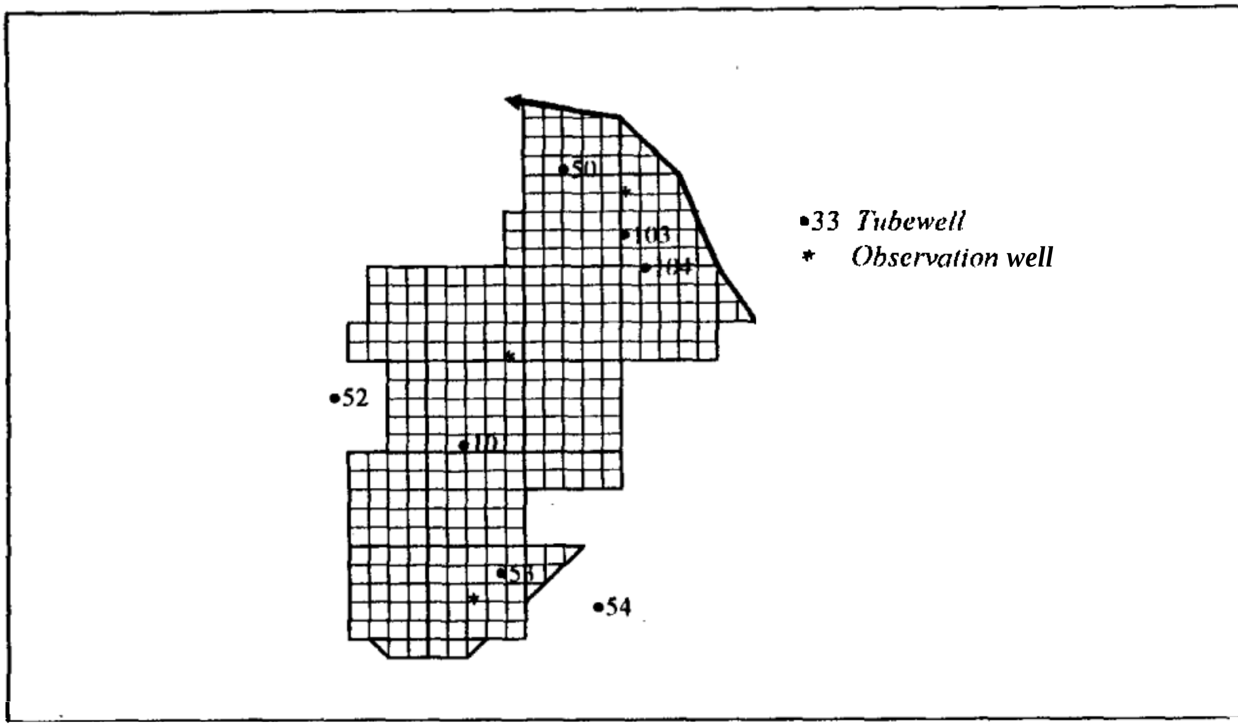
Groundwater table depth and quality

Tlic water table dcptli at the head of tlic watercourse fluctuates between two-and-a-half (April) to three-and-a-half metres (September) dcptli. Tlic water table dcptli is one-and-a-half metres lower than tlic depth at the head of tlic watercourse (Figure 11) For tlic location of tlic observation wells. see Map *20*. Tlic quality of tlic ground water varies between good in tlic head of tlic watercourse (EC: 0.7: RSC: -1.4: SAK: 0.8) and moderate in tlic middle-tail area (EC: 1.2: RSC: -0.1: SAR: 5.1)

Figure 11: Water table depths in Watercourse Azim 20-L.



Map 21: Location of observation wells and tubewells in Watercourse Azim 20-L.



Crops and cropping intensities

Major crops grown during thc Rabi season are whcat and foddcr. Tlic average cropping intensity for wheat is 46 percent, while the average cropping intensity for fodder is 9 percent. The major crops grown during the Kharif season are cotton, sugarcanc, rice and foddcr. Thc average cropping intensities are: I) for cotton 33 pcrccnt ; 2) for sugarcane are 25 pcrccnt; 3) for rice II pcrccnt; and 4) for fodder 8 percent. Thc average cropping intensity during Rabi season is 56 percent and in Kharif 7X pcrccnt. Cropping intcnsities are not related to the location within the watcrcourse.

Canal water supply and distribution

The canal water supply to this watcrcoursc is good due to its position at thc head of the distributary Even during Rabi, thc season that this distributary docs not officially receive water, tlic farmcrs rcceivc a substantial amount of irrigation water. The usc of tubcwcll water is thcreforc limitcd and much lcss as compared to the watercourses downstream.

Tubewell use and quality

The first tubewell was installed in 1987. Until 1993, five tubewells had been installcd in this watcrcourse. Farmers also make usc of two tiibcwclls which arc situated outside the command area of this water-course.

The quality of all the tubcwclls is good. Only one tubcwcll might cause slight to moderatc salinity problcms. Table 9gives an ovcrvicw of thc quality of thc diffcrent tubcwclls, along with tlic bore dcpth. Thc location of tlic tubcwells arc plottcd on Map 2I.

Table 9: Tubewell rvntcr qualities of Watercourse Azim 20-L.

TW NMR	Depth (foot)	EC ( )	S\R	RSC
50	60	0.7	0.8	
52	60	1.2	5.1	
53	80			
54	70	0.7		
101	· 70	0.6	1.6	
103	60	0.6	0.9	
104	65	0.7	2.4	

History of salinity and sodicity

According to tlic farnicrs, 60 to 70 years ago most of tlie watercourse command area was cultivatcd. Only some sand dunes, where the land level was too high for the canal water to reach. were left fallow, but none of tlie soils in tlie watercourse were saline (Map 22). A large part of the land in this watercourse is owned by a landlord. In those days. he leased out niost of the land. A few years after partition (1954), tlie canal bank of Azim Distributary broke and large parts of tlie watercourse filled with water. The following years the area experienced abundant rainfall which made large parts unsuitable or less suitable for cultivation. The lease land was abandoned and the landlord did riot bother about the land and left it fallow for dccadcs. During this period the salinity around tlie 'lake' developed (Map 23).

Present salinity and sodicity status

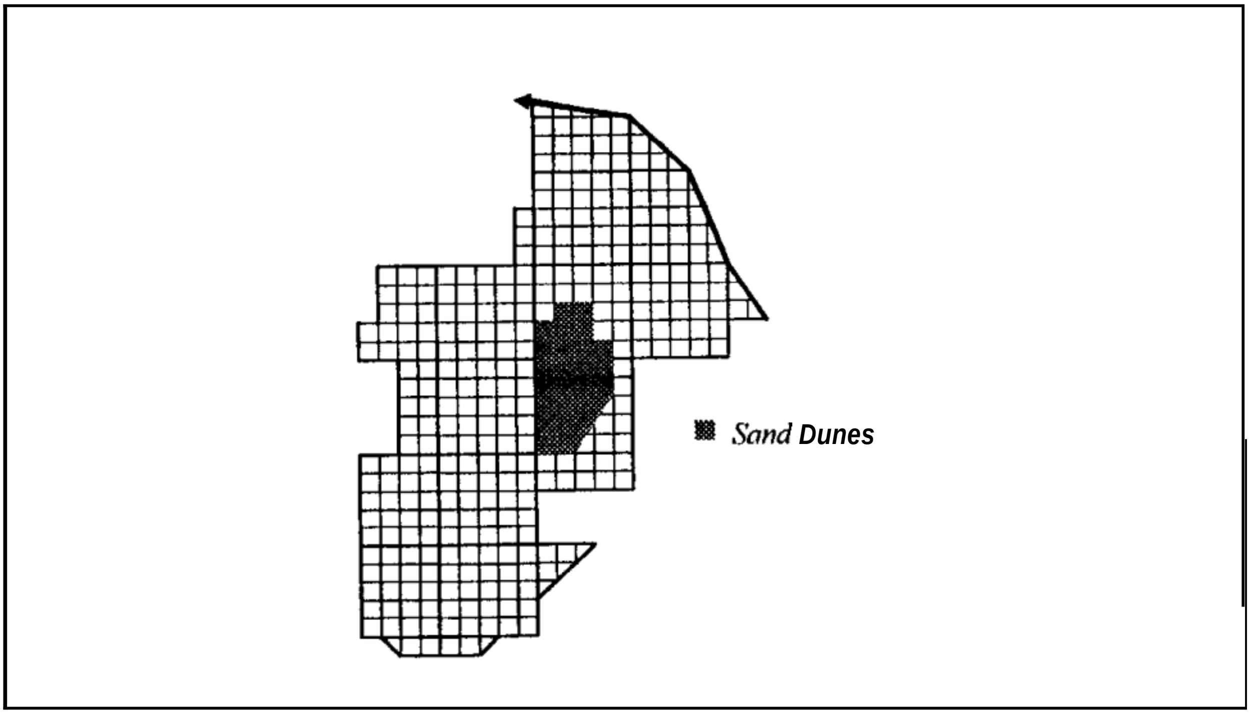
Nowadays, several people liavc bought acres of this land from tlie landlord and started reclaiming it. They initially grow kallar grass and after two to three years all of tlie salinity has disappeared. Also, the landlord started to rcclaini scvcral acres. Some of the reclaimed acres lie leased out to otlicrs and sonic arc cultivated by himself. Due to these reclamation practices, the saline area surrounding the 'lake' has dccreascd in its size (Map 24). Current salinity and sodicity dcvelopnicnt is directly related to the efforts of the farniers to bring saline-sodic areas under cultivation again.

Farm characteristics

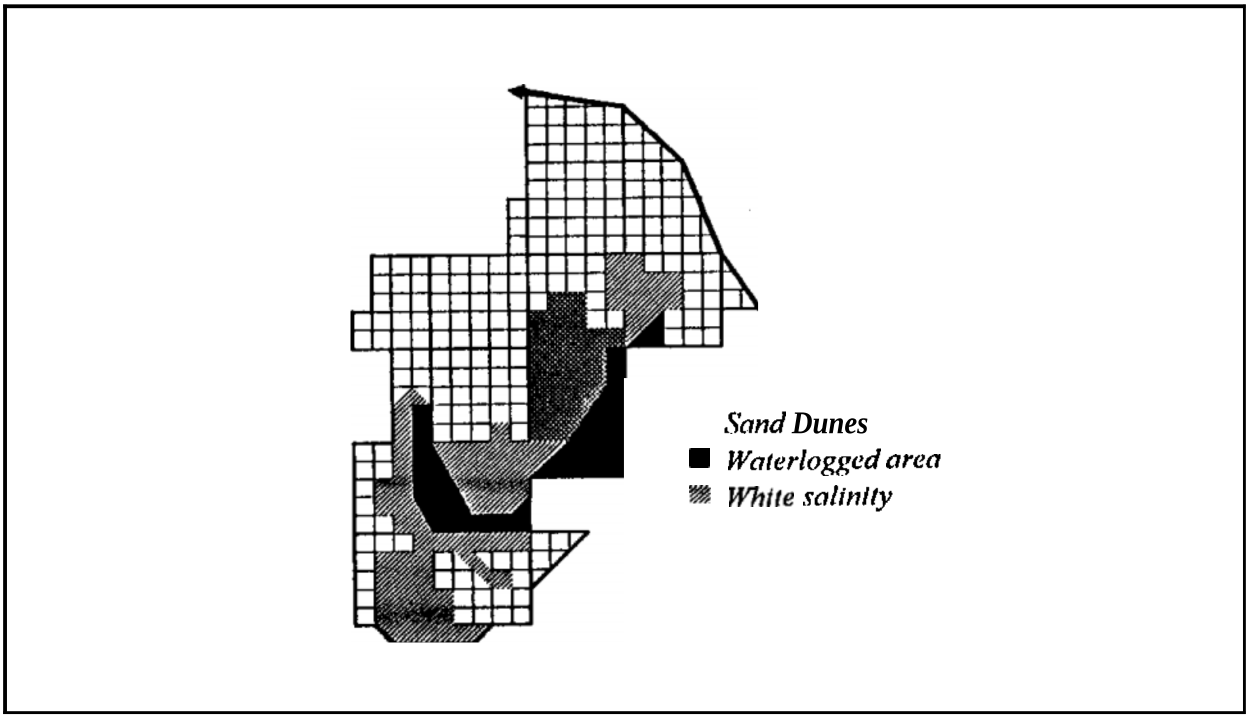
The majority of the cultivators in this watercourse belong to the same group of farnicrs. These farnicrs arc described ns having a medium size of land holding. and a low lcvcl of machinery which is compensated for by a high number of oxen and family labour. A large percentage of tlic farm is cropped with sugarcane due to its favourablc location on tlic distributary so that the canal water supply to thcsc farincrs is good. Cotton production is not very intensive and wheat is grown for home consumption (Rinaudo, 1994)

Cash does not seem to be a constraint, Many farmers receive remittances from family members. It is assunicd that farnicrs try to maximise the area under sugarcane within the given water constraints. (Rinaudo, 1994)

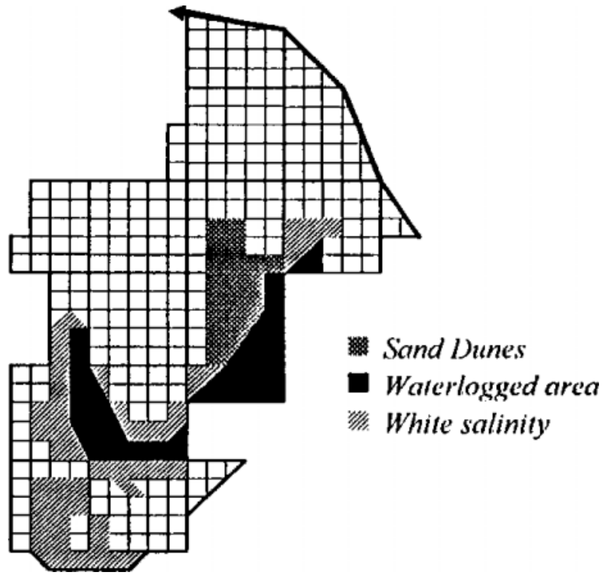
Map 22: Salinity ond sodicity status about 1950 in Watercourse Azim 20-L



Map 23: Salinity nnd sodicity status between, approximately, 1960 nnd 1980 in Watercourse Azim 20-L



Map 24: Present salinity and sodicity status in Watercourse Azim 20-L.



Chapter 3

Farmers' Understanding of Salinity and Sodicity

Farmers' response to salinity and sodicity can be partly explained by their understanding of the salinity and sodicity processes. Based on their understanding and the way they perceive salinity and sodicity in the light of their farming goals and internal and external constraints, farmers 'define' a strategy to cope with salinity and sodicity in their farming systems. From the foregoing chapter, it appeared that farmers have an excellent knowledge of salinity and sodicity processes. In this chapter, farmers' understanding of soil salinity and sodicity shall be presented in more detail, as well as their perception on the influence of using different qualities of tubewell water on the salinisation and sodification processes. A link will be made between farmers' classification and the classification systems and indicators as used by scientists (see the theoretical framework).

Farmers' Salinity and Sodicity Classification for Soil and Water

Indicators for the recognition of saline/sodic soils

The case study in Watercourse Fordwah 14-R, as well as discussion with farmers during this study, showed that farmers use a number of indicators to recognise problems which are related to salinity and sodicity. Table 10 shows these indicators. In the second column, farmers' esplanations 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 10: 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 when the farmer has used a 'good' quality irrigation water, the soil is having a problem. Water can also stand on the field when a farmer has irrigated a 'good' soil with 'poor' quality tubewell water.
Cracks in the soil after irrigation.	If the soil had a good structure and this phenomenon occurs, the farmer knows that he has used a poor quality irrigation water and that the soil will turn hard.
Increased number of ploughings to get a good tillage layer.	The soil is turning hard due to the use of poor quality tubewell water.
Difficult to plough or harrow.	The soil is hard due to the use of poor quality tubewell water or is naturally hard.

Table 10 (continued).

Indicator	Farmers explanation
Sound of walking through a field has changed after irrigation.	A poor quality irrigation water has been used and a flour-like layer on the soil surface, under which is a one-inch hard layer, will develop.
Foot prints which look 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 extended 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.
6 White soil surface.	White salinity. This is either caused by the use of poor quality irrigation water or the salts originate 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 wliite salinity', as well as farmers who have plots with 'black and white salinity'.
Irregular crop growth	Salinity.
Stunted crop growth	Salts also dccpcr in tlic 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 tlic crop yellow.

Soil salinity/sodicity units

Farnicrs use the aforementioned indicators, or sonic of these indicators, to classify different salinity/sodicity units. To get a clear understanding of farmers' perceptions on salinity aiid sodicity, it is worthwhile to explore tlic terms which farmers use to indicate certain types of soil salinity arid sodicity. Farmers defined six salinity/salinity units to distinguish between the different types and levels of saline, sodic or waterlogged soils (Kielen, 1996). These distinct salinity/sodicity units will be used througliout this report. The fnriiicrs 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 tlic crust, or tlicy can be hard underneath. This typc of salinity is rcfcrred to as *chitta kolor* (*chitta* means white aiid *kalar* means salinity).
2. Soils which have only some patches of white crust, or where the crust is very thin. Also, this type of salinity-is rcfcrred to as *chitta kalar*.
3. Soils which have a black appcaraiicc aiid arc hard in tlic upper soil layer. This phenomenon is called ***kolo kolor*** (*kala* means black).

4. Soils which look good but which are hard deeper in the profile. The hardness is called *zacht*. Also, soils that are hard at the surface, or at a deeper depth, are referred to as being *zacht*. In Watercourse Fordwah 14-R the hardness in the soil was referred to as *kalrathi*. In the remainder of this report, the term *zacht* will be used for hardness of the soil.
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 *kolor 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 have to be muddy.
6. Soils which are waterlogged. Waterlogging is called *som*.

Sometimes, some soils have 'stones' at a depth of approximately one foot. These 'stones' are called *roor*. A variety of combinations of the abovementioned soils exist as well. These combinations are, for example: hard and white (*zacht and chitta kalar*); black and white (*kolo ond chitta kalar*); and black, white, and hard (*kala and chitta kalar, ond zacht*).

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 which are recognised by the farmers are: 1) the appearance of white salinity at the soil surface; 2) hardness of soils and water standing at the soil surface after irrigation; and 3) the appearance of black salinity after extensive use of certain types of tubewell water. When farmers talk about a good quality water, it means that the water does not cause a white or black salinity, nor hardness, in the soil.

Discussion on Farmers' Salinity and Sodicity Classification

Farmers classify salinity and sodicity on the basis of the physical appearance of the soil and the effect of salinity/sodicity on crop growth, irrigation, and land cultivation. Scientists classify salinity and sodicity mainly on the basis of EC, SAR_e, ESP, and pH. For evaluating the quality of irrigation water, EC and SAR are the most important factors. In order to reveal the farmers' understanding of salinity and sodicity, it is interesting to relate farmers' classification systems to theoretical classification systems supplemented by soil and water sample analysis.

Farmers' soil classification system

In Table 11, the farmers' soil classification system is compared with the USSL soil classification system. In the first line, the salinity and sodicity groups according to the USSL are given. The fist column contains the farmers' classification unit. In the cells below the USSL classification unit, the percentage of samples from a certain farmers' classification unit which correspond with a certain USSL classification unit is given. In between brackets, the total number of samples is given. This helps to interpret the data, as only a small number of samples were present of some classification units.

Table 11: Soil salinity classification according to the USSL and farmers' salinity classification system.

	Non-sal, non-sod	Saline - Sodic	Saline	Sodic
Black, hard	38 (3)	38 (3)		24 (2)
Black, white, hard	100 (1)			
Hard	94 (31)		6 (2)	
Little white, hard	50 (1)	50 (1)		
Little black, hard	100 (2)			
Little black, little hard	100 (1)			
Little white, little hard	100 (10)			
White	67 (4)		33 (2)	
White, hard	68 (23)	24 (8)	5 (2)	3 (1)
White, black		100 (1)		
White, little hard	100 (1)			
Black	100 (1)			
Little white	100 (3)			
None	99 (159)			1 (2)

The major conclusions which can be drawn from this exercise are:

1. Nearly one hundred percent of the soil samples which were classified by the farmers as having no saline-sodic properties, fall in the USSL classification unit of non-saline and non-sodic. Small differences might occur due to farmers' perceptions and some confusion in *killa* numbering;
2. Saline and hard properties occur under conditions which are classified by the USSL as non-saline and non-sodic; and
3. The occurrence of black salinity does not seem to be related to a certain USSL soil salinity/sodicity class. Organic matter dispersion is related to the soil pH, but pH is not taken into account in this evaluation.

The same exercise was carried out per textural group since sodic properties in the soil are influenced by soil texture (see Annex 1). Also, for this analysis the same conclusions were obtained. This evaluation shows the need to explore different parameters to explain the farmers classification of saline and sodic properties in the field.

The theoretical framework suggested that the EC_e, EC_e/SAR and SAR could be used as indicators for soil salinity, sodicity, and hard setting of the soil, respectively. On the basis of these indicators, a new evaluation was conducted. The average EC_e and SAR of the upper 30 cm was used for the evaluation because farmers judge their soils on the basis of the properties of the upper 30 cm, which corresponds roughly with the average ploughing depth. The analysis was undertaken by textural group (see Annex *2).*

From this analysis, several observations could be made.

- The standard deviations for the salinity (measured in EC_e) and the hardness of the soil (measured by EC_e/SAR) are quite small. Occasionally, the standard deviations are high for soils classified as having white salinity and no hardness. For white salinity, this is due to the fact that above a certain EC_e-value salinity is visible in the field. In recording farmers' perceptions, it was not specified whether the soils were white or very white: though, farmers occasionally mentioned it, For the non-hard soils, similar reasoning applies. Above a certain value of EC_e/SAR, the soils are not hard. It does not matter how high the actual value is above this value, the soils are non-hard which results in a large variability of values for non-hard soils.

- The standard deviations for hardness measured by SAR values are in general large. On the basis of this observation, it niight bc stated that tlic SAR is not a good indicator for the occurrence of hardness in tlic soil. as classificd by tlic farmers.
- Comparing the EC_e/SAR values between the different soil types leads to tlie conclusion that soils with a coarser texture have a lower value (below wliicli they arc classified as hard), than finer textured soils. *Initially*, fine sandy loam was classified as a scparatc texture class since it was not known whether its behaviour was like a medium or moderately coarse textured soil. From tlic EC_e/SAR valucs under which the soils arc classified as hard, it seems that the soil behaviour is similar to niodcratcly coarse textured soils.
- The occurrence of white salinity docs not seem to bc related to soil texture.

On the basis of this interpretation of tlic farmers' classification of saline and sodic soils. tlic following indicative values are suggested:

Moderntely fine		Medium		Moderately coarse	
None	Hard	None	Hard	None	Hard
> 0.65[5]	< 0.65[5]	> 0.45	< 0.45	> 0.30	< 0.30

Farmers' water classification system

A commonly used irrigation water classification system for the assessment of the suitability of ccrtnin types of water for irrigation is tlic water classification system of tlic FAO (Aycrs and Wcstcot. 1989). The fariiicrs water classification system is compared with this classification system. In between bmckcts. the total number of samples is given. This helps to interpret the data, as from some classification units only a small number of samples were present.

Table 14: Potential salinity problems (Ayers and Westcot, 1989).

	None	Slight to moderate	Severe
EC (dS/m)	< 0.7	0.7 - 3.0	> 3.0
None	4x (19)	52 (21)	
Little white		100 (5)	
White		79 (IS)	21 (4)

[5] Based on the average value of one watercourse. This is the only watercourse with moderately fine textured soils.

Table 15: Potential infiltration problems related to salinity (Ayers and Westcot, 1989)

		None	Slight to moderate	Severe
SAR	EC (dS/m)	> 0.7	0.7 - 0.2	< 0.2
0 -3	None	42 (11)	58 (15)	
	Hard	100 (3)		
SAR	EC (dS/m)	> 1.2	1.2 - 0.3	< 0.3
3 - 6	None	13 (1)	87 (7)	
	Hard	70 (7)	30 (3)	
SAR	EC (dS/m)	> 1.9	1.9 - 0.5	< 0.5
6 - 12	None		100 (4)	
	Hard	42 (5)	58 (7)	
SAR	EC (dS/m)	> 2.9	2.9 - 1.3	< 1.3
12 - 20	None		100 (1)	
	Hard	33 (2)	67 (4)	
SAR	EC (dS/m)	> 5.0	5.0 - 2.9	< 2.9
20 - 40	None			
	Hard		100 (1)	

The salinity classification of the farmers seems to be in line with the FAO classification system, though the threshold values are different. But an increased EC value gives increased salinity problems. For the classification of the sodicity problems, the farmers' classification is not in line with the FAO classification system. Many water samples do not fall in the sodicity class where they were expected to fall. Good examples are the water samples that were not expected to create sodicity problems. According to the farmers, many of these tubewell waters cause hardness in the soil. Two things could be concluded from this analysis. 1) the FAO classification system underestimates the sodicity problems. or 2) this analysis shows the need to explore different parameters and values to explain farmers' irrigation water classification. The theoretical framework proposed EC for potential salinity problems, RSC for sodification problems, and EC in comparison to the SAR for infiltration problems. A detailed analysis is given in Annex 3. Here, only the outcome of the analysis is discussed. On the basis of the analysis, the following values for assessment of probable sodicity problems caused by the use of tubewell water for irrigation are suggested:

Table 16: Water sodicity classification for medium textured soils.

	Infiltration		Hardness	
	None	Hard	None	Hard
EC/SAR	> 0.4	< 0.4		
RSC			< 0.8	> 0.8
EC			< 0.8	> 0.8

Table 17: Water sodicity classification for moderately coarse textured soils.

	Infiltration		Hardness	
	None	Hard	None	Hard
EC/SAR	> 0.3	< 0.3		
RSC			< 1.5	> 1.5
EC			< 0.9	> 0.9

A reduction in infiltration ratcs are prevented by a high total cation concentration (TCC) in comparison to the SAR of thc irrigation watcr. Fincr texturcd soils nced a higher TCC to prevent a reduction in infiltration rates. To prevent sodicity problems, tlic RSC in tlic irrigation watcr needs to bc low. In tlimry, tlic RSC-valuc iiccds to bc less than zcro. But according to farmcrs' cxpericncc, thc RSC can bc above zcro and no significant degradation of the soils has been observed, given that the TCC is bclow a certain valuc. Coarser tcxturcd soils can stand higher RSC and TCC lcvels before physical dcgradatioii is observed in the field.

Chapter 4

Farmers' Strategies and Practices to Cope with Salinity and Sodicity

Introduction

In tlic theorctical framework, a model for tlic decision-making process of thc farnicrs was proposed. The model takes tlic present salinity aiid sodicity situation as a starting point for the analysis. Farmers' perceptions on salinity aiid sodicity are formed by these physical conditions, their understanding of the salinity and sodicity processes, and by their farm goals, strategies, aiid internal and external constraints. On the basis of this pcrccptioii, fariiicrs define a salinitylsodicity strategy which results in the implementation of certain nieasurcs.

The foregoing cliaptcr and tlic case study (Kielen, 1996) revealed that most farnicrs have an excellent knowledge and understanding of present salinity and sodicity processes. Therefore, the major aim of this chapter will be to relate the physical environment aiid tlic farm cliaracteristics to the salinity and sodicity stratcgics aiid practiccs.

On tlic basis of the results of tlic case study carried out in Watercourse Fordwah 14-R, and on tlic basis of a first analysis of tlic interviews with farmers carried out in this study. the following hypothesis on farmers' stratcgics for coping with salinity and sodicity were made:

1. *llnder conditions of severe salinity, and where only large-scale changes in canal water distribution or drainage conditions con change the salinity and sodicity situation, farmers will not have a plan to decrease or stabilise the salinity and sodicity levels. Depending on rhe possibilities nnd constraints of the farming system. they might try to mitigate the effect of salinity and sodicity on crop growth.*
2. *Under favourable physical conditions, where there is no danger that salinity will develop. farmers do not need lo have a salinity and sodicity strategy; thus, there is no need to mitigate the effect on crop growth.*
3. *Under conditions where the initial salinity levels ore low. but where there is a hazard that salinity or sodicity might develop. most farmers will try to prevent the development of salinity ond sodicity. Depending on the characteristics of the farming system, some farmers might allow nn increase in (a port) of the farm. Since the initial levels ore low there is no need lo mitigate the effect on crop growth.*
4. *Under conditions that (parts of) the farm hove normal to high salinity levels and there arc hazards that the salinity might increase, ,formers might develop different strategies. The form of the strategy will largely depend on farm characteristics nnd possibilities ond constraints set by the farming systems. Further, it depends on the actual salinity levels ond on the possibilities and constraints set hy the farm, whether farmers will mitigate the effect of present salinity ond sodicity on crop growth.*

For tenants, another hypothesis was made. On tlic basis of the interviews with tenants in tlic case study. and on tlic basis of a first interpretation of the interviews conducted in this study. it will be assumed that: *generally, tenants will not have a salinity/sodicity strategy since they do not feel responsible for the quality of the soil*

Six Physical Conditions

The following six physical conditions have been distiiiguislicd. Initially, physical coiiditioa one and two had been classified as two conditions. but during tlic analysis it became clear that tlic groups had to be split into two parts to give a satisfactory explanation of farmers' reaction to salinity. A brief description of tlic physical coiiditions is presented in Table 19.

Table 18: Characteristics of six physical conditions concerning the salinity situation in Chistian Sub-division

Physical condition		Clinrncteristics
la	Severe problciiis	Extremely low canal watcr supply, (very) poor tubcwcll water quality
lb	Scvcrc problems	Low canal water supply. poor tubcwcll water quality. high saline ground water tables
2a	No problems	(Extremely) high canal water supply. or normally canal water supply with 'good' tubewell water quality
2b	Naturally decreasing problems	(Extremely) liigli canal water supply, or normally canal water supply with 'good' tubcwcll water quality, liigli initial salinity lcvcls
3	Hazards of developing problems	Initial low salinity levels, hazards of developing problems
4	Problciiis. and liazards of increasing problciiis	Normal to low canal water supply. normally to poor tubcwcll water quality. liigli to medium initial lcvcls of saliiiity in (parts of tlic) farm

Farming Systems in Chistian Sub-division

A farming system analysis was undertaken by Rinaudo (1994). in order to identify the main farming strategies, and to relate them to farm resources and constraints. Two hundred seventy eight farms from the 8 sample watercourses were statistically classified into II groups. homogeneous in terms of resources (canal water supply. tubewell ownership, land, labour. machinery), use of inputs, water use strategy (use of tubewell water. participation in water markets) production choices (cropping pattern) and structural constraints (staple food requirements for tlic family, salinity. and credit). Each group is characterised by a global objective (profit maximisation, autoconsumption, etc.) and a strategy defined as a set of rules farmers implement to achieve tlicir objective given ccrtaiii constraints. In order to see whether these groups could be used to explain farmers' reaction to salinity, farmers from all farm groups were interviewed. In Table 19, a sliort presentation of the main farm characteristics is given.

Table 19: Irrigated farm typologies according lo Rinaudo, 1994

Type	Farm clinrncteristic	Farm strntegy	Constraint
1	I. Small total operated area 2. Low capitalisation 3. Good canal water supply	Small percentage under sugarcane which is grown for cash income.	Cash (short run credit)
2	I. Siiiall total operated area 2. Low capitalisntioii 3. Good canal watcr supply	Low cropping intensities. Largc percentage under sugarcane which is grown for cash income.	Cash (short run crcdit)
7	I. Medium farm size 2. Low capitalisation (compensated by oxen and family labour) 3. Good canal water supply	Wlicat is grown for home consumption. Maximise the area under sugarcane within possible farm resources.	Cash Water
4	I. Siiiall total operated area 2. Low capitalisation 3. Non-tubewell owner	High use of inputs, but due to low croppiiig intensities aiid low soil fcrtility, output per hectare is low	Soil fertility
5	I. Siiiall total opcratcd area 2, Low lcvcl of capitalisation 3. Non-tubewell owner	Intensive farming. High purchase of tubewell water to grow wheat, cotton and sugarcane.	Upper limit purchased water
6	1. Tenants 2. Medium land holding 3. Low lcvcl of capitalisation 4. Non-tubewell owners	Intensive farming. Specialisation in wheat and cotton which have low crop water requirement. Low lcvcl of input use. Yields remain low.	Canal water Cash Labour
7	I. Small total opcratcd arca 2. Low level of capitalisation 3. Tubewell owner 4. Good canal water supply	Intensive farming. High cropping intensities of wheat and cotton. High level of inputs and sufficient irrigation water result in high output.	Land
8	I. Siiiall total operated area 2. High number of remittances 3. Large families 4. Poor canal water supply	Extensive farming, low crop intensities, low use of irrigation water. Only satisfy basic requirements, either food or fodder.	Water Salinity
9	I. Large farm size 2. High lcvcl of capitalisation 3. Tubcwcll owner 4. Good canal water supply 5. Good access to crcdit	Intensive farming. High cropping intensities. High use of inputs aiid sufficient irrigation water.	Land
10	I. Small total opcratcd area 2. Low lcvcl of capitalisatioii 3. Tubcwcll owner 4. Very poor canal water supply	Rice is grown as a reaction to salinity. Specialisation in sugarcane and cotton Wlicat is produced for home consumption.	Land
11	1. Large land holdings 2. Very large investment capacity 3. High level of capitalisation	High use of inputs. Market oriented farmers. Spccialiscd in cottoii production	Labour Cash

The typology wliich was obtained by Rinaudo is only one of tlic possible simplifications. The groups obtained reflect the choice of variables that wcrc used for statistical analysis. For the analysis of farmers salinity and sodicity strategies and practices, the variables per farm will he used. Afterwards, tlic link with the aforementioned farm typologies will be made.

Farmers' Strategies to Cope with Salinity and Sodicity

Froni interviews with farniers, it appeared that farmers liavc basically four strategies to cope with salinity and sodicity in their farming systems. These strategies arc:

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

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

Tenants and their Salinity and Sodicity Strategy

Forty seven percent of tlic interviewed farnicrs have some form of tenancy If no distinction is made on the basis of the type of tlic tenancy, tlic outcome of this analysis is as follows:

Percentage of non-owners	Salinity/sodicity strategy
69	No plan
22	Prevent an increase on least saline plots: no plans on saline plots
9	Decrease

Six Physical Conditions, Farm Characteristics, and Farmers' Salinity Strategy

In this section. farniers stratcgies to cope with salinity and sodicity are presentcd in the light of the possibilities and constraints of tlic physical environment This implies that it is cspcctcd that under sonic conditions all farniers will follow tlic samc strategy. Whilc under other physical conditions. it is cxpcctcd that fanners' stratcgics are morc rclatcd to fanning strategy and the possibilities and constraints sct by the fanning systcm

PC[6]	Expected strategy	Percentage
IA	No plan	83
IB	Prevent increase in small part of thc farm, allow an increase in the rest	ino
2A	No plan	Ino
2B	Dccrease	I00

Tlic analysis in tlic following sections shows that farnicrs stratcgics arc, in tlic first placc. rclatcd to tlic physical cnvironmcnt under which tlic farnicrs operate. Under conditions wherc farniers can largely influencc the dcvelopmcnt of salinity and sodicity, farm characteristics determinc the salinity/sodicity strategy. Fanners with high invcstmcnts in tlicir farms try to prevent an incrcasc. or cvcn to rcducc tlic salinity and sodicity. Under conditions where land is not a major constraint and thc lack of credit prevcnts farnicrs from having intensive farming. farnicrs tcnd not to have plans to control thc salinity and sodicity. Under most salinc/sodic conditions, farnicrs mitigate the effects of salinity/sodicity on crop growth. Only tlic largc mcchaniscd farms do not liave special mcasurcs to niitigatc crop grotli cffccts. They givc tlic samc treatment to all plots.

Salinity/sodicity strategies under physical conditions 1-3

Under physical condition IA. wherc fariiicrs have very low canal water supply and very poor tubewell watcr quality. salinity and sodicity is extremely difficult to control. Farmers interviewed who cultivate under these conditions liave experienced an increase in problcnis over thc past years. (Farms are all locatcd in Watercourse 130-R). Attempts by farnicrs to rcduce or prevent an increase in salinity problcnis have failed. In combination with low investment capacity and poor access to credit for thesc fanners, they do not try to prevent or rcduce tlic salinity and sodicity problcnis (anymore). One of tlic farnicrs. who was interviewed. had high hopes that with tlic installation of his new tubewell he would be able to prevent or mitigate present salinity and sodicity problems. All tlic fariiicrs under thesc conditions try to mitigate the effect of salinity and sodicity on crop growth within tlic possibilities and constraints of their farniing systems.

The areas in which fariiicrs. operating under pliysical condition IB. t n to prevent an increase in salinity and sodicity are mostly tlic least saline plots with. most likely. tlic lowest ground water tables. For this group of fariiicrs. tlic most limiting factors arc: I)high and saline ground watcr conditions under which crop growth is inipossiblc: and 2) lack of canal water. By taking tlic least productive areas out of cultivation. tlic fariiicrs

[6] Physical condition (PC)

increase tlic water availability to a smaller area. In tlicsc areas, crops can grow and a downward movement of salts prevents an increase in salinity. All of the farmers in this group try to mitigate the effects of salinity and sodicity on crop growth.

The farmers cultivating under physical condition 2A do not experience any salinity and sodicity problems, and there arc no hazards that salinity problems might develop. Therefore, they do not need to have any strategies to prevent or mitigate the cffccts of salinity. Sonic of these farmers decreased the salinity/sodicity levels in tlicir fields during tlic past.

All interviewed farmers who have farms under physical condition *28* are tenants. Since no landowners who cultivate under tlicsc conditions were interviewed, tlic tenants strategy is discussed here to demonstrate tlic possible stratcgics under tlicsc conditions. Tlic fnrnicrs speed up tlic dcsalinisation process by planting rice. They do iiot have to add amendments to dccrcasc tlic salinity. After several seasons of kallar grass cultivation. followed by rice cultivation, all otlicr crops can be grown on tlicsc plots without showing any salinity or sodicity stress. From this moment, these plots fall under physical conditic 2A.

All farmers wlio cultivate under physical coiiditioii 3, fncc liazards of developing salinity and sodicity problcnis on iion-saline and non-sodic plots. These farnicrs try to avoid the development of salinity/sodicity. Since tlic initial salinity levels arc low, tlicsc fnrnicrs do not need to do anything to mitigate tlic cffccts of salinity and sodicity on crop growth. Two fariiicrs. catagorised under physical condition 3. have in small parts of tlicir farms different physical conditions. One farnicr has two plots with some white salinity. In tlicsc plots. he tries to rcducc tlic salinity. The second farmer has two plots that he left fallow for a long tinic period. On these plots. salinity naturally developed. He docs not liavc plans to rcducc tlic salinity on these plots. Tlic difference in stratcgics of these two farnicrs can bc explained from tlicir farm characteristics. Land was determined to be tlic major constraint for tlic former farnicr. while for tlic latter, labour was identified to be tlic major constraint. In combination with the unfavourable location of tlic two plots of the latter fnriiicr, he leaves these plots fallow.

Salinity/sodicity strategies under phyysical condition 4

Fanners wlio cultivate undcr physical conditioii 4 liavc four diffcrcnt stratcgics to cope with salinity and sodicity. To understand the diffcrcnt stratcgics, tlicsc liave to bc studied in tlic light of tlic farm characteristics. In following sections, an analysis of farm clinrnctcristics per strategy is described.

Prevent increase in salinity under physical condition 4

The most determining characteristic in tlie choice of this strategy of preventing an increase in salinity/sodicity seems to be tlic use of inputs (Table 22). All farmers liavc high total variable costs To keep farming financially profitable. tlicy need to prevent an increase in salinity and sodicity.

Table 22: Farm characteristics of farms preventing an increase in salinity/sodicity.

ID[7]	Input use	Access to canal water	TW owner	Quality of TW water	Access to credit	Labour constraint	Cropping Intensity	Land constraint
72	high	low	owner	poor	good	no	high	yes
77	liigli	low	no		good	yes	high	yes
I12	normal	low	owner	poor	good	no	normal	no
207	high	no	owner	poor	good	no	normal	no
210	high	no	share	poor	good	no	low	no
213	high	extr low	share	poor	no	no	high	yes
220	high	no	owner	poor	good	no	high	yes
81	liigli	low	owner	poor	normal	no	high	yes

Half of these farmers have strategies to mitigate tlic effects of salinity and sodicity on crop growth. Whether farnicrs do adopt methods to niitigatc tlic effects depends on tlic level and cxtcnd of tlic salinity and sodicity problems and on tlic global farming strategy. To support this statement, sonic examples mentioned during tlic farm interviews will be cited licrc:

- *I just do the routine works of applying gypsum, single super phosphate, and potassium. I know that I could obtain better yields in some fields by planting on furrows, but I prefer to plant all my acres with a drill machine* (ID220, large land holding, mechanised, and intensive production).
- *I select the salt effected fields to grow sugarcane and fodder. In the non-effected fields I plant wheat and cotton. Since germination is effected by salinity I spread a 'fresh' layer of sand on the saline looking areas* (ID 72, small land holding, intensive production of wheat and cotton, manual labour).

No salinity/sodicity plan under physical condition 4

The choice of this strategy (no salinity/sodicity plan) seems to be a combination of limited possibilities to adjust irrigation water quality, poor access to crcdit, and tlic absence of a land constraint (Table 23). Through their poor access to credit, these fariiicrs, more or less, operate under tlic same conditions as the farnicrs of PC 1A. Land availability is not a major constraint. Under increasing salinity problems, tlic availability of good farm land is cxpcctcd to become a constraint in the future. Whether the fariiicrs will change tlicir plans and will start to invest in anti-salinity measures is not ascertained. All farmers try to mitigate the effect of salinity and sodicity on crop growth.

ID	Input use	Access to canal water	TW owner	Quality of TW water	Access to credit	Labour constraint	Cropping Intensity	Land constraint
178	normal	cxtr low	owner	poor	no	yes	normal	no
179	low	low	owner	poor	no	yes	low	no

Prevent and reduce salinity/sodicity under physical condition 4

Only one farm under physical condition 4 that follows a strategy to prevent and reduce salinity/sodicity, was interviewed. The most determining factor for this farmer seems to be high total variable costs, like for tlic farmers who try to prevent an increase in salinity and sodicity. This farmer could have been grouped in

[7] Identification number (ID) assigned to farmers during the base-line survey in 1993

the first group o f farmers who prevent an increase in salinity, but **he has some fields where he tries** to reduce **the** salinity levels. **This** farmer tries to niitigate the effects on crop **growth** as well.

ID	**Input** use	**Access** to **canal water**	TW **owner**	**Quality of** TW **water**	**Access to credit**	**Labour** constraint	**Cropping** Intensity	**Land constraint**
75	high	low	no		normal	yes	normal	no

Farmers' Salinity and Sodicity Strategy Related to the Farm Typology

When comparing farmers' stratcgics with tlic **farm** typology, **one** initial **comment** should bc **made**. **There seems** to **be** a great heterogeneity o f fann characteristics within **one** group. Sonic farmers are catcgoriscd in a **certain** group. while **one** or two **farm** characteristics do not **match** the stereotype fariiier o f this **group**. **In cases where these** characteristics explain farmers' strategies to **cope** with salinity and sodicity. it is difficult to **relate** this **strategy** to **farm** type. In Table 2.5 farmers' **strategies** to **cope** with salinity and sodicity **per** physical **environment** are related to **the percentage** of fanners **interviewed** during this study, **that belong** to **a** certain **farm** group.

Physical **condition**	Strategy	**Farm** group	**Percentage**
1A	No **plan**	4	33
		5	33
		7	33
1B	**Prevent increase in small area**	3	20
		8	80
2A	No plan	I	14
		2	14
		3	29
		4	14
3	Avoid **development**	3	33
		9	67
4	**Prevent increase**	7	43
		8	14
		in	14
		11	29
	Prevent **and** reduce	I	100
	No **plan**	10	100

Tlic **farm** groups **operating under physical** condition 1A are **characterised** by **intensive** cultivation **and** a **high use** o f inputs. It would **bc expected** that tlic fanners would **use** a lot o f inputs to **prevent** tlic **development of** salinity **and** sodicity **and** to mitigate tlic cffcct on crop growth. **Instead,** none o f **the** farnicrs **have** a plan. Ecsidcs that, tlic **interviewed farmers** do not **meet the characteristic** o f using **high amounts** o f inputs. all o f the interviewed farnicrs arc situated in Watercourse Fordwah 130-R. In this watercourse salinity and sodicity is a fairly new problem aiid it seems that fanners have not yet reached a stage in which they are willing to invest in salinity and sodicity nieasures.

Most of the fanners operating under physical condition I6 belong to Farm Group 8. These farms are characteriscd by very low cropping intensities. very low canal watcr supply, and are highly dependent on remittances. This seems to rcflcct tlie physical conditions undcr which these faniicrs operate. Their farm strategy consists of satisfying tlicir basic requirements, which reflects their salinity strategy as well (prevent tlie increase of salinity/sodicity on a small area).

Under physical condition 2A. the good canal watcr supply of the majority of fariiicrs (Farm Groups 2, 3, aiid 9) reflects tlie favourable conditions under which thcy opcratc.

The groups of fanners operating under PC 3 arc characterised by a good canal water supply. as well as highly intensive farming with a high use of inputs. These famicrs differ from tlic farmers under physical condition 2A in tlic sense that thcsc farmers rely on poor quality tubewell water for supplementary irrigation. in case of canal water shortage. Farmers operating under physical conditions 2A do not use tubcwcll water at all, or have access to good quality tubewell water. The fariiicrs operating under physical condition 3 try to avoid the development of salinity/sodicity problems, while tlie fanners operating undcr physical conditions 2A do not need to develop a strategy because tlic hazards of developing salinity/sodicity problems do not exist.

The majority of farniers who have the stratcgy to prevent salinity under physical condition 4 (Farm Groups 7, 10. I I) have some characteristics in common: I) they make intensive use of their land; and 2) they use a high amount of inputs in one or more of tlicir crops.

The farmer who prcvciit and rcduccs salinity on his farm under physical condition 4 represents Farm Group I in tlie sense that his farm outputs arc low. He differs from the prototype farmer in this group because he uses a lot of inputs. This reflects the farmer's efforts to increase the farm output.

The two famiers who are classified as belonging to Farm Group 10 do not represent this group. These fanners have an extremely poor access to canal watcr, they own a poor quality tubcwcll. use little inputs, and do not have access to credit. On top of that. they face a labour constraint, Thcsc constraints make it nearly impossible to undertake salinity and sodicity measures.

Physical Conditions, Farm Characteristics, and Farmers' Salinity Practices

During the 'forniulation' of the salinity/sodicity strategies. it was assumed that farnicrs already anticipate the possibilities and constraints set by their farming system, which will occur under different physical circumstances during the implementation of their salinitylsodicity practices. Determining farm characteristics are: tlic availability of labour, land. credit, organic matter. watcr. total variable costs. and the importance of a certain crop in the farming system. These farm characteristics arc presented in Annex 4. In this section, the practices are analysed according to physical environment. For tlic physical environment, a link is made between the salinitylsodicity strategy, farm characteristics, aiid practices.

Salinity/sodicity practices under physical condition 1A

All farmers operating in this physical environment are located in Watercourse Fordwah 130-R. The use of poor quality tubewell water is the cause of the salinity and sodicity problems which evolve at a slow pace. None of these farmers have an excellent access to credit or an intensive way of cultivation. Because of negative experiences and a lack of means to purchase inputs, farmers have stopped trying to overcome the problems. Instead, farmers focus on mitigating the effects of salinity and sodicity on crop growth (Table 26).

Table 26: Salinity/sodicity practices under physical condition 1A.

ID	Mitigate
237	Rice with as much canal water as possible
249	Farm yard manure for cotton, six times ploughing
252	six times ploughing
267	Farm yard manure, canal water to fodder
273	canal water to fodder

The solutions they implement do not seem to have any distinct relation with certain farm characteristics. For example, some farmers with a lot of cattle per hectare try to improve the soil structure by applying FYM, while another farmer with a high number of cattle per ha docs not use FYM to improve the soil structure. Farmers with a labour constraint indicated they have increased the number of ploughings per ha. while fanners without a labour constraint did not mention this option as a method the mitigate the effect of hardness of the soil on germination. The lack of a strong relation between farm characteristics and practices might result from the fact that salinity, and especially sodicity problems. are fairly new in this watercourse and the problems are evolving slowly.

Salinity/sodicity practices under physical condition 1B

All these farmers have remittances and low cropping intensities. They give much attention to the crop which is important for their home consumption. Wheat in the case of ID 114, who has a very high number of family members, along with fodder for cattle in the cases of ID 87, 108, and 112 (Table 27).

Table 27: Salinity/sodicity practices under phyical condition 1B.

ID	Mitigate
87	In time sowing; fodder best fields; FYM; frequent irrigation
108	Fodder on best fields irrigated with canal water; removal of top soil
112	Fodder irrigated with canal water and application of FYM
114	Wheat irrigated with canal water
115	FYM

Salinity/sodicity practices under physical conditions 3

Fnriiicrs operating under physical conditions 3 prevent tlic development of salinity niid sodicity The only threat for these farmers through which snliiiity and sodicity can develop is by using poor quality tubewell wntcr. Tlic fnriiicrs t n to avoid the iisc of tubewell wntcr as much as possible (Table 28).

ID	Prevent development
76	Mix tubewell wntcr with cniinl wntcr in case of canal shortage
135	Avoid tubewell water iisc niid especially with low quality
150	Mix tubewell wntcr with cniinl wntcr in case of cniinl shortage

Practices under physical condition 4 with the strategy to prevent an increase in salinity sodicity

Like iiiidcr physical condition 3, non-tubewell owners seem to linvc the possibility to select tlic best quality tubewell water. tubewell owners seem to be iiiorc inclined to use tlicir own tubewell. There is oiic exception to tlic rule. In this cnsc. a tubewell owner made use of another tubcwcll. The difference in quality is tremendous. This fnriiicr is able to invest a lot of money in farming and docs not have crcdit constraints. Tlic iisc of FYM to improve tlic soil structure is limited to fnriiicrs with cattle. Fnriiicrs who linvc both cniinl and poor quality tubcwcll water, mix tlic cniinl wntcr with tubewell wntcr. For tlic farmers who implement this practice. land is oiic of their major constraints. They try to keep the entire farm salinity free or below a certain snliiiity level. Tlic farmers who completely depend on tubcwcll wntcr include a rice crop in their crop rotation to leach tlic salts froiii the profile. Gypsum is used by the fnriiicrs whose physical condition of land and water requires the application of gypsuiii aiid who have good access to crcdit niid high total variable costs. One farmer grows kallar grass, since growth of other crops give only economic losses under present physical coiiditions (Table 29).

Table 29: Practices under physical condition 4 with the strategy to an increase prevent increase

ID	Prevent an increase	Mitigate the effect
72	TW sclcctioii: avoid TW iisc	Crop sclcctioii: FYM: fresh layer of sand
77	TW sclcctioii; avoid TW use; priority iisc cniinl on snliiic plots; gypsum	Crop clioicc (wheat aiid cotton on non-saline plots)
81	Priority iisc canal on saline plots	
I12	FYM, mix cniinl with TW	Crop clioicc (fodder on non-saline plots)
207	Rice in crop rotntioii: gypsuiii: FYM	SSP. potassium
210	salinity grass	
220	Rice in crop rotation: gypsum: SSP; potassium	
213	Ricc in crop rotation	pre-plant irrigation, furrows

To mitigate salinity effects. crop choice (whereby wheat and cotton are grown in the least saline areas) is practised by farnicrs who have high total variable costs. Two farmers who have high total variable costs but did not mention crop sclcction in particular fields. only grow cotton and wheat. One fariiicr with normal total variable costs. but with a high number of cattle per ha. plants fodder in tlie least saline plots. In short. tlie crops that are most important for a farming system are grown in tlic best plots. Farmers with high investment capacity. high total variable costs, good access to crcdit, and who have. in this case. only access to tubcwcll watcr for irrigation, use fcrtilisers like single super phosphate and potassium to mitigate the effect of salinity and sodicity on crop growth.

Salinity/sodicity practices under physical condition 4 and no salinity/sodicity plan

The three farmers operating under physical conditions 4, liavc not got access to crcdit and have a low investment capacity. They all go for low-cost solutions which arc possible within their farm constraints

ID	Mitigate the effect
I78	pro-plant irrigntion: timing irrigation
I79	pre-plant irrigation; timing irrigation
213	prc-plant irrigation; furrows

Practices under physical condition 4 to prevent an increase and reduce present levels of salinity

This fariiicr seems to be highly aware of the causes of, tlic effects of, and tlic practices to cope with salinity and sodicity problems. This farmer invests a lot of effort and time in reducing, mitigating, and preventing an incrcasc in salinity and sodicity (Table 31).

Table 31: Practices to prevent and reduce an increase and mitigate the effect of salinity and sodicity

	Prevent and reduce	Mitigate
75	janter irrigated with canal water: TW sclcction: mix canal and TW watcr: gypsum; continuous cropping: land levelling	first irrigation nftcr ploughing and sowing; frequent irrigation

Farmers' Salinity and Sodicity Practices Related to Farm Characteristics

Foregoing section showed that the practices that farmers implement are, in the first place. a result of tlic physical conditions under which tlic farmers cultivate. Secondly, they are in line with the salinity/sodicity strategy and the possibilities and constraints set by tlic farm characteristics Table 32 is a summary of the most common relations between farm characteristics and possible practices.

Table 32: Practices related to farm characteristics

Fnrm clinracteristics	Practices
Cattle owners	Farm yard manure application
Non-tubewell owners	Tubewell sclcction
Access to poor tubewell water and canal water	Mix both waters
Important crop in farniing system (high inputs. home consumption, or fodder for cattle)	Plant on lcast saline field Allocate canal water with priority to this crop
Only access to (poor quality) tubcwcll water	Rice in crop rotation
Good access to crcdit and high total variable costs	Use of inputs like gypsum, potassium, and SSP
Poor access to credit and low total variable costs	Low cost practices like timing of irrigatioii and pre-plant irrigation, removal of top soil
Important crop in farming system	Priority canal water, or planted in least saline plots

Chapter 5

Farmers' Ability to Cope with Salinity under Improved Water Supply

The forcgoiiig clinptcr demonstrated that fnriiicrs' salinity and sodicity strategics arc. in tlic first place. related lo the physical and irrigntioii environment and, in tlic sccoiid plncc. to tlic possibilities and constraints of their farming systems. In this chapter. tlic abilities of fnriiicrs to improvc their snliiiity niid sodicity management under management interventions at higher levels of tlic irrigation system will evaluated. The four watercourses that represent the four salinisation niid sodification processes will be used for this purpose.

Watercourse Fordwah 14-R

Currently. two proccsscs play a role in tlic salinisation of this watercourse: 1)salinisation/sodification due to tlic use of poor quality tubewell wntcr; and 2) salinisation/sodification due to capillary rise from high saline-sodic ground wntcr tnblcs. Under iiiiprovcd cniinl wntcr supply. the fariiicrs in tlic iiiiddlc of the watercourse would use less tubewell water. Farmers in this nrcn try to cope with snliiiity by selecting the best quality tubewell water and mixing cniinl water with tubewell wntcr. Some of tlie farmers in the middle of tlic wntercoursc have good access to credit niid linvc high total variable costs. These fnrnicrs would be nblc to control salinity niid sodicity with a high use of amendments iiiidcr present conditions. Though. whether this is financially feasible depends largely on the actual access to cniinl wntcr niid the quality of tubewell water nvnilnblc. Also. tlic availability of gypsum on tlic market would be important. An increase in canal water supply will improve the overall irrigntioii water quality. Especially farmers with a credit constraint. they will be bcttcr armed to cope with the salinity/sodicity problems.

For farmers froiii tlie tail nrcn, where capillary salinisation plays a major role and where good tubewell water is iiot directly nvnilnblc. iiiiprovcd cniinl wntcr supply will help to cope with tlic salinity. The cxpcricncc from watercourse Azim 20-L showed tlint fnriiicrs arc nblc to grow crops under coiiditioiis with high saline ground water tnblcs. An important coiiditioii is tlint tlic depth of wntcr table allows sufficient aeration of the root zone niid tlint cniinl water is regularly available to maintain a downward flow of water through tlic root zone. At places where tlic water tnblcs are too shallow to allow sufficient aeration of tlic root zone, iiiiprovcd cniinl water siipply will iiot iiiiprovc crop prodiictioii. as these fnriiicrs do iiot linvc tlic capability lo pay for a drainage system, and many farmers arc tenants who do iiot invest iii long-term projects.

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Watercourse Fordwah 130-R

The salinisation aiid mainly sodificatioii in Watercourse Fordwnli 130-R is caused by the iisc of poor quality tubewell water. Tccliiiically. tlic situation can be improved by tlic iisc of an extremely high amount of amendments. None of tlic interviewed fariiicrs hnvc good excess to credit or an intensive way of farming. Though improvement of tlic ciirrciit water quality is technically possible, these fariiicrs would iiot be able to cope with the salinity aiid sodicity due to a limited availability of resources. Improved canal water supply will improve tlic quality of the used irrigation water substantially, which would lessen tlic required iiiputs. With tlic required know-how, fariiicrs will bc nblc to coiitrol the situation. Another condition would be that gypsum is availablc iii tlic iiiarkct.

Watercourse Azim 111-L

Tlic historical analysis of the salinity aiid sodicity situation has shown that ciirrciit problems are largely related to the iisc of poor quality tubewell water in tlic absence of canal water. Soiiic of the larger farmers with a good investment capacity arc obtaining high yields with a high iisc of iiiputs. Small fariiicrs. or farmers with low investment capacity. will gain most froiii improved canal water supplies. These farmers try to cope with salinity and sodicity by integrating rice or a salt-tolerant grass iii tlic crop rotation. Other low cost options like prc-plant irrigatioii and planting on furrows, arc practised as well as. Tlic effects of sodicity on tlic nutrient uptake by tlic crop arc not reduced iii this way. Tlic salinity is kept low. but sodicity keeps building up. Unless they get access to better quality tubewell water. these fnriiicrs will never be able to compensate fully for the effects of sodicity on crop growth. Under improved cniinl water supplies. the initial salinity and sodicity has to bc reduced. This can be done citlicr by low cost. but time consuming practices. or by the iisc of gypsum or acids for which cash needs to be availablc. Also. tlic iiiputs need to be available iii the iiiarkct.

Watercourse Azim 20-L

Salinity aiid sodicity dcvclopcd during long fallow periods through capillary rise froiii high (saline) ground water tables. Fariiicrs who have been cultivating their land continuously did not experience any salinity/sodicity problems. Tliis watercourse, bciiig situated at tlic licad of tlic distributary, receives a good canal water supply. At present, fnriiicrs arc reducing salinity and sodicity levels by leaching tlic salts using good quality canal water under tlic cultivation of kallar grass and ricc. Improvement in caiinl water supplies are iiot required in this watercourse. Problems with waterlogging will remain unless owners will collectively invest in drainage facilities.

Chapter 6

Conclusions and Recommendations

Conclusions

Farmers' perceptions on salinity and sodicity

- Farmers have a good set of physical and crop appearance indicators to recognise different salinity and sodicity processes and types of salinity.
- Farmers define five different salinity and sodicity units, and one unit for identifying waterlogged coiiditions. Comparison between tlic fariiicrs' classificatioii system and the USSL soil classification system showed that saline and sodic propcrtics, as defined by the fariiicrs, occur under coiiditioiis which would bc classified as non saline - non sodic by tlic USSL classification system.
- Evaluation of farmers' classification on tlic basis ofotlicr indicators sliowcd that tlic ratio EC_e/SAR is a good indicator for 'hardness' in tlic soil. Tlic 'tlircsliold' values below wliicli soils are classified as being 'hard' differ per textural class. Coarser textured soils have a lower tlircsliold value than finer textured soils. The occurrence of 'white salinity' is related to tlic EC, value of tlic soil but not to tlic textural class.
- Farmers classify tlic salinity hazards of irrigation water in a similar way as tlic FAO irrigatioii water classification system docs. When tlic EC in tlic irrigation water increases, tlic chances of development of soil salinity increases. Tlic sodicity hazards induced by tlic use of irrigation water docs not correspond with the FAO classification system. Water which is not expected to crcatc sodicity problciiis according to tlic FAO system might crcatc sodicity problciis according to fariiicrs' experiences. Tlic exploration of different parameters to explain the fariiicrs' classification system demonstrated that long-term sodicity problciiis. recognised by the fariiicrs as 'hardness' in tlic soil, can bc predicted by tlic RSC and EC levels in tlic irrigation water. Infiltration problciiis, which arc rccogniscd instantaneously by tlic farmers through standing water on the soil surface, can be predicted by tlic EC/SAR ratio of the irrigation water. Tlic 'tlircshold' values for these phenomena differ by textural group.
- Saline or saline-sodic conditions are easier to manage and decrease for the farnicrs than sodic conditions.

Farmers' strategies and practices to cope with salinity/sodicity

- Due to their temporarily rights on the land (often lease contracts arc made-up for one year), tenants do not have a strategy to prevent or reduce salinity/sodicity. They t n to mitigate tlic effect on crop growth.
- For land owners, tlic salinity/sodicity strategy is related to the physical and irrigatioii environment. Only under conditions where it depends largely on tlic farming activities in wliicli direction the salinity/sodicity development will move; farming strategies. possibilities, and constraints start to play an important role in tlic 'formulation' of tlic salinity/sodicity strategy.

- Farmers with large investment costs try to prcvcot an increase iii salinity and sodicity, or even try to decrease salinity/sodicity. Under conditions where land is not a constraint, but limited availability of resources prcvciit farmers from having highly intensive farming, faniicrs tend not to have plans to control salinity/sodicity. Most of these farmers try to mitigate tlic effects on crop growth
- A link is made between farm typology and salinity/sodicity strategy according to the physical and irrigation environment. Due to heterogeneity of farm cliaractcristics within one group, it was impossible to niake a link for all individual farms between farm type and stratcgy.
- The salinity/sodicity practices that famiers implement are, in tlie first place, a result of tlie physical aiid irrigation environment. Secondly, they are in line with tlie strategy, possibilities. and constraints set by the fanning system.

Farmers' ability to cope with salinity/sodicity under improved canal water supply

- At present, farmers in many areas nrc ablc to cope with salinity and sodicity. This are mostly fariiicrs with good access to canal water, or canal water supplemented by good quality tubewell water In places where tlie use of tubewell water might cause salinity/sodicity problems, it are mostly tlic faniicrs with good investment capacity who are able to control salinity/sodicity and mitigate the effects on crop growth.
- Especially famiers with limited farm resources will benefit froiii improved canal water supplies

Methodology

- Participatory Rural Appraisal techniques. aiid in particular mapping exercises. are very useful to obtain a quick insight into current salinity/sodicity problems and processes
- For the interpretation of farmers' perceptions, strategies. and practices, additional data on soil. water, aiid ground water, as well as socio-economical information, is indispensable.

Future Research

- This study has shown that sodicity related problems form a larger threat to sustained crop production than saliiiity. In this study. an attempt was made to come up with new 'paraiictcrs' nnd 'guidelines' to relate sodicity in soil aiid water to soil degradation. The 'guidcliiics' and 'parameters' based on farmers' perceptions could be used as a starting point for an in-depth physical-chemical research program.
- In areas wliere salinity/sodicity is a fairly new problem, which is induced by the use of poor quality tubewell water, farnicrs rcquirc detailed guidcliiics and field demonstrations on the use of soil and water amendments to counteract tlie effects of sodicity on soil and crops. In cases wliere salinity is the major concern, guidcliiics and field dcmoiistrations should include improved irrigation management. To be able to compile these guidelines and to set the demonstrations. field trials are required.
- More research should be done on low cost alternatives to enable poorer farnicrs to control salinity and sodicity.
- There is a strong demand to search for high value crops which can be grown during soil reclamation or under highly saline-sodic conditions.

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Annex 1

Comparison between Farmers' and USSL Classification Systems

None	R3 (5)			17 (1)

Table 2: Classification of moderately coarse textured soils according to USSL and farmers' classification

	Noii sal - non sod	Saline - Sodic	Saline	Sodic
Hard	I00 (4)			
Little white, little liard	100 (I)			
White, hard				100 (I)
None	100 (20)			

Black, hard		33 (I)		67 (I)
Hard	100 (21)			
Little white	I00 (3)			
White. black		100 (1)		
White, hard	64 (7)	18 (2)		
None	91 (74)			3 (2)

Table 4: Classification of medium textured soil according to USSL and farmers' classification system.

	Non sal - non sod	Saline - Sodic	Saline	Sodic
Black, hard	60 (3)	40 (2)		
Black, white, hard	100 (1)			
Hard	83 (5)		17 (1)	
Little white, hard	50 (1)	50 (1)		
Little black, hard	100 (2)			
Little black, little hard	100 (1)			
Little white, little hard	100 (8)			
White	67 (4)		33 (2)	
White, hard	60 (15)	32 (8)	8 (2)	
White, little hard	100 (1)			
None	100 (59)			

	Non sal - non sod	Saline - Sodic	Saline	Sodic
Hard	50 (1)		SO (I)	
Little black, little linrd			100 (1)	
White, linrd	100 (1)			
None	100 (1)			

Annex 2

Evaluation of Indicators per Salinity Class

In the following tables, the average values for the different indicators per salinity class. as defined by the farmers, by watercourse is given. The values given in italics are the standard deviations. Occasionally, samples have not been used for the assessment since they differed significantly from the other samples of a specific class. In these cases, farmers' perceptions on salinity and sodicity might have been different, or there might have been confusion in *killa* numbers.

Table 1: Medium textured top soil.

WC	White salinity (EC dS/m 0-30 cm)			Hardness (EC/SAR 0-30 cm)			Hardness (SAR 0-30 cm)		
	None	Little	White	None	Little	Hard	None	Little	Hard
130-R	1.10 *0.22*			0.44 *0.16*		0.30 *0.10*	3.73 *1.58*		4.45 *1.58*
62-R	1.21 *0.33*	1.36 *0.21*	1.60 *0.07*	0.58 *0.07*	0.85 *0.53*	0.34 *0.13*	2.25 *0.68*	2.71 *1.95*	5.33 *1.84*
46-R	1.04 *0.13*	2.26 *1.23*		3.48 *3.86*			5.90 *7.97*		
111-L	2.14 *0.19*	1.98 *0.18*	2.65 *1.25*	0.30 *0.02*	0.30 *0.03*	0.25 *0.02*	7.13 *0.95*	5.45 *1.07*	12.29 *6.11*
63-L	1.33 *0.35*		2.78 *1.15*	0.65 *0.20*		0.51 *0.22*	2.34 *1.11*		7.39 *6.11*
43-L	1.65 *0.92*	1.88 *0.78*	4.27 *3.56*	0.87 *0.60*		0.48 *0.16*	3.21 *2.35*		9.16 *7.40*
20-L	1.07 *0.23*			1.28 *1.3*			1.21 *0.67*		
Avg	1.36	1.87	2.83	7.60	0.57	0.38	3.68	4.08	7.72

Table 2: Moderately coarse/medium textured top soil.

WC	White salinity (EC dS/m 0-30 cm)			Hardness (EC/SAR 0-30 cm)			Hardness SAR 0-30 cm)		
	None	Little	White	None	Little	Hard	None	Little	Hard
130-R	1.54 *0.34*		2.9 *1.67*	0.30 *0.22*		0.23 *0.09*	8.15 *4.11*		10.80 *5.67*
62-R	1.23 *0.47*		2.37 *0.47*	0.67 *0.40*		0.27 *0.02*	2.70 *2.15*		8.99 *1.27*
46-R		0.82 *0.18*	1.2 *0.47*	0.58 *0.33*			1.89 *1.16*		
111-L									
63-L	1.47 *0.56*			1.20 *0.94*		0.34 *0.10*	2.95 *2.51*		2.37 *0.93*
43-L									
20-L									
Avg	1.41	0.82	2.16	0.69		0.28	3.92		7.39

Table 3: Moderately coarse textured top soil.

WC	White salinity (EC dS/m 0-30 cm)			Hardness (EC/SAR 0-30 cm)			Hardness (SAR 0-30 cm)		
	None	Little	White	None	Little	Hard	None	Little	Hard
130-R	1.12 *0.36*			0.33 *0.13*		0.25 *0.05*	4.01 *2.91*		7.56 *3.88*
62-R									
46-R									
111-L									
63-L									
43-L									
20-L	0.71 *0.24*			1.95 *2.37*			0.80 *0.51*		
Avg	0.92			1.14		0.25	2.41		7.51

Table 4: Coarse textured top soil.

WC	White salinity (EC dS/m 0-30 cm)			Hardness (EC/SAR 0-30 cm)			Hardness (SAR 0-30 cm)		
	None	Little	White	None	Little	Hard	None	Little	Hard
130-R									
62-R	2.46 *0.75*			0.29 *0.02*			8.32 *1.97*		
46-R									
111-L									
63-L									
43-L									
20-L									
Avg	2.46			0.29			8.32		

Table 5: Moderately fine textured top soil.

WC	White salinity (EC dS/m 0-30 cm)			Hardness (EC/SAR 0-30 cm)			Hardness (SAR 0-30 cm)		
	None	Little	White	None	Little	Hard	None	Little	Hard
130-R									
62-R									
46-R									
111-L									
63-L			4.87 *0.93*			0.67 *0.17*			6.1 *1.94*
43-L									
20-L									
Avg			4.87			0.67			6.1

Annex 3

Evaluation of Farmers' Water Quality Assessment

The water quality assessment is done at the watercourse level. In the following tables, the tubewell identification number is given. tlic soil type on which tlic water is used is presented in tlic second column tlic values on which tlic evaluation of farmers irrigation water quality assessment will take place arc presented in tlic third to tlic fifth columns, and some remarks which wcrc given by the farmers to support tlicir water quality evaluation arc presented in tlic last column.

Azim III-L

Table 1: Water classification of Watercourse Azim III-L

TW No	Classification	RSC	EC	SAR	EC/SAR	Soil type	Remarks
31	good	-0.7	1.21	2.62	0.46	medium	Not as good as canal water
32	good	0.7	1.67	4.09	0.41	medium	Two years ago they changed to 18[illegible], now the water is good. Before it made the soil very hard and very white
33	good	-0.5	0.58	1.34	0.43	medium	Boundaries just a bit white
37	hard	1.6	1.29	4.17	0.31	medium	Long term process
35	hard, little white	0.7	0.88	2.08	0.42	medium	
34	hard, white	1.9	0.95	2.33	0.41	medium	
36	hard, white	2.3	1.29	5	0.26	medium	Soil surface is hard. After two years the soil was hard and water was standing on the soil

All water is used on medium textured soils. Tlicrc is not a logic in tlic classification of water causing white salinity by looking at the EC values. The crcatioii of white salinity seems to bc related to the formation of hard soils. Tlic creation of hardness in the soil seems to bc rclatcd to tlic RSC. Irrigation water with RSC values below 0 do not cause hardness, and water with RSC values exceeding 0 cause hardness in the soil. The classification of Tubewell 32, which causes hardness in the soil, could not be explained by looking at the RSC value. In this case, tlic farmer's perception on the quality of his tubewell water might be different. This farmer changed tlic depth of his tubewell two years back. He is now pumping water from 60 metres depth, instead of 53 metres dcptli. He claims that tlic quality of tlic water is much bcttcr compared with the water quality he was pumping before.

Azim 20-L

Table 2: Water classification for Watercourse Azim 20-L.

TW No	Classification	RSC	EC	SAR	EC/SAR	Soil type	Remarks
103	good	-1.6	0.64	0.88	0.73	medium	
101	good	-0.3	0.6	1.6	0.38	mod. coarse	
104	good	-0.4	0.68	1.3	0.52	mod. coarse	

All three tubewell waters have a negative RSC value and a low EC value (average 0.64 dS/m). The water does not cause hardness in the soil, neither does it cause white salinity.

Azim 43-L

Table 3: Water classification for Watercourse Azim 43-L.

TW No	Classification	RSC	EC	SAR	EC/SAR	Soil type	Remarks
56	good	-0.2	0.7	2	0.35	medium	It increases problems if soil is already hard and saline
58	good	0.5	0.56	1.6	0.35	medium	
59	good	-1.6	0.73	0.05	14.6	medium	
99	good	-2.4	1.06	1.07	0.99	medium	
100	good	-4.2	1.18	1	1.18	medium	Uses mostly canal

All tubewell water were classified by the farmers as having a good quality. which does not cause hardness or white salinity. Four of the five tubewells have a RSC value below 0. The EC value of all tubewells is low. By looking at the RSC values. it could be expected that the use of Tubewell 58 would have caused hardness in the soil. though farmers have classified the water from this tubewell as good The water from this tubewell has a very low EC and low RSC values. Due to its low salinity and sodicity content. the sodification process might be so slow that the farmer cannot observe the process as such in the field

Azim 63-L

Table 4: Water classification fir Watercourse Azim 63-L.

TW No	Classification	RSC	EC	SAR	EC/SAR	Soil type	Remarks
45	good	-0.3	0.66	0.82	0.80	mod fine	
89	good	-1.0	0.58	0.11	5.27	mod fine	
43	good	-1.4	0.66	0.3	2.2	medium	
44	good	0.8	0.82	2.3	0.36	medium	
109	good	-0.6	0.46	0.14	3.29	medium	
41	black salinity	2.2	1.5	4.45	0.34	mod coarse	In the long run it will cause black salinity. Now it is only bad for the cotton
43	good	-1.4	0.66	0.3	2.20	mod coarse	
45	good	-0.3	0.66	0.82	0.80	mod coarse	
109	good	-0.6	0.46	0.14	3.29	mod coarse	

Tubewell wntcr having a RSC value below 0. used on soils having different textural classes, are all classified as good qiinlity water. Tubewell 44 has a low positive RSC value and low salinity and sodicity coiicciitrntioiis. For the same reasons as described for Tubewell 5X. this water might have been classified by tlic fariiicr as liaviiig a good quality. In classifying tlic water of Tubewell 44. tlic fnriiicr mentioned only tlic creation of black snliiiity. Tlic creation of hardness in tlic soil might tnkc plncc. but due to tlic texture of the soil. the proccss iiiiglit bc slow. which influences the farmers' pcrccptioiis.

Fordwah 130-R

Table 5: Water classification for Watercourse Fordwah 130-R.

TW No	Classification	RSC	EC	SAR	EC/SAR	Soil type	Remarks
48	good	2.4	1.07	7.5	0.14	coarse	
121	white	4.0	1	11.9	0.08	coarse	no hardness because he uses the TW on sandy soil
3	little white, hard	1.7	1.45	10.1	0.14	mod coarse	
5	black, hard	4.8	1.6	17.2	0.09	mod coarse	
6	hard, little white	2.2	1.3	8.2	0.16	mod coarse	delivery pipe has to be changed every 2 years
9	white, hard	3.7	1.55	12.3	0.13	mod coarse	water stands on the surface
10	white, hard	3.5	1.45	10.3	0.14	mod coarse	if used with canal water no problem. If no canal water problem. Effect after 2-3 irrigation
11	white, hard	5.7	1.65	12.5	0.13	mod coarse	
12	hard	1.5	0.9	4.4	0.20	mod coarse	if soil hard already TW increases hardness When soil does not have problems TW is good
13	black, hard	2.9	1.4	11.7	0.12	mod coarse	effect after 2-3 irrigation
14	better than 11	2.7	0.84	7.7	0.11	mod coarse	
129	good	0.8	0.93	3.6	0.26	mod coarse	
130	black	0.9	0.92	4.7	0.20	mod coarse	short term use not too bad
3	little white, hard	1.7	1.45	10.1	0.14	medium	effect after 2-3 irrigation if there is no canal water
5	black, hard	4.8	1.6	17.2	0.09	medium	

The water of Tubewells 48 and 121. which are use on tlic coarse textured soils. are said iiot to cause any hardness in tlic soil in spite of tlic positive RSC vnluc of tlic wntcr. Tlic coarse tcstiircd soils. in combination with tlic relatively low EC value of tlic wntcr. iiiiglit make tlic sodificatioii proccss slow and the dcgrndntioii proccss iiiiglit iiot have taken plncc visibly in tlic field. The water from Tubcwcll 121 was said to cause wliitc salinity. Irrigation practices iiiiglit linvc played a rolc iii this classificntioii. since the EC is almost equal to tlic EC of Tubewell 4X.

All tubewells which are used on tlic moderately coarse tcstiircd soils linvc a RSC value above 0. All, except for two tubewells, were said to cause hardness in tlic soil. Tlic RSC values are above 1 and the EC values exceed 1 dS/m. Tlic two tubewells which do iiot cniisc hardness according to fnriiicr opinions have a RSC vnluc below 0 aiid the EC is below 1 dS/m. Tlic sodification iiiiglit tnkc plncc slowly. but tlic physical dcgrndntioii iiiiglit be so slow tlint farmers do iiot observe it (yet) iii tlic field. Tubewell 12 has a RSC value of 1.5 and an EC of 0.9 dS/m. Tlic fariiicr who evaluated tlic qiinlity of this tubewell wntcr said tlint it increases tlic liardiicss of soils which nlrcndy have problems, but docs iiot cniisc niiy problems on good soils. This perception iiiiglit be rclntcd to tlic speed of the processes as well. Whether tlic use of the various waters cause white snliiiity seems to be rclntcd to tlic level of EC.

Both tubewells used on the medium textured soils have RSC values exceeding 0, and EC values above I dS/m. Tlic use of both waters arc said to cause hardness in the soils. One tubewell causes white salinity as well, while tlic other one is said to cause black salinity. It can bc observed that most tubewells said to cause black salinity liavc a high SAR valuc.

Fordwoh 62-R

Table 6: Water classification for Watercourse Fordwah 62-R.

TW No	Classification	RSC	EC	SAR	EC/SAR	Soil type	Remarks
15	white, hard	5.1	1.5	15.9	0.09	medium	very poor
17	bad	2.5	0.92	7.8	0.12	mod coarse	
18	white, hard	1.6	1.66	5.5	0.30	mod coarse	if used continuous
19	white, hard	1.8	0.76	2.98	0.26	mod coarse	if used alone and continuously
20	good	-0.2	1.01	1.79	0.56	mod coarse	
22	good	-0.4	0.9	2.7	0.33	mod coarse	if used continuous soil gets weak
23	good	1.6	0.88	7.23	0.12	mod coarse	
24	hard	4.4	0.76	3.79	0.20	mod coarse	use TW and canal always at the same time otherwise soil goes hard
98	good	-3.5	1.14	2.7	0.42	mod coarse	uptill now did not increase problems
102	little white, hard	-0.6	1.6	6.2	0.26	mod coarse	if used alone, is not used alone so soil only gets little white
118	good	0.9	0.56	2.9	0.19	mod coarse	
120	good	-0.5	0.36	0.8	0.45	mod coarse	
127	good	3.0	0.85	12.7	0.07	mod coarse	uptill now did not give problems on new sandy

The development of white salinity seems to bc related to the level of total salt concentratioii measured as EC. and the irrigation practices. Tubewells IS, 18, aiid 19 are said to cause hardness in tlic soil. Tlic RSC is well above 0 aiid tlic EC 0.8 to 1.7 dS/m. But tlic EC/SAR ratio is small; therefore, crust formation might play a role in this classification. The farmer using Tubewell 102 cspects his soil to become hard as well if tlic tubewell is used alone. The RSC value is just below 0 and the EC valuc is greater then I dS/m. Since tlic RSC is only slightly below 0. the CRA might bc above *0* and tlicrcforc the process that tlic farmer expects to occur might occur when tlic tubewell water is used continuously without using canal water. The tubewells which were classified as good liavc a RSC valuc below 0 and an EC valuc of 1.2 dS/m and lower. Three tubewells which were classified as good have a RSC valuc above 0; when tlic EC value is below I dS/m aiid tlicrcforc the proccss might be slow aiid iiot observable in the fields. Otic farmer using Tubewell 127 did not deny that problems might occur in tlic future, but just declared that problems did not occur until now. Tlic classificatioii of Tubewell 23 cannot bc explained from tlic RSC value, aiid the EC valuc is rather low. Hardness might dcvclop. but very slowly. This process might not be directly observable for the farmers; though, crust formation due to a low EC/SAR value iiiiglit bc cspcctcd lo play a role in tlic classiticatioii

Fordwah 46-R

Table 7: Water classification for Watercourse Fordwah 46-R..

TW No	Classification	RSC	EC	SAR	EC/SAR	Soil type	Remarks
78	good	2.8	0.85	4.5	0.19	coarse	
81	good	0.8	0.8	3.4	0.23	mod coarse	used on *reetli* soil
83	good	0.0	0.86	1.5	0.57	mod coarse	used very rarely
126	good	-0.2	0.7	1.11	0.63	mod coarse	
82	hard	2.4	1.12	5.09	0.22	mod coarse	never used alone, mixed or conjunctive use
79	white, hard	3.0	1.21	5.72	0.21	mod coarse	never used alone, mixed or conjunctive use

The tubewells iiscd on tlic medium textured soils which were said to cause hardness, have an RSC value well nbovc 0 niid an EC value of more than I dS/m. Tlic tubewell waters classified as having good quality have an RSC value of 0 or less. For one tubewell, classified as having good quality. the RSC value is above 0 but below I. while tlic EC value is less than I dS/m. Sodificatioii might take place. But due to tlic low values and tlic coarse texture of tlic soil. tlic proccss might be *so* slow that tlic farmer docs not obscrvc tlic proccss in the field. Tlic tubewell which is iiscd on the coarse textured soil is said to have a good quality. in spite of its relative high RSC value. The low EC value combined with tlic coarse texture of tlic soil might make the sodification proccss slow and not visible in tlic field.

Fordwnli 14-11

Table 8: Water classification for Watercourse Fordwah 14-R

TW No	Classification	RSC	EC	SAR	EC/SAR	Soil type	Remarks
54	hard, white	-6.2	2.8	9.5	0.29	medium	
65	hard, white	-6.3	3.7	13.6	0.27	medium	
66	hard, white, black	-5.1	3.0	11.9	0.25	medium	
67	hard, white	-0.1	3.1	16.9	0.18	medium	
68	hard, white	-1.2	2.1	8.4	0.25	medium	
70	hard	-2.9	1.9	6.2	0.30	medium	
110	hard, white	-0.3	1.5	10.1	0.15	medium	
72	hard, white	4.3	3.8	26.4	0.14	medium	
73	hard, white	-0.4	2.4	15.2	0.16	medium	
74	hard, white	-2.0	2.0	9.1	0.22	medium	
75	white	-3.1	1.5	5.0	0.30	medium	
76	good	-1.9	1.0	2.5	0.40	medium	
77	good	-3.6	0.9	1.5	0.60	medium	
108	good	-1.0	0.5	1.0	0.50	medium	
133	hard, white	-3.0	2.1	10.1	0.21	medium	
164	good	-2.2	0.8	1.5	0.50	medium	

All tlic tubewells which were classified as causing hardness have an RSC less than zero. except for oiic tubewell. In this case, the hardness of the soil has to be related to reduced infiltration rates due to a low EC/SAR ratio. The tubewells classified as having a good quality have a considerably higher EC/SAR ratio and a RSC value below zero. These tubewells do not cause sodicity related problems.

On the basis of this analysis. the following 'tliresliold' values for the use of tubewell water on medium and moderately coarse textured soils, based on farmers' classification. caii bc giveii:

Table 9. Water classification for medium textured roils.

	Infiltration		Hardness	
	None	Hard	None	Hard
EC/SAR	> 0.4	< 0.4		
RSC			< 0.8	> 0.8
EC			< 0.8	> 0.8

	Infiltration		Hardness	
	None	Hard	None	Hard
ECISAR	> 0.3	< 0.3		
RSC			< 1.5	> 1.5
EC			< 0.9	> 0.9

Annex 4

Farm Characteristics

ID[1]	Fam/ha[2]	Ox/ha[3]	Tract[4]	Credit[5]	TVC[6]	TVO[7]	Remit[8]	Asset[9]	Cattl/ha[10]	%Rent[11]	CsupK[12]	CsupR[13]	CT[14]	TW[15]
111-L														
207	0.08	0	1	225000	7681	66398	0	4	0.7	0	Extr low	Extr low	149	2
208	1.88	0.63	0	0	1395	7724	0	3	8.2	56	Extr low	Extr low	188	2
210	1.14	0	1	166000	2388	12873	0	2	0.7	62	Extr low	Extr low	116	1
213	1.37	0	0	0	6460	30231	0	1	0.7	75	Extr low	Extr low	183	1
220	0.45	0	1	194000	9754	62171	0	3	0.0	0	Extr low	Extr low	198	2
63-L														
163	0.74	0.09	1	88000	6573	19599	0	2	1.1	0	Low	Low	151	1
164	0.06	0.01	3	1451000	4426	28983	0	6	0.3	0	Low	Low	95	2
172	6.67	0.00	0	0	7954	34301	0	0	1.9	0	Low	Low	200	0
177	0.27	0.00	1	100000	3983	17506	0	1	0.3	100	Low	Low	109	0
178	1.20	0.00	0	3200	4386	18650	0	1	1.2	0	Extr low	Extr low	142	1
179	1.20	0.00	0	150	3956	9096	0	1	1.2	0	Low	Low	112	1
43-L														
5	2.04	0.18	1	11700	6618	33358	0	2	1.0	100	High	High	116	1
12	3.75	0.00	1	3000	6139	13888	0	4	4.4	0	Extr high	Normal	138	1
20	1.33	0.00	0	43000	6177	29758	0	2	0.8	100	Extr high	Extr high	157	2
183	2.19	0.00	0	12000	9191	26893	0	2	3.9	0	Extr low	Extr low	200	2
186	2.00	0.00	0	0	2829	7984	0	0	3.0	39	High	Extr low	118	0
20-L														
1	0.91	0.30	0	0	2471	14567	1	1	1.3	100	Normal	High	123	0
4	2.67	0.44	0	0	1201	15620	1	0	2.1	100	Extr high	Normal	125	0
192	1.62	0.15	1	46000	6908	14104	0	2	1.0	33	Normal	Normal	126	1
201	2.64	0.38	0	0	3481	10122	1	1	1.5	0	Low	Extr high	138	1
202	2.29	0.29	0	0	4673	9008	0	2	1.8	0	Low	High	148	1
204	0.94	0.38	0	5000	1533	3649	0	0	2.1	100	High	Extr high	89	0
130-R														
237	6.11	0.00	0	1965	5221	28249	0	0	2.2	0	Low	Low	142	0
240	2.86	0.95	0	8000	4717	29774	0	2	3.3	0	Low	Low	167	1
249	2.05	0.00	0	6500	5049	19126	0	1	0.6	67	Normal	Low	117	1
252	1.67	0.56	0	0	3447	20075	0	3	5.0	0	Normal	Low	169	1
267	1.60	0.80	0	6000	3235	22879	0	0	2.5	0	Low	Low	152	0
273	1.25	0.63	0	0	5299	34285	0	1	1.4	56	Normal	Low	184	0
62-R														
121	2.15	0.00	0	74000	5758	14390	1	1	0.9	48	Normal	High	135	0
135	4.29	0.00	0	0	10311	37192	0	0	4.3	100	High	Extr high	157	0
143	2.61	0.00	0	2000	3505	12273	0	0	1.6	0	Normal	Extr high	126	0
150	3.48	0.87	0	21000	8594	42099	0	3	3.5	0	High	Extr high	191	2
151	2.59	0.26	0	24500	10815	18297	0	3	1.0	0	High	Extr high	167	2
157	3.33	0.00	0	12900	6249	23024	0	0	1.3	100	Normal	Extr high	147	0

ID	Fam/ha	Ox/ha	Tract	Credit	TVC	TVO	Remit	Asset	Cattl/ha	%Rent	CsupK	CsupR	CI	TW
14-R														
65	4.09	0.45	0	17000	5219	26513	2	0	1.4	100	Normal	Normal	141	0
68	2.04	0.41	0	30000	5811	16795	0	3	2.2	36	Normal	Normal	113	2
72	20.00	0.00	0	15600	9130	11861	1	3	15.0	0	Low	Low	200	2
75	1.50	0.25	0	7000	7413	6079	0	0	1.5	0	Extr low	Low	123	0
76	2.22	0.00	0	30	6267	20338	1	2	0.9	33	Extr low	Extr low	136	2
77	1.67	0.00	0	42000	11594	42150	0	0	1.3	0	Extr low	Low	161	0
80	3.89	0.56	0	3000	6359	29295	0	0	2.8	33	Low	Low	144	0
81	11.00	0.00	0	6600	7241	28090	1	2	2.0	0	Normal	Extr low	200	1
86	4.17	0.42	0	7000	4900	26518	0	0	0.8	50	Extr low	Extr low	113	0
87	1.67	0.24	0	0	3736	19569	2	0	0.9	87	Low	Low	104	0
98	3.48	0.43	0	9000	4669	98931	2	0	0.4	0	Low	Low	156	0
102	2.86	0.00	0	4000	3956	14722	2	0	0.9	92	Extr low	Low	85	0
108	7.89	0.00	0	0	5962	22052	2	0	0.0	0	Extr low	Low	126	0
112	3.24	0.54	0	5000	4895	29285	3	2	2.0	0	Extr low	Low	141	2
114	11.54	0.00	0	0	24119	25211	5	2	2.6	0	Extr low	Low	81	2
115	2.80	0.80	0	0	1962	47611	2	0	2.0	0	Extr low	Low	92	0
116	1.15	0.38	0	6500	2763	4504	0	0	0.8	100	Extr low	Low	72	0

[1] Identification number given to each farmer during a base-line survey in 1993
[2] Nuiiibcr of family members per licctnrc
[3] Number of oxen per licctnrc
[4] Nuiiibcr of tractors
[5] Outstanding credit
[6] Total variable costs
[7] Total variable output
[8] Nuiiibcr of family members sending remittances
[9] Number of farm assets
[10] Nuiiibcr of cattle per hectare
[11] Pcrcciitngc of total opcrntcd area rented in
[12] Canal water supply during Kharif as comynircd to other fnriiicrs
[13] Canal water supply during Rabi as compaitcd to other fnriiicrs
[14] Yearly cropping intensities
[15] Tubewell ownership

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-dry 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 sodicitv 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