Setting up a database for analyzing the relationship between various irrigation related variables and soil salinity

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INTRODUCTION

Irrigation in Pakistan

Pakistan has one of the largest contiguous irrigation systems in the world, irrigating annually an area of about 16 million hectares. Water is diverted from river headworks or barrages into main canals, which in turn feed secondary canals (distributaries), that distribute water to the tertiary units or watercourses. Farmers in these watercourses divide the water amongst themselves by means of a roster of turns (warabandi), where the length of each turn is determined by the size of the landholding.

Groundwater has increasingly become an important source of irrigation, tapped through a large number of (especially) private tubewells.

Salinity and sodicity have been phenomena that have always been related with irrigation in Pakistan, even before the conception of the present irrigation system. After the large scale development of irrigation systems in the last century, groundwater tables rose, impacting on the water and solute transport in the rootzone. The "twin menace" of waterlogging and salinity was identified as one of the major irrigation-related problems in the Indus Basin. Presently, water tables in the Punjab are generally going down, influenced by the large scale exploitation of the aquifer by farmers. Recent research suggests that waterlogging and salinity can be disassociated, as salinity has continued to pose threats to irrigated agriculture even in areas where groundwater tables are low (Kijne and Vander Velde, 1992). In addition to that, the use of groundwater, which is always of lower quality than the canal water resources, has been shown to contribute to problems of salinity and sodicity.

Institutional context

This report is the final output of a six week practical training with the International Irrigation Management Institute in Pakistan (IIMI). The study forms part of the larger collaboration between IIMI and the Institute for Agricultural and Environmental Engineering in France (CEMAGREF).

IIMI has been working since 1989 on inter-related issues of irrigation management, salinity and agricultural production. The main objective of the research is to devise management interventions that have a potential to contribute to increased agricultural production and mitigate salinity/sodicity. Research efforts have focused on the Fordwah/Eastern Sadiqia area (FES) in south-east Punjab, where a multi-disciplinary team works on the various research components. The Chishtian sub-division, located in the northern part of FES has traditionally been IIMI's research area, where new approaches and methodologies are tested.

A large number of data sets have been collected in the Chistian sub-division, entered in computer and processed. The data sets have been used in a number of research reports that have reported on the different research components as well as on the integration of data of different research components. During the course of the analyses carried out for these exercises, data sets were found to be difficult to handle and almost impossible to cross-reference.

Thus, the present study aims to develop a database structure integrating the data sets of the different research components in the Chishtian sub-division. This structure enables quick cross-referencing and will facilitate (statistical) analyses. This is presented in part 1 of this report. An application of the newly established structure will be tested on a watercourse in the Chishtian sub-division and reported on in part 2.

PART I:

COLLECTION AND COMPUTER PROCESSING OF AVAILABLE DATA

I - CONTEXT AND OBJECTIVES OF THE DATA PROCESS

A - CONTEXT

Over the last five years, data related to soil salinity, water table level and Guelph permeameter (which evaluates the soil porosity) have been collected for eight sample watercourses in the Chishtian sub-division; each watercourse contains a group of fields (about 300) which are referenced to each one, by the watercourse code and, by a specific code (Block\Square\Killa) that we will be using later. The salinity studies are carried out on eight sample watercourses; AZIM20, AZIM43, AZIM63, AZIM111, FORDWAH14R, FORDWAH46R, FORDWAH62R and FORDWAH130R (see location on the map, annex 1). These data have only been processed and used for a specific analysis, but are not in a format that facilitates different types of analyses.

Other information has also been collected and used for different studies or research programs. For example, the socioeconomic (Rinaudo, 1994), agronomic data on wheat crop (Pintus, 1995) and the water supply data are available for each watercourse.

B - OBJECTIVES

Within this context, the main objective was to prepare all data files to facilitate analysis that links salinity phenomena with other aspects (hydraulic, socio-economic, agronomic) at the farm level.

First, an inventory and processing of all the available data was required.

II - APPROACH

The different steps of the work are listed and developed just below.

A - COLLECTION OF ALL THE AVAILABLE DATA

Firstly all the available data files for each watercourse and for several years were collected from different researchers in IIMI headquarters and then an inventory was drawn up.

Secondly some missing data in the list were collected from the field station.

The final list of all the available types of data useful for a further analysis is presented in annex 2.

B - IDENTIFICATION OF THE SAMPLE FARMS

The second step of this work consisted of focussing on the farm level (and not only on the watercourse level) to observe precisely what types of data are available for each farm. For that it was necessary to find the parameter which could best identify a "farm" with regard to the types of data (particularly salinity data).

1 - The warabandi, owner's names, cultivator's names: some parameters not usable

All of these parameters are actually used for different studies.

*** The warabandi code (waterturn):** this code is attributed to the farmers three times a year . Each code corresponds to a precise waterturn (i.e. the timing of delivered water per week) and is so used as the identification code for the cultivators and by extension for the farms especially in the case of some hydraulic data.

Salinity data was collected in most cases for the same sample fields for several years. The warabandi code, nearly linked to the cultivator's name and changing several times a year, appears as maladjusted to follow along the different seasons the sample fields (identified with the help of a spatial code).

*** The owner's and cultivator's name:** in a typology of the farms based on an analysis of socio-economic data (J. D. Rinaudo, 1993), each of the 278 farms was identified by a code (FARMID) according to the cultivator's name. This approach was possible in that case because the study was based on data collected for one season. But the substitutions of some cultivators by others or modifications of land holding between two seasons rendered this codification unusable for our type of data.

2 - A "farm" is a group of fields identified by a location name.

Actually no identification is now available to compare data between several seasons. The location code (Block\Square\Killa), single for each acre, is thus the most appropriate "key" to combine all the data files. A block is a group of 16 squares which contains each 25 Killa; the surface of this one is 1 acre (about half a hectare).

3 - The new codification of the farm

Each farm will be identified by a single code (one code for each farm for all the seasons). The structure of this farm code will be developed in a parallel study shortly (Renaudet, 1995)

With this code it is possible to follow the characteristics of each farm for several seasons; that was impossible before now.

. All the water supply data (waterturn, discharge,...) should be referenced in this way.

To make the data of the study compatible with the water supply data, a list of correspondences between the LOCATION key and the WARABANDI for each season is necessary. It should be made soon for the most recent seasons from the maps providing the warabandi for each Killa.

C - FILE (RE)FORMATTING

In order to combine all the different files, it was necessary to make them homogeneous. The steps are represented on the following figure.

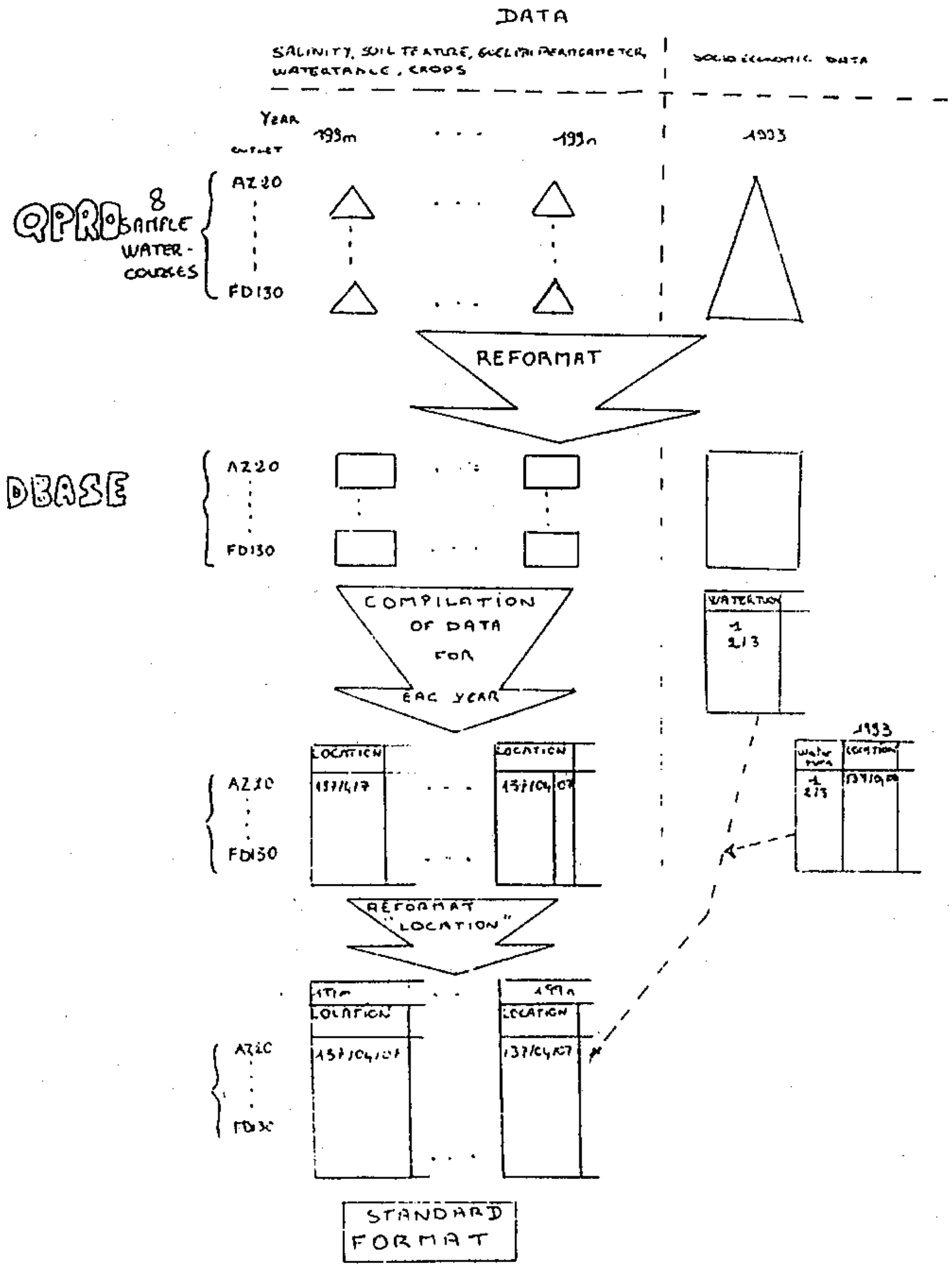

Figure 1: approach used for the files reformat

1 - Transformation of Quattro Pro files into Dbase files

In most cases, the files have been built using Quattro Pro (QPRO), though this software is not appropriate to process data from several files.

DBASE is by far more useful and safer than QPRO because it sorts and locates specific data, links the files, selects chosen fields, uses programs and at last because the "fields" are processed and not directly the data. All the QPRO files were modified and reformatted as Dbase files.

2 - Homogenization of the new files

Data have not been entered in the same way in each file (different "designs" according to the person or to the year) which prevents combining the files easily.

Some of the problems encountered relative to the location code (Block, Square, Killa) and the way to solve them are developed here.

This code was written in one, two or three columns, with or without "/" (13704/07, 137/04/07) with or without "0" (e.g. 137/4/7, 137/04/07), in numeric or character format. Because of these "minor" differences it was impossible to combine files: indeed a similar "key" was absolutely necessary.

To solve these problems three Dbase programs have been made (see annex 3) which can respectively transform the location code from three, two and one columns (with or without the "0") into the same format (137/04/07 in one column).

III - RESULTS

Salinity, soil texture, crops, Guelph permeameter and wheat data files now have a similar key which make them compatible each other. They can then be combined according to the data we want to compare. These files as well as the description of them are available on floppies.

The water table data have not been transformed yet because it was not relevant for this preliminary study on salinity; indeed, only a few sample fields have data. Nevertheless, a better format looking like the new salinity files has been proposed for the further data input.

From now on, the format for each parameter should be used for future seasons.

PART II:

PROCESS AND ANALYSIS OF SALINITY DATA

I - PROCESSING OF SALINITY DATA

Salinity data files have already been formatted in Dbase files and compiled (one file for each sample watercourse and each year). The aim of this new process is to solve the specific problems encountered in the use of these data. Three main steps can be distinguished:

A identification of the sample fields with complete data series;
B rearrangement of data to make the files usable;
C identification of the available salinity parameters.

A - IDENTIFICATION OF THE SAMPLE FIELDS

1 - Objectives

With regard to the main objective of the analysis which is to follow salinity trend through the years, it is essential to draw up a list of sample fields with complete data (i.e. data for each year).

2 - Approach

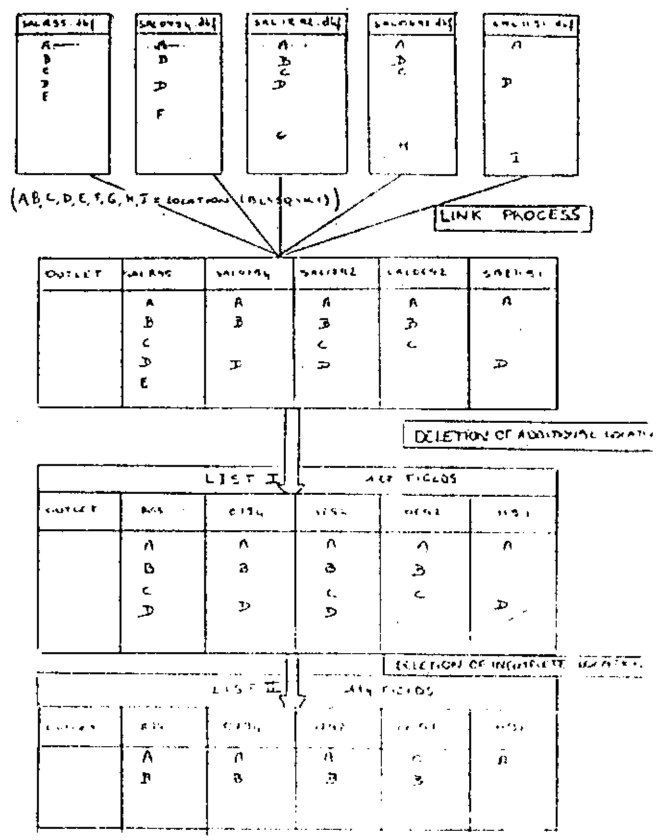

Figure 2: approach used to draw up a list of sample farms

Firstly, all the salinity files (Dbase function "LINK") have been linked. The key for the link was the list of sample fields for Rabi (winter) 94/95, which is supposed to include all the sample fields 1994 and to be followed for the next seasons. That means that the possible common fields between 1991 and 1992 would not be kept by this method.

Secondly, files with missing data series were deleted in order to obtain two tables of lists of sample fields.

* The first table (list I, available in annex 4-a) is the list of sample fields with more than two series (data available at less for three seasons).

* The second table (list II, available in annex 4-b) contains all the fields with more than three series (data available at least for four seasons). Actually, these fields have complete data for June 1992, December 1992, July 1994, Rabi 1994/1995 and in a few case for November 1991.

At the time of writing, only the list of the sample fields Rabi 1994/95 was not available.

3 - Results

The first list contains 127 fields and the second one only 115 fields.

Only a few data are available for November 1991. It can be partly explained by the fact that, at that time, only four of the eight watercourses were studied. Be that as it may, it should be difficult to keep these data to study the global evolution of salinity rate, for each watercourse for example (the sample fields are not enough representative). Nevertheless, it may be useful to compare punctually salinity data for December 1991 and June 1992 for a few fields to observe if there are many changes between these two seasons.

The lack of data for 1993 is regrettable. According to this situation it becomes risky to make appear an evolution of the salinity trend between 1992 and 1994 (only data for July are available). However, a comparison between Kharif 1992 and Kharif 1994 may be acceptable.

B - REARRANGEMENT OF DATA

1 - Objectives

Salinity data was entered without preparing a way for analysis resulting in files that are not user-friendly and unusable without transformation. This transformation has been done with the help of a Dbase program.

2 - Approach

* Initial situation

The initial arrangement of data inside the files is represented below.

YEAR 199n

BL/SQ/KI	DEPTH (cm)	SAR	EC (10^3 of extract 25°C)	OTHER PARAMETERS
173/11/14	6	3	4	X
173/11/14	12	1	5	
173/11/14	24	2	1	
173/11/14	36	4	2	
184/12/04	6	0,5	5	
184/12/04	24	3	2	x
184/12/04	36	4,5	2,5	

Figure 3: initial format of data file

For each location (BL/SQ/KI), there are, in most of the cases, four series of data, one for each depth of sampling (6,12,24,36 inches for the salinity files and 15, 30, 60, 90, 120, 150, 200 cm for the four sample fields files). The data were entered into rows and not into columns. From computing point of view, there are thus 115*4=460 rows of data and not 115 sample fields with for each 4 rows of data. If this representation may be understood in a visual way, in return, it can not be in a logical way.

For several fields, some data for one depth are missing (184/12/04 at 12 inches in the example above). Presumably it was done because these data were not available. But that implies that according to this depth, the sample fields don't exist; if then we decide to compare salinity at this depth (12 inches) for all the fields with salinity at another depth, the fields with one missing depth will, through the Dbase function "LINK", disappear forever.

* Rearrangement of the data according to the SAR (Soil Absorption Ratio) and EC (Electrical Conductivity)

First, I created a new file (salnew.dbf) with the following computer fields (OUTLET, LOCATION, EC6,..EC36, SAR6,..SAR36) for each season.

Then a Dbase program was written (see annex 5-a) to convert rows into columns for each location (BL/SQ/KI) in case of salinity data with depths written in inches and a similar one for the four sample fields files with depths written in centimeters (see annex 5-b).

3 - Results

The structure of the new files is presented through this example.

YEAR 1990

BL/SG/KI	SAR 6	SAR12	SAR24	SAR36	EC6	EC12	EC24	EC36
173/11/14	.3	1	2	4	4	5	1	2
184/12/04	0,5	0	3	4,5	5	0	2	2,5

Figure 4: new structure of salinity files

There is now one column for each type of data which makes all the comparisons or arithmetic operations (for instance the mean of salinity in 6 and 12 inches) possible and easy. The missing data have been replaced by 0.

The salinity files have been converted only with reference to SAR and EC parameters. With an easy modification of the program (changing the field name) the same conversion is possible for other parameters. The names of the former files as well as the new one are presented in annex 6.

This process just described underlines, once again, the importance of the data entry process. Each initial salinity file (see part I) was transformed at least four times before becoming usable. This point should be kept in mind for the next data entry. A similar format as the "new salinity files" could be used.

C - IDENTIFICATION OF THE AVAILABLE SALINITY PARAMETERS

1. Objectives

First, the availability of the salinity parameters for each year had to be determined before choosing which ones to include in the study.

2. Approach

Automatic treatment was not possible. All the parameters from all the seasons were collected by hand and drawn on a table (see annex 7).

To explain the parameters used here, a description is given just below of the main processes they characterize. The main soil alteration processes by salts are also presented.

* **The salinization process** consists of an accumulation of salts in a soil profile; the chloride and the sulphate of the cations Na, Ca, Mg are the main ones. These salts can be disintegrated which increases the concentration of the cations in the soil. All these cations are involved in the soil adsorption complex and thus determine directly the soil structure. The salinity trend is measured by the **Electrical Conductivity (EC)** of the saturation extract which is obtained, at 25 degree C, by suction-filtration of a water-saturated paste of the soil. This parameter can be measured either in mmhos/cm or in dS/m. **The concentration of the different ions (Na+, K+, Ca++, Mg++, Cl, SO4-)** can also provide some information.

* **The sodification process** is the increase of the percentage of exchangeable Na-ions fixed on the exchange complex. At high concentration, these ions, which are the most soluble occurring in Nature, are adsorbed easier than the other which leads to an alteration of the soil complex. The soil might become then compressed, and so, non airy which makes it sterile. The sodification can be evaluated by the **Soil Adsorption Ratio (SAR)**, a ratio between the Na ions and the other divalent cations (Ca++, Mg++):

SAR=Concentration NA+/(Concentration Mg2++Concentration Ca2+)/2.

The concentration of divalent cations may also be useful.

* **The alkalinization** is due to the increase of the pH to alkaline valued. At this pH, there is precipitation of the divalent cations with the carbonates provided in most of the cases by irrigation water, which gets the SAR higher and may induce sodification. The **pH** as well as the **HCO3 and CO3 concentrations** are relevant parameters.

These three processes are quite linked. Alkalinization can lead to sodification; but salinization can do that also. If the solution is concentrated in ions (Na+ and Ca++) with a factor X, the SAR rate will be increased with a factor X which may infer sodification.

In all these processes the soil texture is involved. The different types of soil are more or less affected by salinity or sodicity according to their texture usually described by the **percentage of sand, silt or clay**. This information must be cross-referenced with all the other ones.

The gypsum requirements. Gypsum is used by the farmers as a improvement to improve permeability of the soil; gypsum ($CaSO_4$) precipitates the Na ions as it is shown by the following reaction that occurs on the adsorption complex:

$$CaSO_4 + Na^+ \text{ ---------> } Ca \text{ soil} + Na_2SO_4$$

Referring to the table present in annex 7, it can be easily ascertained that all the parameters are not available for each season making them unusable according to the short series of data available. That is the case for the Na^+, Ca^{++} and Mg^{++} concentrations missing for 1994, for the K^+, HCO_3^-, CO_3^{2-} concentrations, the pH that are not available for June 1992, December 1992 and July 1994.

As a result, the analysis will be carried out through the study of EC and SAR.

II - ANALYSIS OF SALINITY DATA

A - OBJECTIVES

The main objective is to highlight some facts relative to the salinity trend and its evolution for each watercourse. Actually this first study needs to be augmented and validated by another when the salinity and water quality data are available for other seasons (e.g. December 1994 and June 1995).

B - APPROACH

Some soil classes were made according to the sample depths. For the both parameters (EC and SAR) four classes can be distinguished. Two for the surface of the soil profile: 0-15 cm and 0-30 cm. Two others for the deeper layers: 30-90 cm and 60-90 cm.

Arithmetic means were made for each sample watercourse and each class and graphs representing the SAR or EC rates for all the years have been drawn up.

C -ANALYSIS

Before starting the analysis, it has to be kept in mind, firstly, that it is inappropriate to study an evolution of the salinity trends (1993 is missing), secondly, that only data for 12 fields (among 114) for the eight watercourses are available in November 1991 which get them not representative for all the watercourses; at last, that this analysis relies on less than 15 fields per watercourse which contains about 300 fields each.

1. Separate analysis of the EC and SAR parameters

a - The electrical conductivity

* FORDWAH sample watercourses

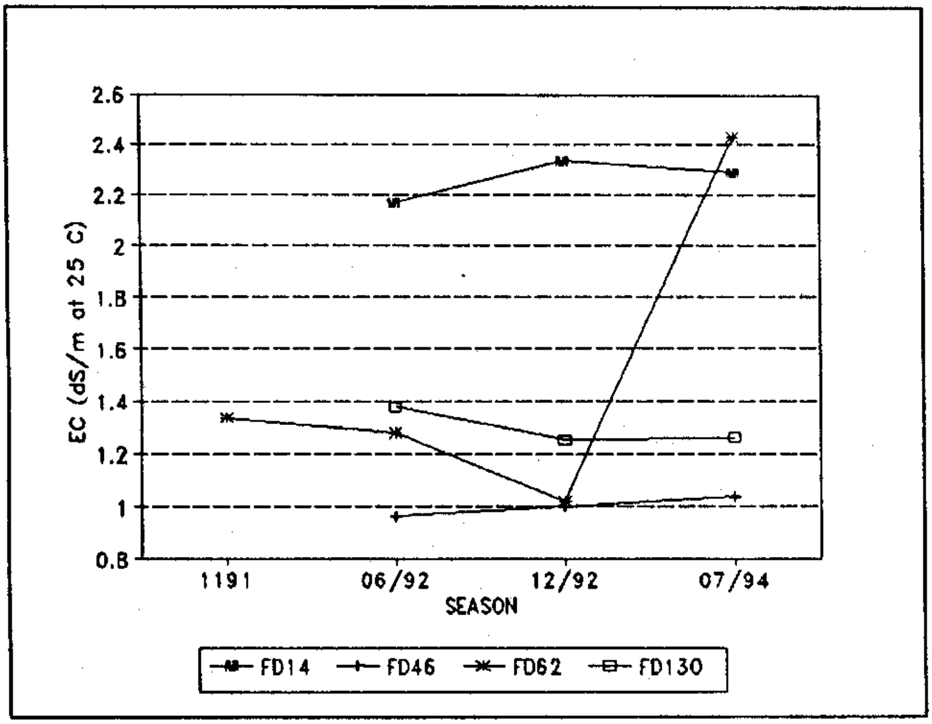

Figure 5: electrical conductivity measured between 0 and 15 cm for all the FORDWAH sample watercourses.

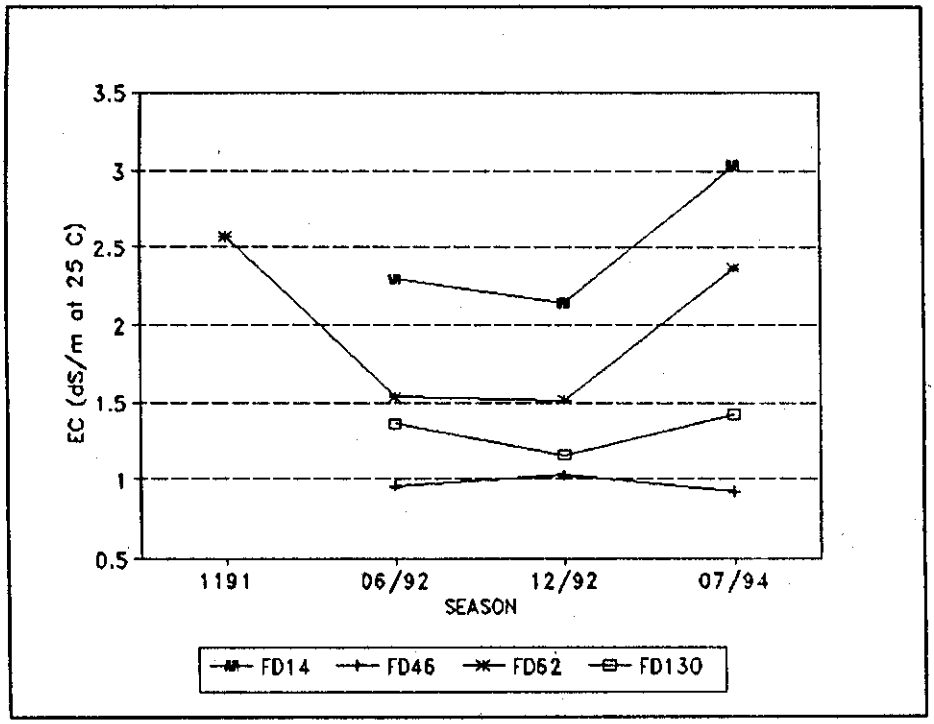

Figure 6: electrical conductivity measured between 30 and 90 cm for the FORDWAH sample watercourses.

Before 1994 two groups can be distinguished along the whole soil profile : FD 14 with high level of salinity (between 2.1 and 3 dS/m) and the others with EC included between 0.9 and 1.5. In Kharif 1994 FD 62 "leaves" the second group and gets the same (0-15 cm) or fairly the same (30-90) salinity trend as FD 14.

On the whole, salinity level is a bit higher between 30 and 90 cm than in the surface (this is also shown by the comparison between 0-30 cm and 60-90).

When a comparison is made between two similar seasons, namely Kharif 1992 and Kharif 1994 **a similarity in salinity level can be found for FD 14, FD 46 and FD 130, except FD 14 in depth.** In that last case the rise of the salinity trend between these two seasons is, indeed, all the more noticeable because the depth of the soil is high (+1% between 0 and 15 cm, +33% between 30 and 90 cm, +56% between 60 and 90 cm). In return, **what is striking is the strong increase of EC in the whole soil profile for FD 62** (+ 90% between 0 and 15 cm, +55% between 30 and 90 cm).

When Kharif (summer season) 1992 and Rabi (winter season) 1992 are **compared, in most of cases the salinity trends are equivalent.**

* AZIM sample watercourses

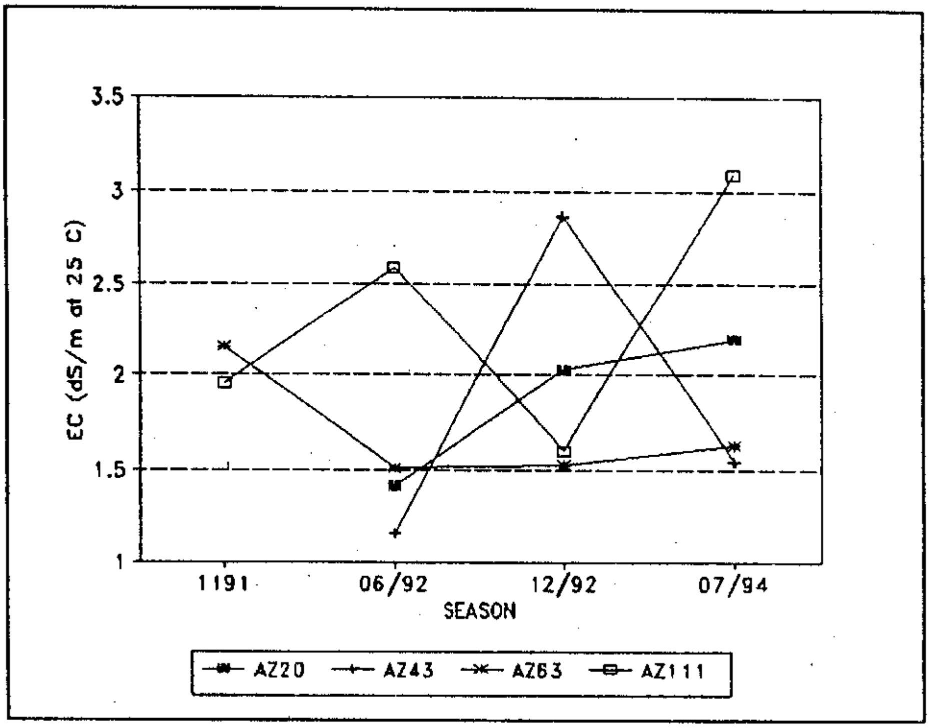

Figure 7: the electrical conductivity measured at 15 cm for the AZIM watercourses

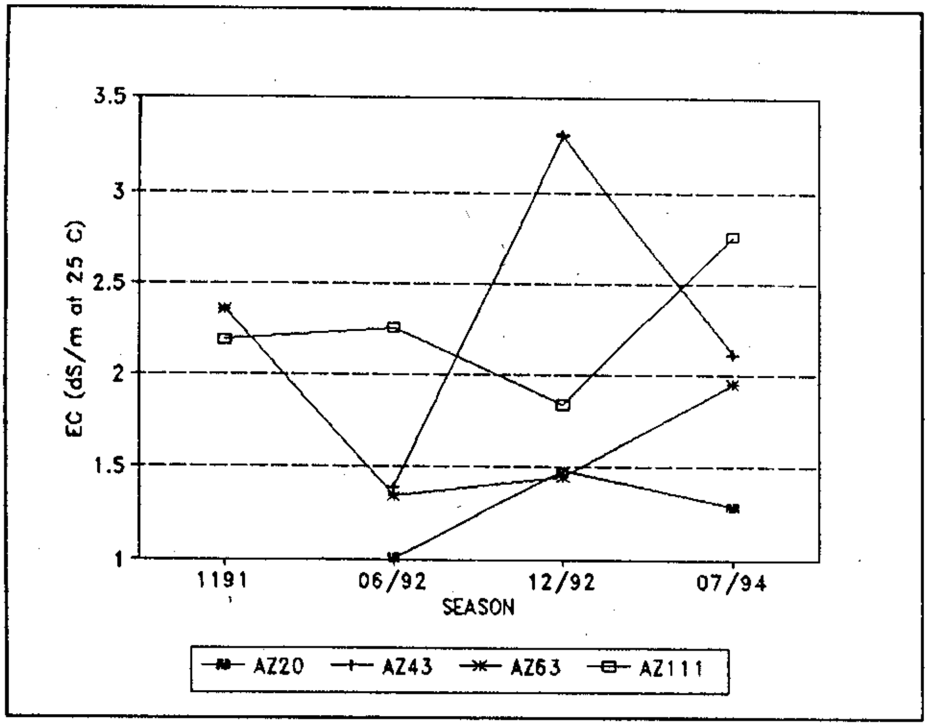

Figure 8: the electrical conductivity measured between 30-90 cm for the AZIM watercourses.

From the graph, follows :

- **no group of watercourses with a similar behavior according to salinity can be clearly distinguished either in the surface or deeper in the soil profile.** Nevertheless we can see that **AZIM 111 is globally most affected by salinity** for the two classes (between 1.6 and 3.1 dS/m).

- **for all the watercourses the values belong to the same interval in the two depth classes** and it can not be said that they are higher in the deep soil than in the surface.

- **the salinity trend increases between June 1992 and July 1994 for all the watercourses.** The increase rate is included between +0.3 and +0.7 points excepted for AZIM 63 which stays at low level (1.5 dS/m) between 0 and 15 cm. As it is the case for FD 14, the rise is more important according to the depth; for example +19% between 0 and 15 cm, +35% between 30 and 90 cm for AZIM 111.

- **a comparison between Kharif 1992 and Rabi 1992 does provide us some information about a possible "season effect".** Indeed the values are always different, sometimes higher in Rabi, sometimes lower, except once again for AZIM 63 between 0 and 15 cm which keeps a constant trend.

b - The sodium adsorption ratio

* The FORDWAH sample watercouses

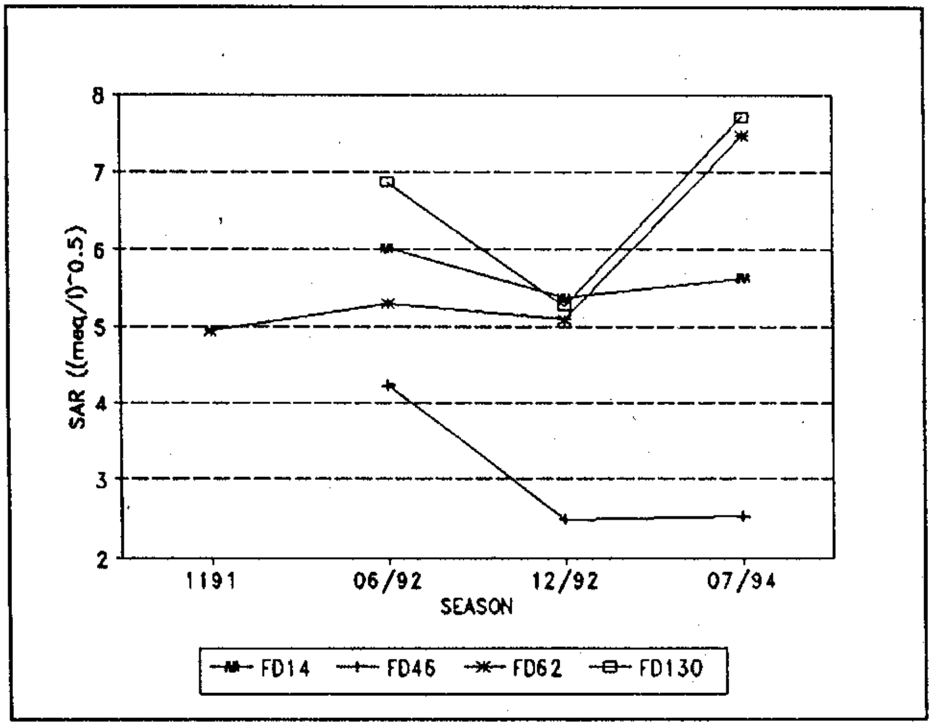

Figure 9:the SAR between 0 and 15 cm for the FORDWAH sample watercourses.

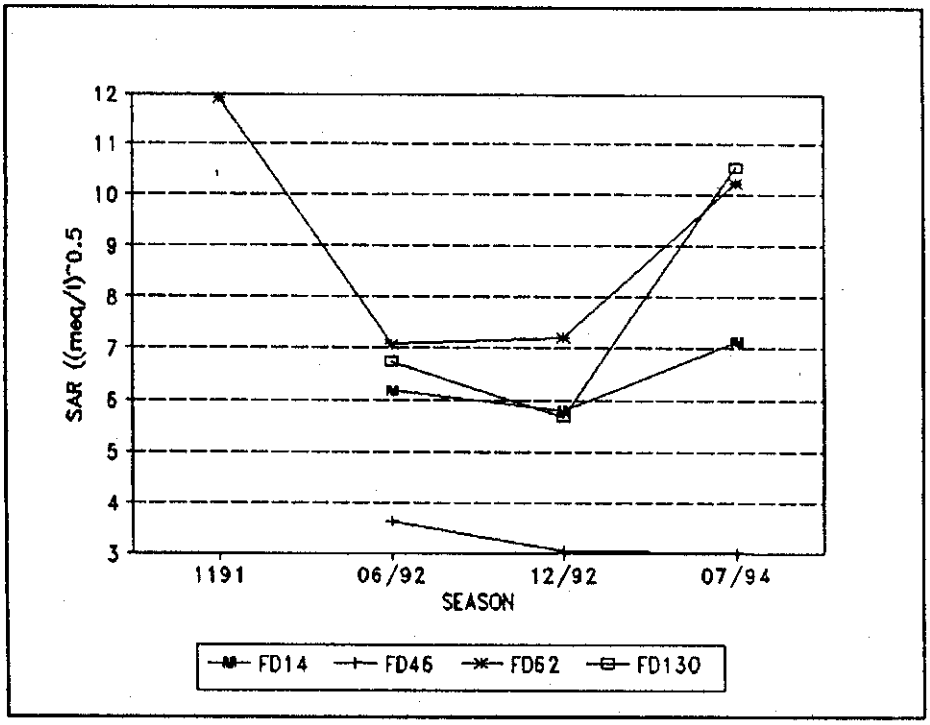

Figure 10: the SAR between 30 and 90 cm for the FORDWAH sample watercourses.

From the graphs:

- on one hand, FD 46 has very low SAR rate (between 2.4 and 4.20) and on the other hand the rates for the three other watercourses are higher (between 5 and 7.7).

- **SAR is globally the same along the whole soil profile**, punctually a bit higher in depth (FD 62 and FD 130 1994).

- the evolutions of the SAR rate between 1992 and 1994 are quite different according the watercourses and the depth. The SAR is higher in 1994 than in 1992 for FD62 and FD130, nearly the same for FD 14 and lower for FD46. In return, all of them seem to follow the trend already seen for the EC, namely **that the rise is all the more important (or the decrease is all the less important) according the depth**; for instance the increases for FD130 are respectively +12%, +18%, +56% and +70% for 0-15 cm, 0-30 cm, 30-90 cm, 60-90 cm.

- the SAR levels are a bit lower in Rabi 1992/1993 than in Kharif 1992.

* The AZIM sample watercourses

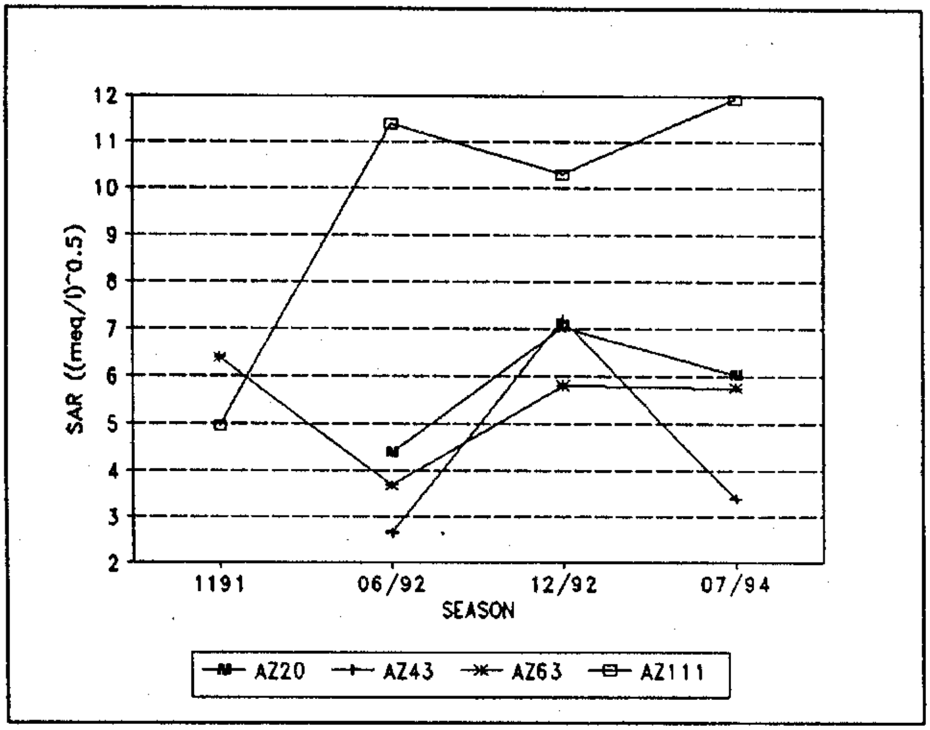

Figure 11: the SAR between 0 and 15 cm for the AZIM sample watercourses

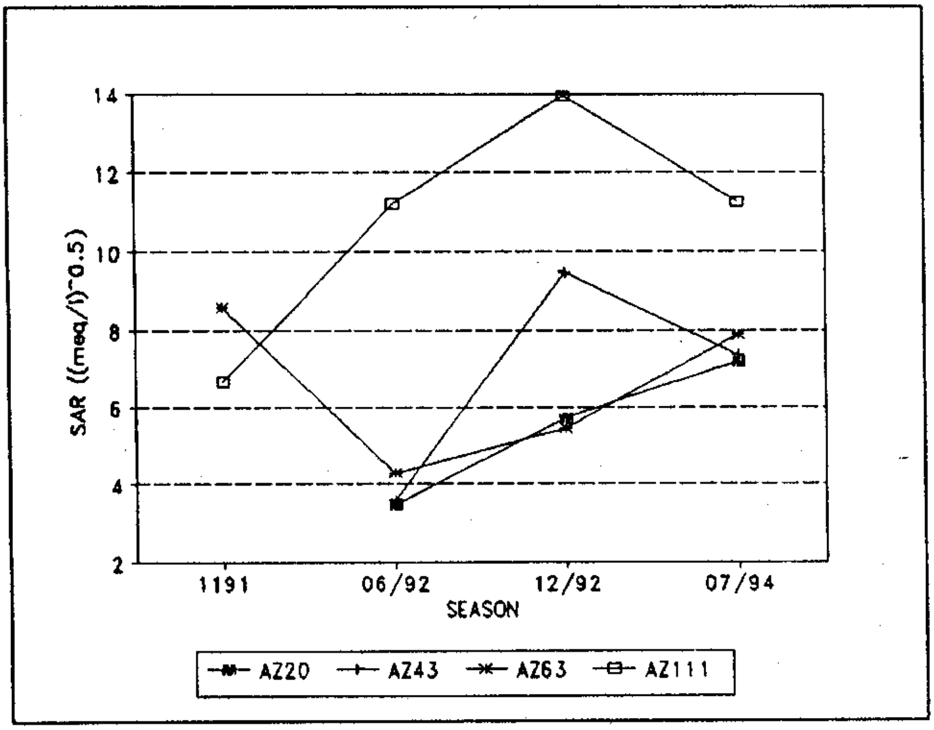

Figure 12: the SAR between 30 and 90 cm for the AZIM sample watercourses

These graphs provide the following indications:

- **the four watercourses split in two distinct groups**: on one, AZ 111, with high level of SAR in all the profile (between 10 and 12); the other is the three other watercourses with much lower rates (between 2.5 and 7).

- **the SAR levels are similar between the two classes of depth.**

- **the SAR has increased for all the watercourses between 1992 and 1994.** It is interesting to notice that the rise is far lower for AZ111 (+1 to +5%) whereas increase for the other watercourses is on average +40% between 0 and 15 cm (37%, 27%, 57% respectively for AZ20, AZ43, AZ63) and 98% between 30 and 90 cm (106%, 105%, 82% respectively for AZ20, AZ43, AZ63). For the three others, **the rise of the SAR rate is proportional to the depth**; for example, for AZ 20 the rise is +37%, +55%, +106% and +110% respectively for the classes 0-15 cm, 0-30 cm, 30-90 cm, 60-90 cm).

- **the SAR rates are quite different between Kharif 1992 and Rabi 1992/1993**; and in most of the cases, higher in Rabi.

2. Crossed analysis of EC and SAR parameters

a - Objectives

As noted before EC and SAR were some parameters of different processes which could be linked (salinization et sodification for instance). It is then reasonable to assume that these two parameters may be linked; the study tried to verify on the one hand by statistics, with the help of a correlation method (Pearson Coefficient, available in SPSS PC+ or Winstat), and on the other hand by drawing up a classification of the salinity level of the different watercourses according the classification proposed by Kuper and Van Waijjen, 1993.

b - Statistic approach

Several pairs of vectors including 114 data have been taken: (EC 0-15_0692/SAR 0-15_0692,...,EC 0-15_0794/SAR 0-15_0794, EC 30-90_0692/SAR 30-90_1292,...,EC 30-90_0794/SAR 30-90_0794).

The different correlation coefficients obtained are listed just below:

TYPES OF COMBINATIONS	CORRELATION COEFFICIENT (PEARSON)
EC 0-30 CM 0692 * SAR 0-30 CM 0692	0.82
EC 0-30 CM 1292 * SAR 0-30 CM 1292	0.78
EC 0-30 CM 0794 * SAR 0-30 CM 0794	0.76
MEAN 0-30 CM	**0.79**
EC 60-90 CM 0692 * SAR 60-90 CM 0692	0.74
EC 60-90 CM 1292 * SAR 60-90 CM 1292	0.67
EC 60-90 CM 0794 * SAR 60-90 CM 0794	0.64
MEAN 30-90 CM	**0.68**
EC 0-15 CM 0692 * SAR 0-15 CM 0692	0.82
EC 0-15 CM 1292 * SAR 0-15 CM 1292	0.79
EC 0-15 CM 0794 * SAR 0-15 CM 0794	0.58
MEAN 0-15 CM	**0.73**
EC 30-90 CM 0692 * SAR 30-90 CM 0692	0.77
EC 30-90 CM 1292 * SAR 30-90 CM 1292	0.71
EC 30-90 CM 0794 * SAR 30-90 CM 0794	0.71
MEAN 30-90 CM	**0.73**

Figure 13: correlation coefficients between Electrical Conductivity and Sodium Adsorption Ratio

Looking at the table we see that, on average, the coefficients are in the range of 0.68 and 0.73. They have been obtained with a high significance level ($p=0.01$). It may be easily concluded that the Electrical Conductivity and the Sodium Adsorption Ratio are two dependent parameters. These data confirm the link between salinization and sodification processes at the watercourse level.

c - Classification of saturation extract of soil sample

The classification as it has been established by Kuper and Van Waijjen is reproduced here:

CLASS	DEGREE OF SALINIZATION EC IN dS/m	DEGREE OF SODIFICATION SAR in (meq/l)^0.5
NON (N)	0-2	0-8
SLIGHT (SL)	2-4	8-13
SUBSTANTIAL (SU)	4-8	13-20
SEVERE (SE)	>8	>20

Figure 14: soil salinity classification

All the watercourses have been classified according to this table. The results are shown below.

SEASON	06/92		12/92		07/94	
DEPTH (cm)	0 - 15	30 - 90	0 - 15	30 - 90	0 - 15	30 - 90
AZIM 20	N	N	N	N	N	N
AZIM 43	N	N	SL/N	SL	N	N
AZIM 63	N	N	N	N	N	N
AZIM 111	SL	SL	N/SL	N/SL	SL	SL
FD 14	N	SL/N	SL/N	N	SL/SU	SL/N
FD 46	N	N	N	N	N	N
FD 62	N	N	N	N	SL/N	SL
FD 130	N	N	N	N	N	SL

Figure 15: classification of the sample watercourses according to the salinity and sodicity

This table reveals clearly that the soils for the sample watercourses on average are not or slightly affected by salinity. Nevertheless, it points out some differences between the watercourses; most of them have been already revealed by the analysis of the EC and SAR parameters:

- soils in Azim 111 have been slightly affected since 1992. This is the case also for FD 14.
- FD 62, can be assumed in regard to the EC and SAR rates, has become recently affected by salinity and sodicity.
- soils in Azim 43 are not saline anymore. This may be due to a different use of the canal and tubewell water by the farmers. If this were the case it would be interesting to try to determine how it has led to a decrease of salinity.

III - CROSS-ANALYSIS WITH SOIL TEXTURE AND PERMEABILITY DATA APPLIED ON FORDWAH 130-R

A - OBJECTIVES

It was established that salinity and sodicity were two processes which were found very correlated also in the case of the eight sample watercourses. It is now important to observe what sort of relationships may exist between salinity, sodicity and other specific characteristics for each watercourse.

This part aims to study the link between salinity , sodicity, soil texture, soil permeability, water table level and water quality of the pumped water for one particular watercourse (Fordwah 130-R) for one season (Rabi 91/92); indeed for this season and for this watercourse all the parameters are available which is not the case for four of the eight watercourses in Rabi 1991/1992 and for all of them for the other season (permeability data missing).

Nevertheless, a similar approach could be used with some variants according the available data for further analysis for the other sample watercourses. In fact, in this part a first application of the database structure, described in the first part, is carried out.

B - APPROACH

In a first step the same approach as the one used for salinity analysis has been adopted, id est, an analysis at the watercourse level but based on a same group of sample fields for each parameters. This approach failed because no similar group exists for all the parameters.

Another approach based on groups of fields built on the one hand from similar characteristics and on the other hand from their nearness in the watercourse were then considered.

The different steps of these two approaches are detailed just below.

1 - Computer process of permeability data

Several measurements of soil permeability were available for each sample field and for each date; the data has been entered again in rows so that a same field could have some data on several rows. Such a file is not easily and immediately usable because neither graph or means could be created, a comparison based on the list of sample fields between different files was impossible.

A Dbase program has been made in order to solve this problem by establishing one arithmetic mean for each sample field.

2 - First approach: cross-reference based on similar sample fields

Salinity and permeability files have been crossreferenced in order to determine the similar fields and then to evaluate the correlations between all the parameters. Unfortunately, only two fields have common data which render the statistic treatment impossible.

Another method would have been to make means (based on different sample fields) for each parameter and for the whole watercourse and then to study the correlations. This is only possible if these sample fields are representative for the watercourse which is not the case for November 1991; there are only 10 to 20 sample fields among 300 in watercourse. Moreover there is an important heterogeneity among the data for a same parameter which get the mean not representative.

Because of the few available sample fields, this approach can not be successful.

3 - Second approach: cross-reference in a spatial way

The main idea is to identify on a map of the watercourse which are the fields with available data in order to build homogeneous soil classes.

The following parameters that have been kept are:

- the electrical conductivity for the salinity and the sodium adsorption ratio for the sodicity,
- the soil texture,
- the hydraulic conductivity K and the pressure head PHI for the permeability,
- the depth to water table,
- the SAR, EC, the Residual Sodium Carbonate (RSC) for the quality of tubewell water, the discharge.

Cropping pattern are also available for this period. It is reasonable to suppose that crops may have an effect on the soil salinity but evaluating it for just one season is insufficient. A comparison between several seasons would be more relevant; indeed, a type of crops in a particular season may induce modifications on the salinity trend which would be only observed through the data collected in the following season. According to the available data, this analysis could be carried out in the future, without permeability data, for Kharif 1992 and Rabi 1992/1993.

C - RESULTS

1 - Soil classification

The observation of the map according the salinity and soil texture data makes appear three groups of fields with similar characteristics; one group at the head of the watercourse (class A), another in the middle (class B) and the last one in the tail (class C) (see annex 8).

This classification was built according to the location of the sample fields in the watercourse and to the SAR data.

CLASS	LOCATION	SAR 0-15 cm or SAR 30-90 cm	TEXTURE (11/1991)
A	HEAD	< 10	Sandy-Loam
B	MIDDLE	10 - 25	Sandy-Loam
C	TAIL	> 25	Sandy-Loam

Figure 16: soil classification along the watercourse

From the table, two points can be made.

Firstly, for this particular watercourse, the texture is homogeneous. This criteria can not also explain the differences of sodicity trends between the different classes.

Secondly, there is definitely a relation between the location and the sodicity trend on the watercourse. The sodicity trend increases from the head to the tail.

2 - Cross analysis with other parameters

All the data for each class are summarized in the following table.

CLASS	SALINITY		SODICITY		PERMEABILITY		WATER -TABLE	TUBEWELL WATER QUALITY			
	EC 015	EC 3090	SAR 015	SAR 3090	K 10^-3	PHI 10^-3	DEPTH TO WT	EC	SAR	RSC	Q
A	1.39 (3)	1.56 (3)	6.25 (3)	10.09 (3)	1.32 (3)	19.6 (3)	5.1 (3)	1316 (5)	6.08 (5)	4.13 (5)	1.2 (5)
B	2.29 (5)	3.66 (5)	15.23 (5)	34.78 (5)	0.86 (13)	0.735 (13)	4.2 (6)	1399 (9)	6.50 (9)	3.9 (9)	1.27 (9)
C	3.5 (1)	10.6 (1)	32.61 (1)	123.1 (1)	0.14 (4)	0.12 (4)	-	-	-	-	-

Table 17 : characteristics of the soil classes in Fordwah 130-R

(The figures in brackets relate to the number of sample fields).

EC (soil salinity) is given in dS/m, K in 10^{-3} m/s, PHI (pressure head) in 10^{-3} m (K is the speed of leaching water through a 'slice of soil with a constant water level at the top applying a pressure PHI on the soil), depth to water table in m, EC (water quality) in mmhs/cm, RSC (Residual Sodium Carbonate) in Meq/L and Q (discharge) in cusecs.

Before starting an analysis of this table, it is important to keep in mind that:

- the values have were obtained from only one to thirteen sample fields, at the most; the analysis will then be specific to this particular watercourse and will be absolutely necessary to be crossreferenced with the ones of the other watercourses to be eventually generalized;

- the class C has been distinguished from the others regarding only one field but with very high salinity and sodicity trends; moreover the area is much smaller than the other with more sample fields. Providing that the measurement would not be wrong, one field is as representative for the class C as five fields for the class B;

- unfortunately, there is no data of water table and water quality for the class C.

An analysis of these data point out that these three classes belong to three different soil salinity classes according to the classification we have already used (Kuper and v. Waijjen, 1993) (see second part-II-C-2-c). The fields of the class A are non affected, the ones of the class B are slightly to substantially affected and the fields of the class C are severely affected. It shows how important the variability within a same watercourse may be; according to this fact the means for a whole watercourse as they has been established before need to be completed by precise spatial analysis on each watercourse.

The data disclose clearly that the salinity (EC) , as the sodicity, increases according to the distance from the outlet. This fact has been hypothesized by Kijne and Vander Velde (1990) and explained by the decreasing availability of surface water supplies and decreasing groundwater quality with the distance from the head to the tail in the distributary. Seepage losses are especially important in the case of sandy soil as it is the case here; moreover its length is quite long which makes the decreasing trend of water supply from the head to the tail more significant (Barral, 1994). It has not been verified in further analysis on several sample watercourses (Kuper and V. Waijjen, 1993).

This table shows that permeability decreases from the head to the tail. This tends to indicate once again the link between sodicity or salinity and permeability. A statistic regression between SAR or EC and PHI or K for both of the depth classes point a clear correlation; on average, R square between K and EC, K and SAR are very close to 1 (respectively 0.99 and 0.98) as well as R square between PHI and EC, PHI and SAR are close to 0.85 (0.85 and 0.81). The results of the correlations based on three series of means need to be confirmed by correlations for other watercourses and other seasons. Nevertheless, this may validate in the case of this particular watercourse that the salinization and specifically the sodification processes lead to the destruction of the soil texture and so to the reduction of the soil porosity.

Lastly, the water table level seems to be higher in the tail than in the head of the distributary. Presumably there is an influence of the water table level and the salinity trend. The Bahawal canal alongside the tail of the watercourse may also influence the water table level. Nevertheless these levels are considered, on the whole, low enough to allow leaching and prevent salts moving upward; indeed lands are considered well drained for a water table higher than 3 m (WAPDA's data, 1981).

In conclusion a spatial analysis is certainly not as rigorous as an analysis based on a large number of similar sample fields with available data for each parameters. Nevertheless it appears very useful and profitable when these data are not available as it was the case here. Moreover such an analysis is carried out at "a group of fields level" and not at the watercourse level as it was done for the salinity analysis which is, in a way, more precise and makes appear the inner variability for each watercourse. For the seasons with larger number of sample fields, both of these approaches could be followed.

The aim of this precise study was more to test an approach rather than to draw conclusions which become possible only after further analysis. In the future all the watercourses could be studied in the same way for all the available seasons. It would also be necessary to focus on the farmers' cultural practices by studying, for instance, the input of organic matter which plays an important rule on soil texture, the choice of crop pattern and rotation which may influence the salinity trend or the soil preparation which modifies the soil texture; all these data are available for 1993 (Rinaudo, 1993) and for 1995 (Pintus, 1995). It would also be useful to insist on the farmers' water management which may mitigate salinity and sodicity (Kuper and v. Waijjen, 1993).

CONCLUSIONS AND RECOMMENDATIONS

The objective of the study, i.e. to develop a database structure that allows easy cross-analysis for the large data sets in the Chishtian sub-division, has been met. The approach formulated in part 1 and further focussed on salinity in the beginning of part 2, was applied to a single watercourse, Fordwah 130R. This allows a verification of the approach. A number of conclusions can be obtained from the study.

Data base management

The existing data base had a great variability and diversity according to the format of the files or the type of data. The problems encountered in linking the data often required some specific solutions but often revealed some similar malfunctions in the data management. These ones can be appear at two different levels of the data management.

1. A part of the incompatibility observed in data files came from the data production line which include the different steps of Data request, Data collection, Data entry, Data processing and Data analysis. This process is generally initiated by a small group of persons who develop research programs. The data were collected and transformed several times by a large number of people automatically introducing some variability, rendering data inaccessible and difficult to link.

To prevent this, quality checks must be reinforced at each step. At the collection step, it relevant to check if the data being collected correspond exactly to those which have been requested. Before the data entry, it would be useful to check systematically if all the requested data have been received from the fields station. The data entry must be done meticulously concerning the content and also the format of these data. The last check should occur at the tail of the line to evaluate the efficiency of the process by comparing what was requested and what was obtained.

2. The insufficient coordination and consultation between data users is another reason for data incompatibility. This aspect is more difficult to predict initially because it is revealed only during cross-referencing analysis, which usually occurs long after the beginning of the research programs. More consultation between those who request data the data entry specialist and also the file assistants who collect data would increase the efficiency of all the process. The formats of the files should be also compatible with the previous ones. According to the quantity of data collected and not necessarily entered, a person in charge of the data management and collection would certainly better ensure integration of different research programs.

Salinity analysis

1. The salinity analysis which has been made in the study was limited by the lack of similar sample fields between all the parameters. Nevertheless some analysis can be carried out sometimes with prudence when they are based on a few sample fields. Other approaches are possible and especially a spatial approach as it has been developed for one of the eight watercourses.

2. At present, a large group of compatible data is available for analysis on salinity; moreover they should soon systematically be linked with water supply and hydraulics data. For the further year the sample file format established could be used and some multiple cross-analysis may then be carried out.

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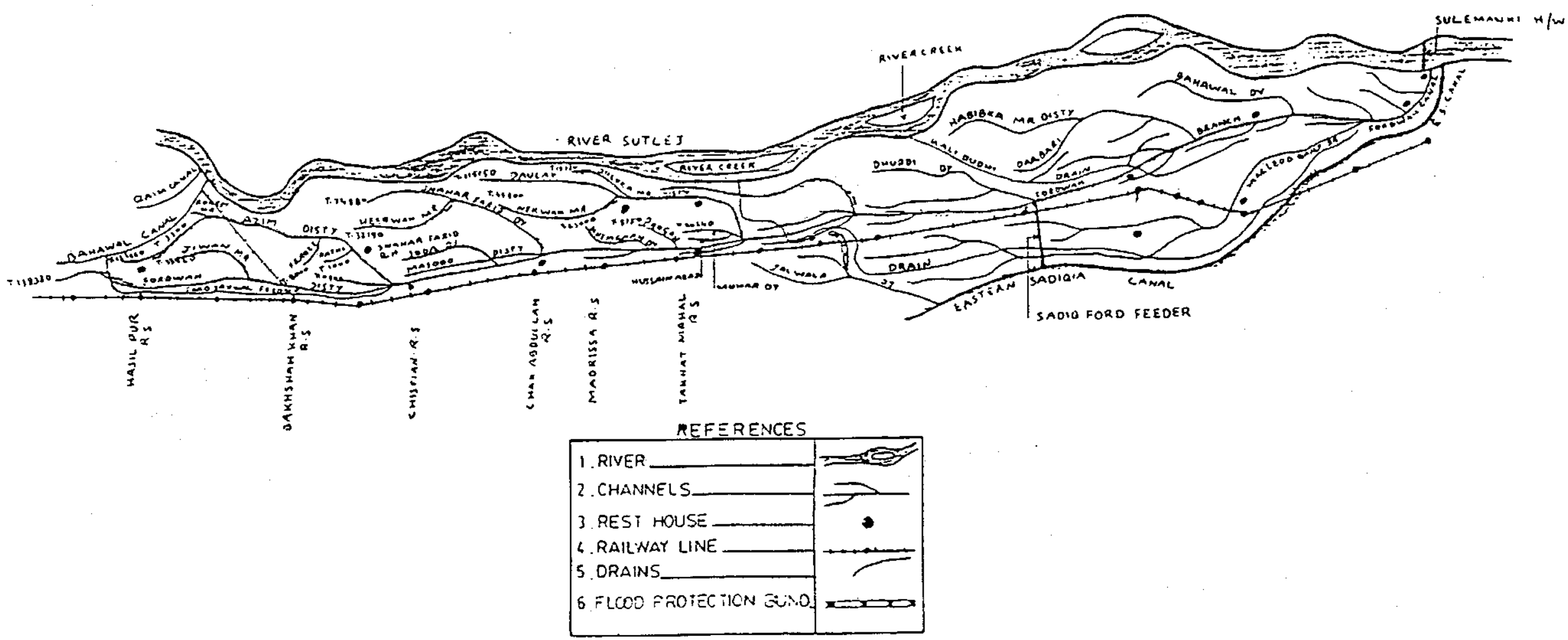
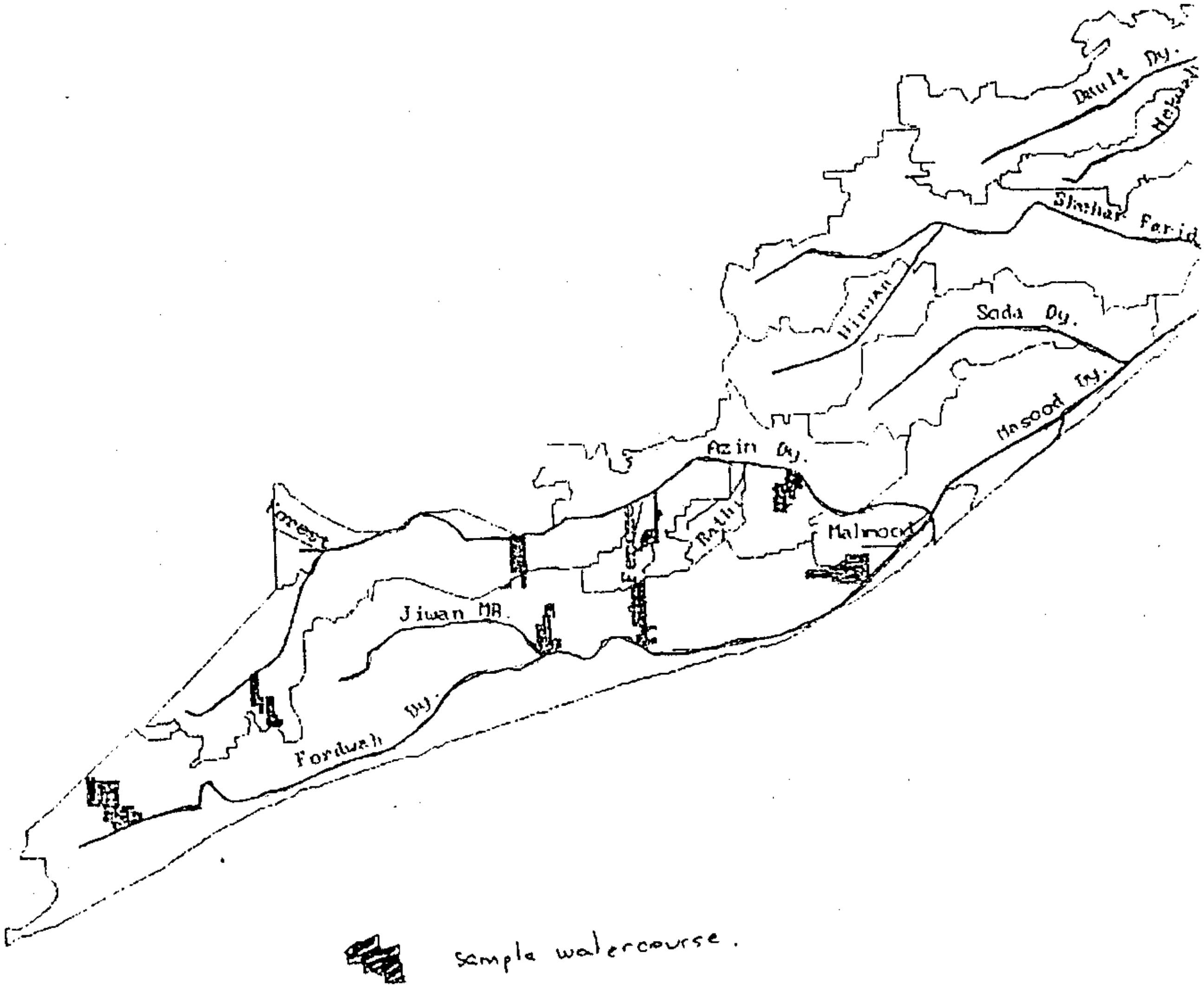
Annex 1 (a) Plan of Fordwah Division



Annex 1(b) Fordwah Irrigation Division
Location of the eight sample watercourses



Annex 2 LIST OF THE AVAILABLE DATA FOR EACH WATERCOURSE (08/16/95)

* present
_ not available
0 not available yet

TYPE	OUTLET AZ20	AZ43	AZ63	AZ111	FW14	FW46	FW62	FW130
WATERTABLE								
year								
O990	_	_	*	_	_	_	*	_
91	_	_	*	*	_	_	*	*
92	_	_	*	*	_	_	*	*
93	_	_	*	*	_	_	*	*
94	_	_	*	*	_	_	*	*
95	*	*	*	*	*	*	*	*
depth to WT	*	*	*	*	*	*	*	*
dipper reading	*	*	*	*	*	*	*	*
H above ground	*	*	*	*	*	*	*	*
CROPS								
K90	_	_	*	*	_	_	*	*
R91	_	_	*	*	_	_	*	*
K91	_	_	*	*	_	_	*	*
R92	_	_	*	*	_	_	*	*
K92	_	_	*	*	_	_	*	*
R93	*	*	*	*	*	*	*	*
K93	*	*	*	*	*	*	*	*
R94	*	*	*	*	*	*	*	*
K94	*	*	*	*	*	*	*	*
R95	*	*	*	*	*	*	*	*
SOIL TEXTURE (91)	_	_	*	*	_	_	*	*
SOIL TEXTURE K94 (4 sample fields)	_	_	*	*	_	_	*	*
SOIL TEXT. R94/95 (4 sample fields)	_	_	*	*	_	_	*	*
SALINITY								
1191	_	_	*	*	_	_	*	*
O692	*	*	*	*	*	*	*	*
1292	*	*	*	*	*	*	*	*
O794	*	*	*	*	*	*	*	*
R94/95	0	0	0	0	0	0	0	0
GUELPTH PERMEA								
O691	_	_	*	*	_	_	*	*
92	_	_	_	_	_	_	_	_
93	_	_	_	_	_	_	_	_
94	_	_	_	_	_	_	_	_
95	_	_	_	_	_	_	_	_
SOCIO ECONOMIC DATA 1993 (JDR)	*	*	*	*	*	*	*	*
WHEAT DATA (FP)	*	*	*	*	*	*	*	*
WATER QUALITY	–	–	x	x	–	–	x	x

Annex 3(a) Listing of LOC 3 C

```
set escape on
set echo off
set talk off
use c:\nicolas\az1111.dbf
go top
do while .not. eof()
chaine=location
long=len(ltrim(chaine))
ch1=ltrim(str(val(chaine)))
l1=len(ch1)+1

chaine=right(chaine,long-l1)
ch2=ltrim(str(val(chaine)))
l2=len(ch2)+1
     if l2=2
          ch2="0"+ch2
     ENDIF
chaine=right(chaine,long-l1-l2)
ch3=ltrim(str(val(chaine)))
l3=len(ch3)
     if l3=1
          ch3="0"+ch3
     endif

chaine=ch1+"/"+ch2+"/"+ch3
replace location with chaine
skip
enddo
wait
return
```

Annex 3(b) Listing of LOC 2 C

```
set escape on
set echo off
set talk off
use c:\nicolas\initial\crops\final\croR91.dbf
go top
do while .not. eof()
champ1=BLKSQ
champ2=KILLA

long1=len(ltrim(champ1))
ch1=ltrim(str(val(champ1)))
l1=len(ch1)+1

champ1=right(champ1,long1-l1)
ch2=ltrim(str(val(champ1)))
l2=len(ch2)
     if l2=1
          ch2="0"+ch2
     ENDIF

long2=len(ltrim(champ2))
ch3=ltrim(str(val(champ2)))
l3=len(ch3)
     if l3=1
          ch3="0"+ch3
     endif

champ1=ch1+"/"+ch2+"/"+ch3
replace blksq with champ1
skip
enddo
wait
return
```

Annex 3(C) Listing of LOC 3 C.

```
set escape on
set echo off
set talk off
use c:\nicolas\flo\flofile.dbf
go top
do while .not. eof()
champ1=BLOCK
champ2=SQUARE
champ3=KILLA

long1=len(ltrim(champ1))
ch1=ltrim(str(val(champ1)))
l1=len(ch1)
     if l1=1
          ch1="0"+ch1
     ENDIF

long2=len(ltrim(champ2))
ch2=ltrim(str(val(champ2)))
l2=len(ch2)
     if l2=1
          ch2="0"+ch2
     endif

long3=len(ltrim(champ3))
ch3=ltrim(str(val(champ3)))
l3=len(ch3)
     if l3=1
          ch3="0"+ch3
     endif

champ1=ch1+"/"+ch2+"/"+ch3
replace BLOCK with champ1
skip
enddo
wait
return
```

Annex 4(a) **List of fields with more than two data series available**

OUTLET	SALR 949	SAL0794	SAL1292	SAL0692	SAL1191
AZ/111-L	172/11/14	172/11/14	172/11/14	172/11/14	
AZ/111-L	172/11/23	172/11/23		172/11/23	172/11/23
AZ/111-L	172/12/14	172/12/14	172/12/14	172/12/14	
AZ/111-L	173/11/05	173/11/05	173/11/05	173/11/05	173/11/05
AZ/111-L	173/11/07	173/11/07	173/11/07	173/11/07	173/11/07
AZ/111-L	173/11/08		173/11/08		
AZ/111-L	173/15/01	173/15/01	173/15/01	173/15/01	
AZ/111-L	173/15/03	173/15/03		173/15/03	
AZ/111-L	173/15/04	173/15/04	173/15/04	173/15/04	
AZ/111-L	173/15/05	173/15/05	173/15/05	173/15/05	
AZ/111-L	173/15/08	173/15/08		173/15/08	
AZ/111-L	193/03/09	193/03/09	193/03/09	193/03/09	
AZ/111-L	193/03/10	193/03/10		193/03/10	
AZ/111-L	194/01/02	194/01/02	194/01/02	194/01/02	
AZ/111-L	194/01/13	194/01/13	194/01/13	194/01/13	
AZ/111-L	194/01/18	194/01/18	194/01/18	194/01/18	
AZ/111-L	194/01/19	194/01/19	194/01/19	194/01/19	
AZ/111-L	194/02/01		194/02/01		
AZ/111-L	194/02/07	194/02/07	194/02/07	194/02/07	
AZ/111-L	194/02/14	194/02/14	194/02/14	194/02/14	
AZ/111-L	194/02/17	194/02/17		194/02/17	194/02/17
AZ/111-L	194/02/18	194/02/18		194/02/18	194/02/18
AZ/20-L	506/08/05	506/08/05	506/08/05	506/08/05	
AZ/20-L	506/08/17	506/08/17	506/08/17	506/08/17	
AZ/20-L	506/10/19	506/10/19	506/10/19	506/10/19	
AZ/20-L	506/10/23	506/10/23	506/10/23	506/10/23	
AZ/20-L	506/11/05	506/11/05	506/11/05	506/11/05	
AZ/20-L	506/11/07	506/11/07	506/11/07	506/11/07	
AZ/20-L	506/11/16	506/11/16	506/11/16	506/11/16	
AZ/20-L	506/12/09	506/12/09	506/12/09	506/12/09	
AZ/20-L	506/12/09	506/12/09	506/12/09	506/12/09	
AZ/20-L	506/14/19	506/14/19	506/14/19	506/14/19	
AZ/20-L	506/14/21	506/14/21	506/14/21	506/14/21	
AZ/20-L	506/15/19	506/15/19	506/15/19	506/15/19	
AZ/20-L	506/15/24	506/15/24	506/15/24	506/15/24	
AZ/20-L	506/16/02	506/16/02	506/16/02	506/16/02	
AZ/20-L	507/05/06	507/05/06	507/05/06	507/05/06	
AZ/20-L	507/06/05	507/06/05	507/06/05	507/06/05	
AZ/43-L	408/14/17	408/14/17	408/14/17	408/14/17	
AZ/43-L	427/05/20	427/05/20	427/05/20	427/05/20	
AZ/43-L	427/06/02	427/06/02	427/06/02	427/06/02	
AZ/43-L	427/06/19	427/06/19	427/06/19	427/06/19	
AZ/43-L	427/07/01	427/07/01	427/07/01	427/07/01	
AZ/43-L	427/07/12	427/07/12	427/07/12	427/07/12	
AZ/43-L	427/07/24	427/07/24	427/07/24	427/07/24	
AZ/43-L	427/08/20	427/08/20		427/08/20	
AZ/43-L	428/02/02	428/02/02	428/02/02	428/02/02	

AZ/43-L	428/02/25	428/02/25	428/02/25	428/02/25	
AZ/43-L	428/05/09	428/05/09	428/05/09	428/05/09	
AZ/43-L	428/05/20	428/05/20	428/05/20	428/05/20	
AZ/43-L	428/06/02	428/06/02	428/06/02	428/06/02	
AZ/43-L	428/07/20	428/07/20	428/07/20		
AZ/63-L	328/14/05	328/14/05		328/14/05	
AZ/63-L	328/14/07	328/14/07	328/14/07	328/14/07	328/14/07
AZ/63-L	328/15/24	328/15/24	328/15/24	328/15/24	328/15/24
AZ/63-L	328/16/16	328/16/16		328/16/16	
AZ/63-L	328/16/23	328/16/23	328/16/23	328/16/23	328/16/23
AZ/63-L	329/12/19		329/12/19	329/12/19	329/12/19
AZ/63-L	329/12/21	329/12/21	329/12/21	329/12/21	
AZ/63-L	329/12/22	329/12/22	329/12/22	329/12/22	
AZ/63-L	329/13/13	329/13/13	329/13/13	329/13/13	
AZ/63-L	329/13/14	329/13/14	329/13/14	329/13/14	
AZ/63-L	329/14/08	329/14/08	329/14/08	329/14/08	
AZ/63-L	329/14/09	329/14/09	329/14/09	329/14/09	
AZ/63-L	348/02/11	348/02/11	348/02/11	348/02/11	
AZ/63-L	348/02/20	348/02/20	348/02/20	348/02/20	
AZ/63-L	348/04/10	348/04/10	348/04/10	348/04/10	
AZ/63-L	348/04/13	348/04/13	348/04/13	348/04/13	
AZ/63-L	348/04/18	348/04/18	348/04/18	348/04/18	
AZ/63-L	349/01/01	349/01/01	349/01/01	349/01/01	349/01/01
FD/062-R	350/16/03	350/16/03	350/16/03	350/16/03	
FD/062-R	350/16/04	350/16/04	350/16/04	350/16/04	
FD/062-R	350/16/14	350/16/14	350/16/14	350/16/14	350/16/14
FD/062-R	351/12/01	351/12/01	351/12/01	351/12/01	351/12/01
FD/062-R	351/12/02	351/12/02	351/12/02	351/12/02	
FD/062-R	351/14/03	351/14/03	351/14/03	351/14/03	351/14/03
FD/062-R	351/14/04	351/14/04	351/14/04	351/14/04	
FD/062-R	352/09/03	352/09/03	352/09/03	352/09/03	
FD/062-R	352/09/04	352/09/04	352/09/04	352/09/04	
FD/062-R	352/09/10	352/09/10	352/09/10	352/09/10	
FD/062-R	352/09/11	352/09/11	352/09/11	352/09/11	
FD/062-R	352/09/20	352/09/20	352/09/20	352/09/20	352/09/20
FD/062-R	352/13/17	352/13/17	352/13/17	352/13/17	352/13/17
FD/062-R	352/13/24	352/13/24	352/13/24	352/13/24	
FD/062-R	352/13/25	352/13/25	352/13/25	352/13/25	352/13/25
FD/130-R	77/13/05	77/13/05	77/13/05	77/13/05	
FD/130-R	77/13/13	77/13/13	77/13/13	77/13/13	
FD/130-R	77/13/24	77/13/24	77/13/24	77/13/24	
FD/130-R	77/14/06	77/14/06	77/14/06	77/14/06	
FD/130-R	77/14/07	77/14/07	77/14/07	77/14/07	
FD/130-R	96/03/17	96/03/17	96/03/17	96/03/17	
FD/130-R	96/03/18	96/03/18	96/03/18	96/03/18	
FD/130-R	97/01/21				97/01/21
FD/130-R	97/06/23	97/06/23	97/06/23	97/06/23	
FD/130-R	97/07/19	97/07/19	97/07/19	97/07/19	
FD/130-R	97/10/16	97/10/16	97/10/16	97/10/16	
FD/130-R	97/10/25	97/10/25	97/10/25	97/10/25	
FD/130-R	97/11/01	97/11/01	97/11/01	97/11/01	
FD/130-R	97/11/02	97/11/02	97/11/02	97/11/02	
FD/14-R	529/04/17	529/04/17	529/04/17	529/04/17	
FD/14-R	529/08/06	529/08/06	529/08/06	529/08/06	

FD/14-R	529/16/10	529/16/10	529/16/10	529/16/10
FD/14-R	549/03/25	549/03/25	549/03/25	549/03/25
FD/14-R	549/04/21	549/04/21	549/04/21	549/04/21
FD/14-R	549/07/08	549/07/08	549/07/08	549/07/08
FD/14-R	549/08/07	549/08/07	549/08/07	549/08/07
FD/14-R	549/10/21	549/10/21	549/10/21	549/10/21
FD/14-R	549/11/14	549/11/14	549/11/14	549/11/14
FD/14-R	549/12/14	549/12/14	549/12/14	549/12/14
FD/14-R	549/14/08	549/14/08	549/14/08	549/14/08
FD/14-R	549/15/18	549/15/18	549/15/18	549/15/18
FD/14-R	549/16/11	549/16/11	549/16/11	549/16/11
FD/14-R	550/09/17	550/09/17	550/09/17	550/09/17
FD/14-R	550/13/10	550/13/10	550/13/10	550/13/10
FD/46-R	410/08/16	410/08/16	410/08/16	410/08/16
FD/46-R	410/09/22	410/09/22	410/09/22	410/09/22
FD/46-R	410/10/11	410/10/11	410/10/11	410/10/11
FD/46-R	410/11/12	410/11/12	410/11/12	410/11/12
FD/46-R	410/12/12	410/12/12	410/12/12	410/12/12
FD/46-R	410/14/04	410/14/04	410/14/04	410/14/04
FD/46-R	410/15/14	410/15/14	410/15/14	410/15/14
FD/46-R	410/16/22	410/16/22	410/16/22	410/16/22
FD/46-R	411/09/11	411/09/11	411/09/11	411/09/11
FD/46-R	411/10/06	411/10/06	411/10/06	411/10/06
FD/46-R	411/13/13	411/13/13	411/13/13	411/13/13
FD/46-R	411/14/14	411/14/14	411/14/14	411/14/14
FD/46-R	411/15/06	411/15/06	411/15/06	411/15/06
FD/46-R	411/16/14	411/16/14	411/16/14	411/16/14
FD/46-R	412/13/06	412/13/06	412/13/06	412/13/06

Annex 4(b) **List of the common sample fields (salinity data)**

OUTLET	SALR9495	SAL0794	SAL1292	SAL0692	SAL1191
AZ/111-L	172/12/14	172/12/14	172/12/14	172/12/14	
AZ/111-L	173/11/05	173/11/05	173/11/05	173/11/05	173/11/05
AZ/111-L	173/11/07	173/11/07	173/11/07	173/11/07	173/11/07
AZ/111-L	173/15/01	173/15/01	173/15/01	173/15/01	
AZ/111-L	173/15/04	173/15/04	173/15/04	173/15/04	
AZ/111-L	173/15/05	173/15/05	173/15/05	173/15/05	
AZ/111-L	193/03/09	193/03/09	193/03/09	193/03/09	
AZ/111-L	194/01/02	194/01/02	194/01/02	194/01/02	
AZ/111-L	194/01/13	194/01/13	194/01/13	194/01/13	
AZ/111-L	194/01/18	194/01/18	194/01/18	194/01/18	
AZ/111-L	194/01/19	194/01/19	194/01/19	194/01/19	
AZ/111-L	194/02/07	194/02/07	194/02/07	194/02/07	
AZ/111-L	194/02/14	194/02/14	194/02/14	194/02/14	
AZ/20-L	506/08/05	506/08/05	506/08/05	506/08/05	
AZ/20-L	506/08/17	506/08/17	506/08/17	506/08/17	
AZ/20-L	506/10/19	506/10/19	506/10/19	506/10/19	
AZ/20-L	506/10/23	506/10/23	506/10/23	506/10/23	
AZ/20-L	506/11/05	506/11/05	506/11/05	506/11/05	
AZ/20-L	506/11/07	506/11/07	506/11/07	506/11/07	
AZ/20-L	506/11/16	506/11/16	506/11/16	506/11/16	
AZ/20-L	506/12/09	506/12/09	506/12/09	506/12/09	
AZ/20-L	506/12/09	506/12/09	506/12/09	506/12/09	
AZ/20-L	506/14/19	506/14/19	506/14/19	506/14/19	
AZ/20-L	506/14/21	506/14/21	506/14/21	506/14/21	
AZ/20-L	506/15/19	506/15/19	506/15/19	506/15/19	
AZ/20-L	506/15/24	506/15/24	506/15/24	506/15/24	
AZ/20-L	506/16/02	506/16/02	506/16/02	506/16/02	
AZ/20-L	507/05/06	507/05/06	507/05/06	507/05/06	
AZ/20-L	507/06/05	507/06/05	507/06/05	507/06/05	
AZ/43-L	408/14/17	408/14/17	408/14/17	408/14/17	
AZ/43-L	427/05/20	427/05/20	427/05/20	427/05/20	
AZ/43-L	427/06/02	427/06/02	427/06/02	427/06/02	
AZ/43-L	427/06/19	427/06/19	427/06/19	427/06/19	
AZ/43-L	427/07/01	427/07/01	427/07/01	427/07/01	
AZ/43-L	427/07/12	427/07/12	427/07/12	427/07/12	
AZ/43-L	427/07/24	427/07/24	427/07/24	427/07/24	
AZ/43-L	428/02/02	428/02/02	428/02/02	428/02/02	
AZ/43-L	428/02/25	428/02/25	428/02/25	428/02/25	
AZ/43-L	428/05/09	428/05/09	428/05/09	428/05/09	
AZ/43-L	428/05/20	428/05/20	428/05/20	428/05/20	
AZ/43-L	428/06/02	428/06/02	428/06/02	428/06/02	
AZ/63-L	328/14/07	328/14/07	328/14/07	328/14/07	328/14/07
AZ/63-L	328/15/24	328/15/24	328/15/24	328/15/24	328/15/24
AZ/63-L	328/16/23	328/16/23	328/16/23	328/16/23	328/16/23
AZ/63-L	329/12/21	329/12/21	329/12/21	329/12/21	
AZ/63-L	329/12/22	329/12/22	329/12/22	329/12/22	
AZ/63-L	329/13/13	329/13/13	329/13/13	329/13/13	
AZ/63-L	329/13/14	329/13/14	329/13/14	329/13/14	
AZ/63-L	329/14/08	329/14/08	329/14/08	329/14/08	

AZ/63-L	329/14/09	329/14/09	329/14/09	329/14/09	
AZ/63-L	348/02/11	348/02/11	348/02/11	348/02/11	
AZ/63-L	348/02/20	348/02/20	348/02/20	348/02/20	
AZ/63-L	348/04/10	348/04/10	348/04/10	348/04/10	
AZ/63-L	348/04/13	348/04/13	348/04/13	348/04/13	
AZ/63-L	348/04/18	348/04/18	348/04/18	348/04/18	
AZ/63-L	349/01/01	349/01/01	349/01/01	349/01/01	349/01/01
FD/062-R	350/16/03	350/16/03	350/16/03	350/16/03	
FD/062-R	350/16/04	350/16/04	350/16/04	350/16/04	
FD/062-R	350/16/14	350/16/14	350/16/14	350/16/14	350/16/14
FD/062-R	351/12/01	351/12/01	351/12/01	351/12/01	351/12/01
FD/062-R	351/12/02	351/12/02	351/12/02	351/12/02	
FD/062-R	351/14/03	351/14/03	351/14/03	351/14/03	351/14/03
FD/062-R	351/14/04	351/14/04	351/14/04	351/14/04	
FD/062-R	352/09/03	352/09/03	352/09/03	352/09/03	
FD/062-R	352/09/04	352/09/04	352/09/04	352/09/04	
FD/062-R	352/09/10	352/09/10	352/09/10	352/09/10	
FD/062-R	352/09/11	352/09/11	352/09/11	352/09/11	
FD/062-R	352/09/20	352/09/20	352/09/20	352/09/20	352/09/20
FD/062-R	352/13/17	352/13/17	352/13/17	352/13/17	352/13/17
FD/062-R	352/13/24	352/13/24	352/13/24	352/13/24	
FD/062-R	352/13/25	352/13/25	352/13/25	352/13/25	352/13/25
FD/130-R	77/13/05	77/13/05	77/13/05	77/13/05	
FD/130-R	77/13/13	77/13/13	77/13/13	77/13/13	
FD/130-R	77/13/24	77/13/24	77/13/24	77/13/24	
FD/130-R	77/14/06	77/14/06	77/14/06	77/14/06	
FD/130-R	77/14/07	77/14/07	77/14/07	77/14/07	
FD/130-R	96/03/17	96/03/17	96/03/17	96/03/17	
FD/130-R	96/03/18	96/03/18	96/03/18	96/03/18	
FD/130-R	97/06/23	97/06/23	97/06/23	97/06/23	
FD/130-R	97/07/19	97/07/19	97/07/19	97/07/19	
FD/130-R	97/10/16	97/10/16	97/10/16	97/10/16	
FD/130-R	97/10/25	97/10/25	97/10/25	97/10/25	
FD/130-R	97/11/01	97/11/01	97/11/01	97/11/01	
FD/130-R	97/11/02	97/11/02	97/11/02	97/11/02	
FD/14-R	529/04/17	529/04/17	529/04/17	529/04/17	
FD/14-R	529/08/06	529/08/06	529/08/06	529/08/06	
FD/14-R	529/16/10	529/16/10	529/16/10	529/16/10	
FD/14-R	549/03/25	549/03/25	549/03/25	549/03/25	
FD/14-R	549/04/21	549/04/21	549/04/21	549/04/21	
FD/14-R	549/07/08	549/07/08	549/07/08	549/07/08	
FD/14-R	549/08/07	549/08/07	549/08/07	549/08/07	
FD/14-R	549/10/21	549/10/21	549/10/21	549/10/21	
FD/14-R	549/11/14	549/11/14	549/11/14	549/11/14	
FD/14-R	549/12/14	549/12/14	549/12/14	549/12/14	
FD/14-R	549/14/08	549/14/08	549/14/08	549/14/08	
FD/14-R	549/15/18	549/15/18	549/15/18	549/15/18	
FD/14-R	549/16/11	549/16/11	549/16/11	549/16/11	
FD/14-R	550/09/17	550/09/17	550/09/17	550/09/17	
FD/14-R	550/13/10	550/13/10	550/13/10	550/13/10	
FD/46-R	410/08/16	410/08/16	410/08/16	410/08/16	
FD/46-R	410/09/22	410/09/22	410/09/22	410/09/22	
FD/46-R	410/10/11	410/10/11	410/10/11	410/10/11	
FD/46-R	410/11/12	410/11/12	410/11/12	410/11/12	

FD/46-R	410/12/12	410/12/12	410/12/12	410/12/12
FD/46-R	410/14/04	410/14/04	410/14/04	410/14/04
FD/46-R	410/15/14	410/15/14	410/15/14	410/15/14
FD/46-R	410/16/22	410/16/22	410/16/22	410/16/22
FD/46-R	411/09/11	411/09/11	411/09/11	411/09/11
FD/46-R	411/10/06	411/10/06	411/10/06	411/10/06
FD/46-R	411/13/13	411/13/13	411/13/13	411/13/13
FD/46-R	411/14/14	411/14/14	411/14/14	411/14/14
FD/46-R	411/15/06	411/15/06	411/15/06	411/15/06
FD/46-R	411/16/14	411/16/14	411/16/14	411/16/14
FD/46-R	412/13/06	412/13/06	412/13/06	412/13/06

Annex 5(a) **Listing of ROWCOL 06.PRG**

```
set escape off
set echo off
set talk off
use c:\nicolas\initial\sar\final\sal1191.dbf in 1
use c:\nicolas\initial\sar\final\salnew6.dbf in 2

go top
nec6=0
nec12=0
nec24=0
nec36=0
nsar6=0
nsar12=0
nsar24=0
nsar36=0


Do while .not. eof()
select 1

KL=BLSQKI
champ0=DEPTH
champ1=EC
champ2=SAR
champ3=OUTLET


     if champ0=6
     nec6=champ1
     nsar6=champ2
     endif

     if champ0=12
     nec12=champ1
     nsar12=champ2
     endif

     if champ0=24
     nec24=champ1
     nsar24=champ2
     endif

     if champ0=36
     nec36=champ1
     nsar36=champ2
     endif
```

```
skip
     if BLSQKI<>KL
     select 2
     append blank
     replace BLSQKI with KL
     replace OUTLET with champ3
     replace EC6cm with nec6
     replace EC12cm with nec12
     replace EC24cm with nec24
     replace EC36cm with nec36
     replace SAR6cm with nsar6
     replace SAR12cm with nsar12
     replace SAR24cm with nsar24
     replace SAR36cm with nsar36
     nec6=0
     nec12=0
     nec24=0
     nec36=0
     nsar6=0
     nsar12=0
     nsar24=0
     nsar36=0

     endif

enddo
wait
return
```

Annex 5(b) **Listing of ROWCOL15.PRG**

```
set escape off
set echo off
set talk off
use c:\nicolas\initial\sar\final\4samfk94.DBF in 1
use c:\nicolas\initial\sar\final\salnew15.dbf in 2

go top
nec15=0
nec30=0
nec60=0
nec90=0
nec120=0
nec150=0
nec200=0
nsar15=0
nsar30=0
nsar60=0
nsar90=0
nsar120=0
nsar150=0
nsar200=0


Do while .not. eof()
select 1

KL=BLSQKI
champ0=DEPTH
champ1=EC
champ2=SAR
champ3=OUTLET

     if champ0=15
     nec15=champ1
     nsar15=champ2
     endif

     if champ0=30
     nec30=champ1
     nsar30=champ2
     endif

     if champ0=60
     nec60=champ1
     nsar60=champ2
     endif

     if champ0=90
     nec90=champ1
     nsar90=champ2
     endif
```

```
    if champ0=120
    nec120=champ1
    nsar120=champ2
    endif

    if champ0=150
    nec150=champ1
    nsar150=champ2
    endif

    if champ0=200
    nec200=champ1
    nsar200=champ2
    endif

skip

    if BLSQKI<>KL
    select 2
    append blank
    replace BLSQKI with KL
    replace OUTLET with champ3
    replace EC15cm with nec15
    replace EC30cm with nec30
    replace EC60cm with nec60
    replace EC90cm with nec90
    replace EC120cm with nec120
    replace EC150cm with nec150
    replace EC200cm with nec200

    replace SAR15cm with nsar15
    replace SAR30cm with nsar30
    replace SAR60cm with nsar60
    replace SAR90cm with nsar90
    replace SAR120cm with nsar120
    replace SAR150cm with nsar150
    replace SAR200cm with nsar200

    nec15=0
    nec30=0
    nec60=0
    nec90=0
    nec120=0
    nec150=0
    nec200=0
```

```
      nsar15=0
      nsar30=0
      nsar60=0
      nsar90=0
      nsar120=0
      nsar150=0
      nsar200=0

      endif

   enddo
   wait
   return
```

Annex 6 List of the new files after transformation

PREVIOUS FILES	NEW FILES
SAL1191.dbf	ECSA1191.dbf
SAL0692.dbf	ECSA0692.dbf
SAL1292.dbf	ECSA1292.dbf
SAL0794.dbf	ECSA0794.dbf
4samfk94.dbf	4ECSAK94.dbf
4samfr95.dbf	4ECSAR95.dbf

Annex 7 List of available parameters in salinity files

	sal1191.dbf	sal0692.dbf	sal1292.dbf	sal0194.dbf	4saafh94.dbf	4saafc95.dbf
SAMPLE W.C.	AZ63-111, FD62-130	8 sample W.C. (20,43,63,111,14,46,62,130)	8 sample W.C.	8 sample W.C. +4 sample fields	4 sample fields	4 sample fields
DATE	*	*	*	*	*	*
OUTLET	*	*	*	*	*	*
BL\SQ\ET	*	*	*	*	*	*
LOCATION (Head, Middle, Tail)		*	*			
OWNER'S NAME				*		
CULTIVATOR'S NAME				*		
AERA				*		
LAND HOLDING				*		
DEPTH (cm)	6,12,24,36	6,12,24,36	6,12,24,36	6,12,24,36	15,30,60,90,120,150,200	15,30,60,90,120,150,200
SATURATION (% age)	*				*	*
pH	*				*	*
EC (*10^3 OF extract at 25 C)	*	*	*	*	*	*
Ca (milliеq./l)	*	Ca+Mg	Ca+Mg		*	Ca+Mg
Mg	*	Ca+Mg	Ca+Mg		*	Ca+Mg
Na	*	*	*		*	*
K	*					
CO3	*				*	
HCO3	*					
Cl	*				*	
SO4	*				*	
SQ					*	
TOTAL	*	*	*		*	
SAR	*	*	*	*	*	*
SAND (%)	*					*
SILT (%)	*					*
CLAY (%)	*					*
TEXTURE	*					*
GYPSUM REQUIRTS (TONS/acre)	*					

Annex 8 Spatial representation of available data for watercourse Fordwah 130R, Rabi 1991/1992