

## IMPACT OF SUBSURFACE DRAINAGE ON SOIL SALINITY IN PAKISTAN

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### ABSTRACT

In this study three subsurface drainage projects namely; Fourth Drainage Project, Faisalabad (FDP), Chashma Command Area Development Project (CCADP) and Mirpurkhas Tile Drainage Project (MKDP) have been assessed in terms of their impact on soil salinity improvement in irrigated areas. At FDP, the analysis of surface and profile salinities revealed that both the salinities were significantly decreased. The decrease in surface and profile salinities was 20% and 14% respectively against the benchmark year (i.e. 1984). The surface salinity showed an improvement of 30% in the salt free area. Profile salinity results indicated an improvement of 28% in non saline-non sodic (NS-NS) area. The improvement in S-SN, NS-S and S-S areas was of the order of 50%, 63% & 18% respectively. At CCADP, the salinity of area was very low and was not considered to be a problem in the project area due to drainage system installation. The investigations showed that 17% area was slightly saline, 1% was moderately saline, and 82% area was salt free. At MKDP, profile salinity in bench mark year (i.e. 2000) was 65%. Significant improvement (i.e. 86%) was observed during post-project 2001 year. However, during the year 2002 the profile salinity aggravated and showed improvement of only 14% with respect to bench mark year. Saline-Sodic (S-S) area was reduced by 33% in year 2001. Nevertheless, the situation was reversed showing the deterioration of 11% in year 2002 as compared to bench mark year. The aggravated soil salinity situation during year 2002 was mainly due to the poor operation of drainage system in MKDP area. Overall, the investigations revealed the positive impact of subsurface drainage system installation in terms of salinity control of irrigated lands of affected areas. The rate of improvement was very high in the initial years of systems' operation.

**Keywords:** impact, subsurface drainage, soil salinity, waterlogging

### INTRODUCTION

Pakistan is bestowed with abundant water resources in the form of gigantic rivers fed from worldly renowned lofty snow & ice clad mountain peaks and rainy water, their tributaries, rivulets, hill torrents besides vast underground water reservoir. The rivers and their tributaries constitute the "Indus River System" - nearly a century old world's largest canal irrigation system which provides irrigation facilities to 36 million acres of land that corresponds to about 46% of the total cultivable area of the country (WAPDA, 2002).

The water wing of WAPDA is not only responsible for the development of water resources for agriculture but also undertakes measures for mitigation of the problems emerging as a consequence of over-irrigation to agricultural lands. Amongst various measures adopted, the subsurface drainage technology was introduced by WAPDA in Pakistan about three-and-a-half decades ago to combat the twin menace of waterlogging & salinity. As such, Government of Pakistan has invested considerable funds (~Rs.37 billions) to improve the land & groundwater conditions through installation subsurface tile drainage projects (Azhar *et al*, 2004a).

To-date, eight drainage projects have been

completed in various provinces of Pakistan. In the past, different aspects of those drainage systems have been investigated by various researchers (Iqbal *et al*, 1997; IWASRI, 1997, Azhar *et al*, 2004a; Azhar *et al*, 2006). However, no systematic effort has been made to analyse the data of these systems in terms of "improvement evaluation". The exception was the study (Kahlowan *et al*, 1998) regarding the waterlogging, salinity and crop yield relationships only for Fordwah Eastern Sadiqia, South (FESS) Project, Bahawalnagar of Punjab province. Keeping in view the huge investments incurred and the benefits attached with these projects, there is a great need to evaluate the performance of these systems and to suggest improvements for future drainage systems. As such, the reported study was conducted by the International Waterlogging & Salinity Research Institute (IWASRI) under National Drainage Programme (NDP) where three subsurface drainage projects namely Fourth Drainage Project, Faisalabad (FDP), Chashma Command Area Development Project (CCADP) and Mirpurkhas Tile Drainage Project (MKDP) were assessed for their impact on improvement of irrigated agriculture conditions (Fig. 1). For this purpose, various impact indicators were investigated, however, this paper presents only one impact indicator namely soil salinity.

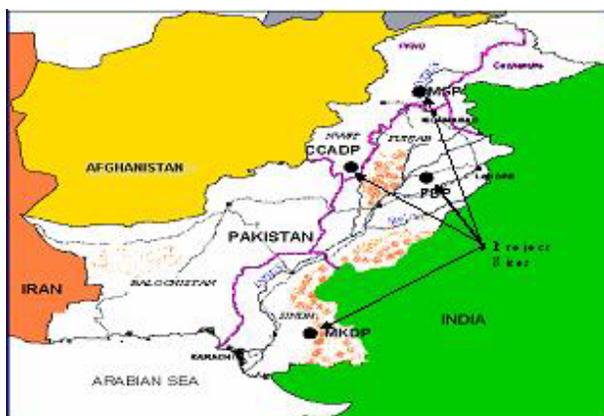


Fig. 1. Location map of selected drainage projects

**STUDY AREA:** In order to mitigate the impact of waterlogging & salinity, to-date eight drainage projects have been installed in the affected areas of Pakistan. For this study, only three project sites namely; FDP (Punjab), CCADP (NWFP) and MKDP (Sindh) have been selected (Fig. 1). These sites have been selected based on their wide range of geohydrological, climatic & socio-economic conditions as well as availability of soil salinity data. As such, this range of selection would facilitate to investigate drainage projects in different provinces of Pakistan. The salient features of those selected project sites are given in Table 1.

Table 1. Salient features of selected subsurface drainage projects

Description	FDP	CCADP	MKDP
Gross Area (ha)	52,609	63,509	36,165
Subsurface Drainage Area	30,351 ha	60,936 ha	24,281 ha
Installation Period	1988-94	1984-94	1994-97
Design WT Depth (cm)	122	140	122
Type of System	Pumped	Pumped	Pumped
Executive agency	WAPDA	WAPDA	WAPDA
Consultancy	USBR	Harza Nespak	M. Macdonald
Total cost	Rs 1127x10 <sup>6</sup>	Rs 1127.8 m	Rs 2473 m

## MATERIALS AND METHODS

In this study only one impact/performance indicator viz. *soil salinity* has been discussed. In general, under salinity head two types of salinities viz; *surface salinity* and *profile salinity* are investigated. The major aim of drainage system installation is reclamation of waterlogged & saline lands. From the performance point of view of the drainage system operation, soil salinities

are generally expected to decrease with the installation of subsurface drainage system. For this analysis, relevant data were collected from various sources such as Harza (1995), Agricultural Department, and through farmers' interviews conducted by the IWASRI staff. The required data were aimed at to be collected for three stages i.e., *before, during* and *after* the installation of drainage systems. The collected data were first screened for their integrity, and then analysed in various ways to assess the success of drainage project based on above stated performance indicator. In this study, for quantitative comparison between pre & post-project conditions, the pre-project value of salinity level was used as the *base value* for respective site.

As mentioned earlier, for soil salinity investigations two types of surveys namely: *surface salinity* and *profile salinity* are done. For these surveys, the methodologies are detailed in WAPDA (2001). The salinities were mapped according to the previously established salinity classes. For surface salinity, saline and non-saline areas were marked separately according to the intensity and frequency of salt patches assessed through visual observations, aerial photo interpretation, crop condition and kind of natural vegetation where present. In order to describe the surface salinity status, based on the USDA hand book 60 four salinity classes viz; Salt free (S1), slightly salt-affected (S2), moderately salt-affected (S3), and strongly salt-affected (S4) have been recognized (WAPDA, 2001).

The profile salinity survey is carried out to determine the magnitude of the hazard in the soil profile. For this purpose, the soil samples were air dried and analysed for Electrical Conductivity (ECe), Calcium, Magnesium and Sodium Adsorption Ratio (SAR). Under this head, the soils are classified under four classes as per the criteria laid down in WAPDA (2001), given in Table 2.

Table 2. Profile salinity classification of soils

Salinity/Sodicity Class	Criteria
Non-Saline Non-Sodic (NS-NS)	ECe < 4; SAR < 13.
Saline Non-Sodic (S-NS)	ECe > 4; SAR < 13.
Saline Sodic (S-S)	ECe > 4; SAR > 13.
Non-Saline Sodic (NS-S)	ECe < 4; SAR > 13.

## RESULTS AND DISCUSSION

The impact on soil salinity environment of various project sites is discussed hereunder.

### Fourth Drainage Project (FDP) Area

**Surface salinity:** Based on the four surface salinity classes namely: salt free (S1), slightly salt-affected (S2),

moderately salt-affected (S3), and strongly salt-affected (S4) described earlier, the summary of surface salinity status observed at FDP during 1984 (Bench Mark), 1986-87, 1990-91 and 2000-01 available surveys is graphically presented in Fig. 2.

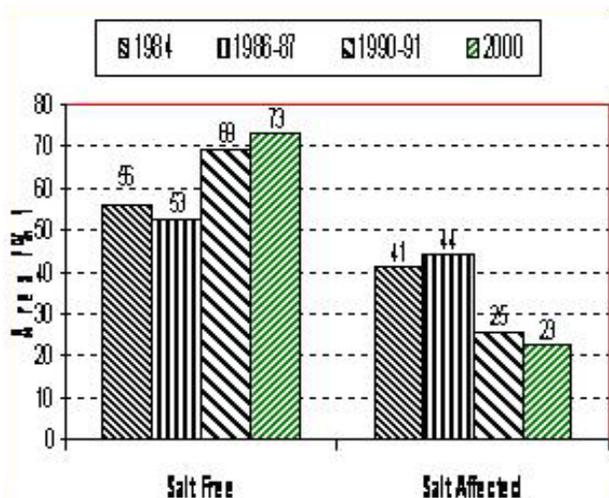
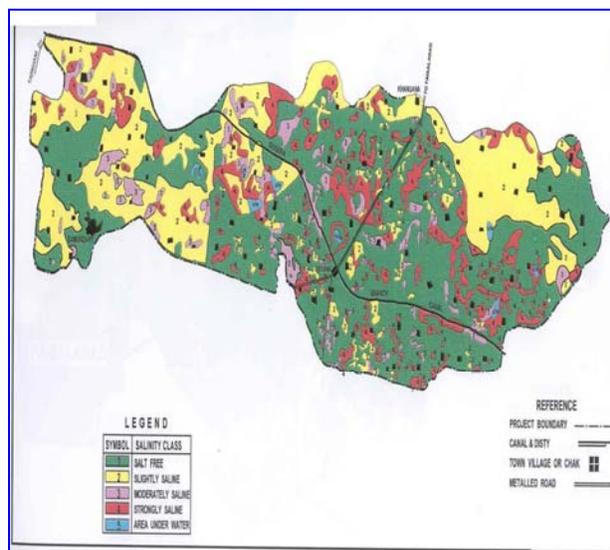


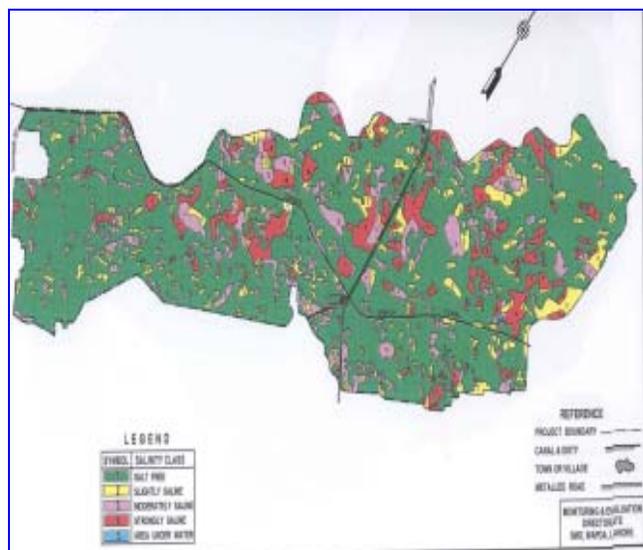
Fig. 2 Surface salinity status at FDP

As can be observed (Fig. 2), salt affected (i.e. S2, S3 & S4) area showed a decrease during 2000 year over pre-project 1984 (Bench Mark) year. An improvement in salt free area can also be observed during the latest survey period (year 2000) over bench mark (1984) year. The salt affected (S2, S3 & S4) area in pre-project (1984) year was 42%, which reduced to 23% during the 2000 year, indicating a net decrease of 19% with respect to the base year.

The salt free (S1) area in pre-project year (1984) was 56% that increased to 73% during 2000 year, indicating a net increase of 17%. This shows a significant improvement of the order of 30% in S1 area. This improvement can mainly be attributed to the leaching of salts below 180 cm depth due to the lowering of watertable resulting from the installation of subsurface drainage system in addition to the application of irrigation water & rains. Hence, it indicates the positive impact of pipe drainage system in terms of surface salinity control in FDP area. The pre-project (year 1984) and post-project (year 2000) surface salinity maps of FDP area are shown in Fig. 3.



Pre-Project (1984)



Post-Project (2000)

Fig. 3. Comparison of surface salinity status at FDP area

**Profile salinity:** Based on the four profile salinity classes namely: *Non-Saline Non-Sodic* (NS-NS), *Saline Non-Sodic* (S-NS), *Saline Sodic* (S-S) and *Non-Saline Sodic* (NS-S), the summary of profile salinity status at FDP during various available surveys is graphically presented in Fig. 4. It can be observed, NS-NS area showed a significant improvement. The area under this class was 50% during the pre-project (1984) year that increased to 64% during post-project (2000) year, thus showing a net increase of 14% over the bench mark (1984) year. This indicates an improvement of 28% during post-project

(2000) year over the bench mark (1984) year. Similarly, the salt affected area reduced from 50% (B.M year) to 36% during the post-project year 2000, thus showing a net decrease of 14% over the bench mark (1984) year.

The area under S-NS class was 4% in pre-project (1984) year that decreased to 2% during post-project (2001) year, showing a net decrease of 2% over the bench mark (1984) year. This indicates an improvement of 50% (i.e. decrease in S-NS) area during post-project (2001) year over the bench mark year. The area under S-S class was 38% in pre-project (1984) year

that decreased to 31% during post-project (2001) year, showing a net decrease of 7% over the bench mark (1984) year. This indicates an improvement of 18% (i.e. decrease in S-S) area during post-project (2001) year over the bench mark year. Similarly, the NS-S area was 8% in pre-project (1984) year that decreased to 3% during post-project (2001) year, showing a net decrease of 5% over the bench mark (1984) year. This indicates an improvement of 63% (i.e. decrease in NS-S) area during post-project (2001) year over the bench mark year. As such, this aspect also indicates a positive impact of subsurface pipe drainage system installation in terms of profile salinity control in the FDP area.

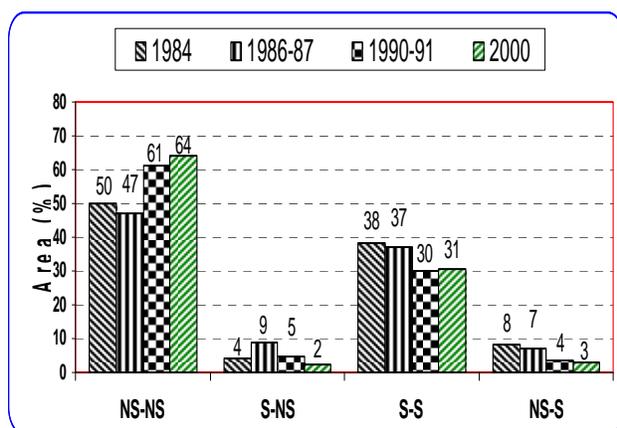


Fig. 4 Profile salinity status at FDP area

#### Chashma Command Area Development Project (CCADP)

For CCADP area, very less information was available regarding the soil salinity improvement aspect. According to the surveys conducted at CCADP, the salinity of area was very low and it was not considered to be a problem in the project area (HARZA, 1995). However, if a subsurface drainage system had not been provided, then it was only a matter of time before salinity would have become a severe problem. As reported by HARZA (1995), the soil surveys conducted in the project area indicated that 25,109 acres (17%) were slightly saline, 1308 acres (1%) were moderately saline, and 121,100 acres (82%) were salt free.

#### Mirpurkhas Tile Drainage Project (MKDP)

The execution period of MKDP was 1994-97. At MKDP area, about surface salinity no information was available; whereas for profile salinity status only three post-project surveys' (year 2000, 2001 & 2002) data were available. Based on four profile salinity classes described earlier (Table 2), the summary of profile salinity status at MKDP during various available surveys is graphically presented in Fig. 5.

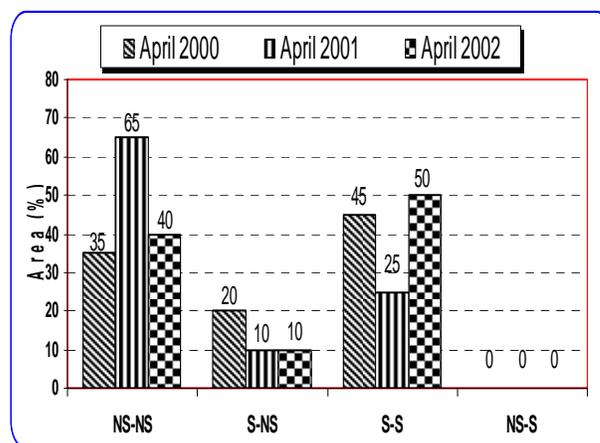


Fig. 5 Profile salinity status at MKDP area

As stated earlier, for this study site only three post-project surveys' data was available. Hence, for quantitative comparison at MKDP area the post-project 2000 year salinity status was adopted as the base value. Profile salinity at MKDP in base year (i.e. 2000) was 65%. The observed profile salinity data (Table 5 & Fig. 5) revealed that salt affected area reduced from 65% to 35% during the post-project year 2001. As such, the corresponding NS-NS area increased from 35% (base year 2000) to 65% during the post-project year 2001, showing a significant improvement (86%) during the post-project year 2001 over the base year (i.e. 2000). However, during the year 2002 the profile salinity aggravated and showed an improvement of only 14% with respect to the base year; which may be attributed to poor operation of the drainage system.

The S-NS area was 20% in base year, which reduced/improved during both 2001 & 2002 years. The improvement in S-NS area was of the order of 50% during both 2001 & 2002 years as compared with the base year. Similarly, the S-S area was 45% in base year, which decreased to 25% during 2001 year, showing an improvement of 33% (i.e. decrease in S-S area) during the year 2001 over the base year (i.e. 2000); whereas during the year 2002 the situation was reverse showing a deterioration of 11% (i.e. increase in S-S area) with respect to the base year (i.e. 2000), which may be due to poor management practices as well as poor operation of drainage system in the project area.

The non saline-sodic (NS-S) area did not exist at MKDP study site. The overall results, however, indicate the positive impact of tile drainage system in terms of profile salinity control in MKDP area.

The aggravated soil salinity situation during year 2002 was mainly due to the poor operation of drainage system in MKDP area as reported by Azhar *et al.*, (2004b).

**CONCLUSIONS:** Based on the analysis of soil salinity data of three project sites, following conclusions were drawn:

- At FDP, the results of surface and profile salinities revealed that both the salinities were significantly decreased. The net decrease in surface & profile salinities was 20% and 14% respectively with respect to the pre-project i.e. year 1984; thus showing decrease in the salinity/sodicity extent of the FDP soils. The surface salinity data investigations indicated a significant improvement of 30% in the salt free (S1) area. The profile salinity data investigations indicated an improvement of 28% in NS-NS area. Similarly, the improvement in S-SN, NS-S and S-S areas was of the order of 50%, 63% & 18% respectively. This indicates positive impact of pipe drainage system installation in terms of salinity control in the FDP area.
- At CCADP, the salinity of area was very low and was not considered to be a problem in the project area. The survey indicated that 17% of area was slightly saline, only 1% was moderately saline, and 82% area was salt free. In general, it was observed that the sub-surface drainage significantly improved the soil salinity status in the project area
- At MKDP, profile salinity in base year (i.e. 2000) was 65%. The salt affected area decreased from 65% to 35% during the post-project year 2001. As such, the corresponding NS-NS area increased from 35% (base year 2000) to 65% during the post-project year 2001, showing a significant improvement (86%) during the post-project year 2001 over the base year (i.e. 2000). However, during the year 2002 the profile salinity aggravated and showed an improvement of only 14% with respect to the base year. The aggravated soil salinity situation during year 2002 was perhaps due to the poor operation of drainage system in MKDP area.

## **RECOMMENDATIONS**

- There should be a regular and systematic mechanism of performance evaluation at subsurface drainage project sites in Pakistan.
- The beneficiaries (i.e. farmers) should be involved in drainage projects right from the planning stage through to the O&M stage, so that a sense of ownership is developed in them.
- The benefits of existing drainage systems can further be enhanced by educating the beneficiaries through agricultural extension services in the drainage areas.

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