APPLICATION OF "SALTMOD" TO EVALUATE PREVENTIVE MEASURES AGAINST HYDRO-SALINIZATION IN AGRICULTURAL RURAL AREAS (A Case Study of Faisalabad, Pakistan)

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ABSTRACT

In Pakistan, the salt-affected soils are now covering an area of 4.22 Mha, which constitutes about 26% of irrigated rural area. About 55 Salinity Control and Reclamation Projects (SCRAP) were launched as a remedial measures in the past with huge investments, mainly comprising vertical and surface drainage system. The results were found generally far below expectations, due to many reasons/factors which were not taken into account before project-implementation. This model-study has been initiated, therefore, as an effort to test the generalized hydro-salinity model 'SaltMod' for different soil and water-management scenaries and to evaluate the SCRAP project as remedial measures in the rural areas in order to enhance over all agro-productivity.

INTRODUCTION

Secure balance in the global supply and demand for food has forced humans to develop agriculture in semi-arid to arid lands, which are generally less suitable for agriculture and sensitive to environmental changes. Irrigation has always been considered as an effective way for progressive and sustainable irrigated agriculture in rural areas since ancient times, to bridge the gap of water-shortage. Large investments have been made in the past on irrigation developments, to maximize the production. Owing to irrigation-system, the farmers have obtained quite stable productivity, but they started facing an acute problem of waterlogging and salinity due to seepage from this huge system in most of the developing countries like Pakistan. Sustainable agriculture is a most important issue, not only for the rural community's economic survival but also for the country's economy to keep balance with increasing demand of food. The farmers, and many local and international organizations are struggling now against the so-called 'white death' to their lands.

A newly introduced tile-drainage system was installed as an alternative solution in appropriate locations of the country, covering an area of 74,494 ha., to combat the twin menace (WAPDA, 1991). Monitoring and evaluation of a project in different ways is a key-factor in its further planning and development. The identification of causative factors and extent of the critical areas by salt-water balance studies help a great deal in the implementation of proper solutions in future.

DESCRIPTION OF STUDY-AREA

Large areas has been severely affected with the twin menace of waterlogging and salinization and thousands of hectares of land has gone out of production in the Fourth Drainage Project (FDP) area near Faisalabad. The FDP (SCARP scheme) project was initiated in 1983 and consists of many sub-drainage Sump units. The selected study area SIB-9 (Sump-9 unit), which was completed in 1989-90, is a part of this project, covering 121 ha and lying on the tail end of canal-irrigation system in the area (Figure-1). Physiographically, the area has almost flat topography (0.02%) with low annual rainfall (> 300mm), and mean monthly maximum temperature is between 19.4 & 41.2 C°. Geologically, the soils are alluvial deposits classified as silt loam, loam, and silt clay loam and loamy sands. There are two cropping seasons i.e. winter (Rabi) and summer (Kharif). Main Rabi crops (October-March) are wheat, sugarcane, pulses, and fodder, while corn, paddy, cotton, sugarcane, and fodder occupy lands in Kharif season (April-Sept.).

DESCRIPTION OF THE HYDRO-SALINITY MODEL AND DATA USED

The hydro-salinity model 'SALTMOD' developed by Oosterbaan and Pedrose de Lima (1989) was selected (for this study area) which computes the salt and water balance for the root zone, transition zone and aquifer zone. The schematic illustration of SALTMOD is shown in Figure-2. The computation method SALTMOD is based on seasonal water and salt-

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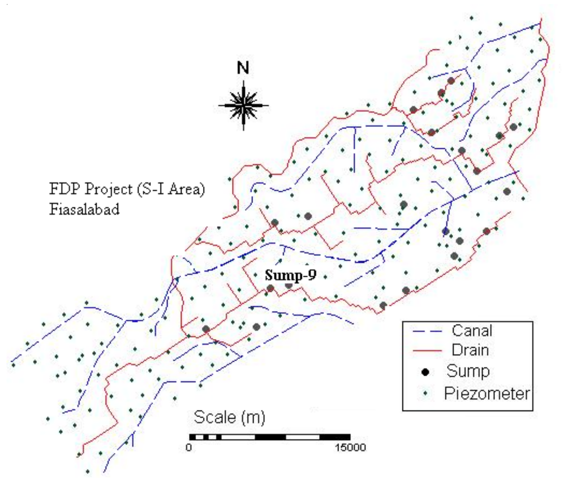

Figure - 1: Irrigation & Drainage Network at SIB-9 Area

balance of agricultural lands, which can be expressed by the general water-balance equation as:

Incoming Water = Outgoing Water ± δ (where δ is the change in water stored)

The detailed method consists of a number of iterative calculations of water and salt-balance equations to find out the final equilibrium in each zone separately. The method calculates the salt-balance for each zone, based on the water-balance of the individual zone and using their respective salt-concentrations of the incoming and outgoing water. The detailed principles of SALTMOD are reported in the manual published by ILRI, The Netherlands (Oosterbaan, 1989).

The data required by the model are seasonal average values of the areal fractions of the rice and non-rice (all other crops), rainfall, depth of different soil-layers, leaching-efficiency values, initial salinity of the different soil-layers, groundwater and irrigation water, evapotranspiration, surface runoff, and reuse of drainage-water, etc. Model takes input-data of each year as average over two seasons, a wet and a dry season. Most of the data was collected on seasonal basis from Punjab Iirigation Dept., Int. Waterlogging & Salinity Research Inst., and Soil-Monitoring Organization of WAPDA, Pakistan (WAPDA Annual Reports, 1990 - 1992) for the period of 1989-90 to 1991-92. These agencies are monitoring and analyzing different kinds of hydro-salinity (soils and groundwater)

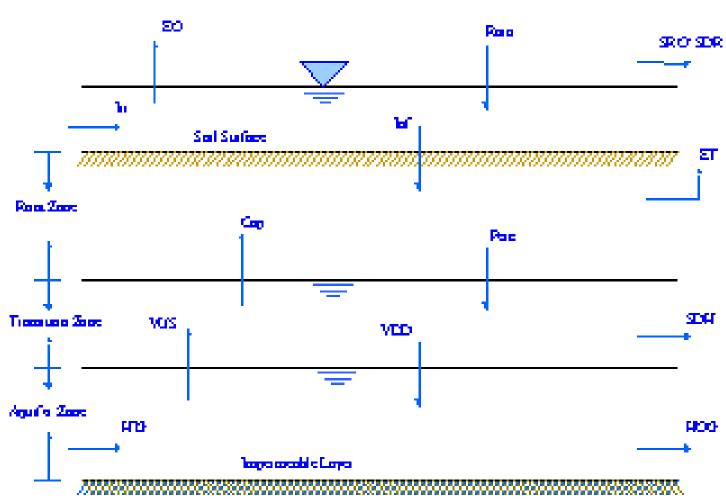

Figure - 2: Simplified Illustration of Waterbalance factors for SALTMOD

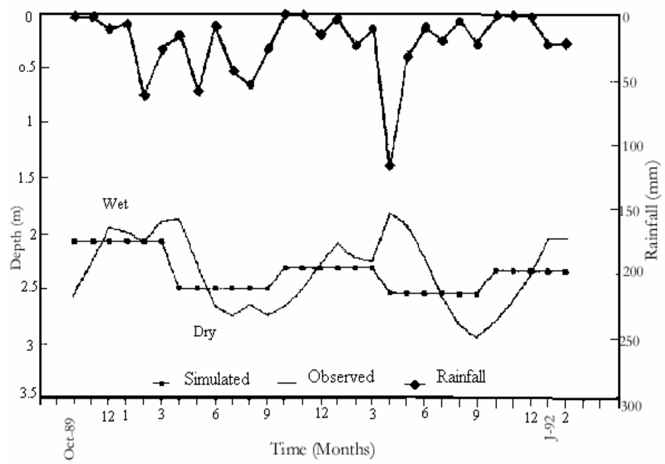

Figure - 3: Simulated and Observed Water-Table Changes

and climatic data for the study area and publish it on annual basis.

CALIBRATION AND VALIDATION OF THE MODEL

After collection of necessary input-data, it was then converted into the input-format as required by the model. The input-data for each year was given as average values over two seasons i.e. wet season (Kharif) and a dry season (Rabi) of each year, given separately to simulate the results for the next year. The model was applied to calibrate for local conditions of SIB-9 area, under existing irrigation and cropping practices, to simulate seasonal watertable changes, root-zone salinity, quantity, and quality of tile drainage-flow. The match of the data was obtained by optimizing and varying the leaching-efficiencies and the natural drainage to the aquifer, establishing the validity of the model. The simulated results were analyzed and compared with field-data collected for all four calibration-parameters and got statistically justified by the model, which was modified to analyze the measured and simulated results by statistical means. The Model was also upgraded for checking some irrelevancy in the input-data, if given by user and give warning to make correction for that particular illogical input-combination of data. The model was also modified for providing compatible tabulated results, easily accessible to any spreadsheet graphical package like Lotus, Excel, for its quick graphical comparative view.

Once the model is calibrated and verified to the acceptable limits, it can be then used to determine the future status of hydro-salinity for the area. Then, after its validation to the area, the SALTMOD has been applied to predict the hydro-salinity status for the area for next 20 seasons, to evaluate the newly launched SCARP (FDP project) in the area. All the results are discussed in detail below.

RESULTS AND DISCUSSION

Comparison of Watertable Fluctuations

SALTMOD was first calibrated for the seasonal change of watertable depth. The comparative results show the higher watertable at initial stage than all the later stages for the simulated periods and did not reach higher levels, as before, even after monsoon rainfall (Figure-3). The decreasing trend of water-table might be because of functioning of the drainage system, less rainfall and also due to the canal-closure during Rabi season for one month, every year. Generally the corresponding simulated seasonal average trends are found in close agreement with the observed values ($R^2 = 0.72$), if one observe as seasonal single average, except for an exception during the Kharif-1991 season, as the observed water-table remains higher in Rabi 90 than the simulated trend. This is because of the instantaneous heavy rainfall (136 mm) just before the Kharif season and the model does not consider the instantaneous hydro-dynamics, but simulates the seasonal average values; the model has been developed for long-term predictions, which

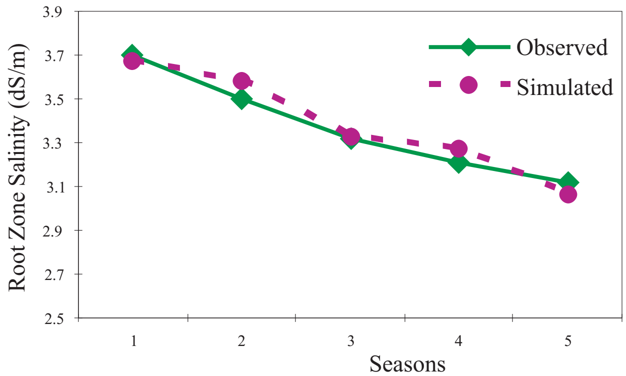

Figure - 4: Rootzone Salinity Comparison

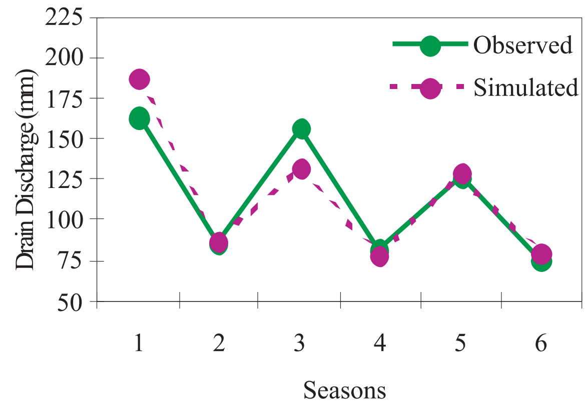

Figure - 5: Comparison of Seasonal Effluent Discharge

depends more on long-term average input conditions of the area, rather than short-term variations, for macro-scale planning and evaluation of reclamation projects.

Change in Root-Zone Salinity

The SALTMOD simulated the soil-profile salinity and compared it with the actual data (Figure-4). As is clear from the figure, the salinity level is decreasing after the project-installation, gradually from 3.7 dS/m to 2.78 dS/m, indicating the good performance of the FDP project. The simulated root-zone salinity is also following the same trend as seasonal basis, and the deviations are very small (R^2 = 0.93). The match of the results were found at a smaller value of the leaching-efficiency of the root-zone, which also confirms the hypothesis reported by Bhutta et al. (1992).

Variations in Drain Discharge

The discharge fluctuations are following the same decreasing trend as of watertable, higher in Rabi and lower in Kharif season, with relaible matching (R^2=0.81) with filed values (Figure- 5). Great variation was again found in Rabi season of 1990 in tile-flow due to the periodic rainfall as mentioned earlier. The other smaller variations seen are due to the collector-pipe laid at greater depth, which remains in operation for a longer time, than the average drain-depth provided to the model as input. In addition to this, periodic stoppage of pumpage of Sump-9 (an auto-motor pumping-machine, which pumps collected drain-water from sub-surface reservoir to desired level) was also reported sometimes, due to electricity failure. The total depth of drained water is also verified by another research study conducted by Bhutta et al. (1992).

Changes in Effluent Salt Concentration

Lastly, the model was used to calibrate for the tile- flow quality. The results were compared for computed and observed value in terms of EC_e (dS/m). The decreasing trends have been observed overall between simulated and field-data, except in the last season-5 (Figure-6). The drainage-water salt-concentration data was not available for all seasons but monitored in

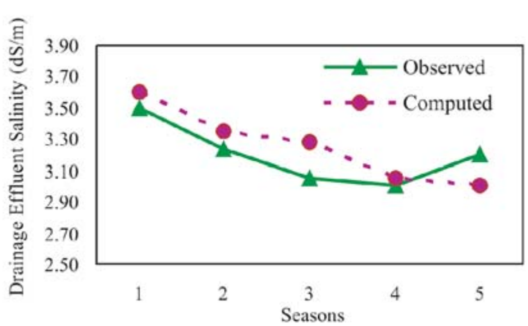

Figure - 6: Observed and Computed Drainage Water Salinity

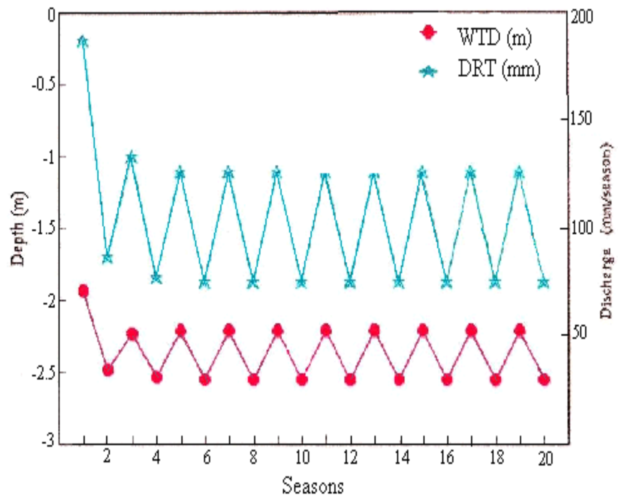

Figure - 7: Predicted Watertable and Drain-Discharge

different irregular events by the agencies. The input values given are not the seasonal average values in actual, but monitored once in the season (not average value but periodic value) and therefore most of the seasonal deviation is due to this factor. The second reason is due to the increasing collectors' pipe depth with slope, receiving saline groundwater from the top layer of aquifer zone. The results can be upgraded if one can use average seasonal data.

Another interesting conclusion can be drawn from these results that the quality of drainage-effluent is relatively independent of root-zone moisture percolating downward. The main reason is that this percolating water, carrying salts, is not captured directly by the drainage-system but passes firstly through the transition-zone (above and below drains). Therefore, the value might indicate the quality of the root-zone percolating-water, which is mixed (or has got mixed) with groundwater. Such kinds of results are of some importance for the reuse of drainage-water as a supplement to irrigation supplies. The good agreement was found ($R^2 = 0.89$) at higher value of leaching-efficiency (LT) for the area, which also confirms the higher value below root-zone, as reported in soil-investigation survey reports (Bhutta et al. 1992).

PREDICTIONS FOR HYDRO-SALINITY STATUS

Once the model has got verification-reliability for an area, it could then be applied with confidence for further use and application, to make predictions and for various alternative water-management scenarios. In this study, the model has been applied to predict the long-term fluctuations of hydro-salinity status for the next 10 years to know the future trends. For the prediction period, it was assumed that there will be no significant yearly deviations of the input parameters, such as rainfall, irrigation, evapotranspiration, cropping-pattern, etc., from the observed data given as average input to the model for the period Rabi-1989 to Rabi-1991.

Drain-Discharge and Watertable Behavior

The predicted values in Figure-7 show that the watertable depth (WTD) fluctuate within the lower transition-zone to the aquifer zone in the successive wet and dry seasons, with average rise to 2.24 m (after monsoon) and drop to 2.55 m (before monsoon) respectively. No significant rise in the watertable depth was predicted for the next 20 seasons in the area. It may be due to lower rainfall trends for the last 3-4 years than the average before and the canal-closure during Jan-Feb. (watertable rising periods), and good functioning of the subsurface drainage system which leads to lowering of watertable in the area. Regarding the seasonal prediction of drain-discharge (DRT), the trend shows the same follow-up of watertable behavior during wet and dry seasons. From these predictions, it is inferred that the watertable will not affect crop-growth, since prolonged waterlogging conditions are not expected in near future in the area. Additionally, this maintained watertable, due to the drainage-

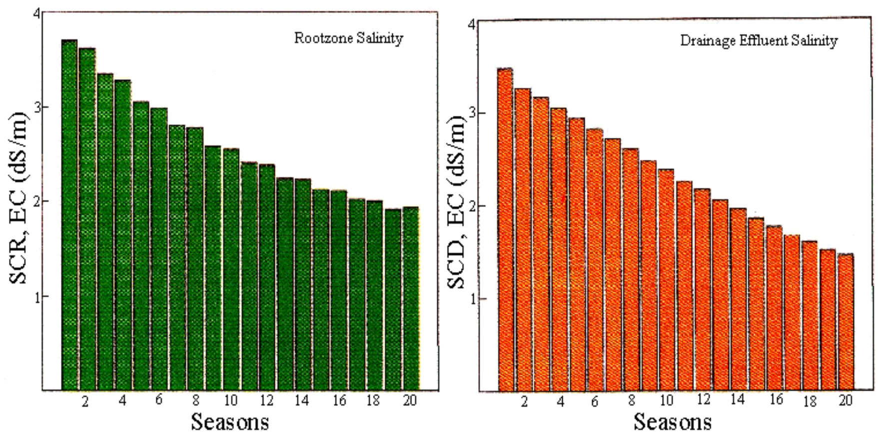

Figure - 8: Predicted Rootzone & Drainage Effluent Salinity Trends

system installed in the area, can act as supplemental irrigation to some extent by upward movement of water to root-zone through capillary rise, subject to the reduction in salinity-levels of the subsurface zone.

Salt Concentration of Root-Zone and Drainage-Water

The predicted salinity levels of root-zone depth in terms of EC (dS/m) are shown in Figure-8, which indicates the gradual reduction in the root-zone salinity-levels from 3.70 dS/m to 1.90 dS/m in succession of wet and dry seasons. The trend shows the overall improvement of the area in terms of soil-salinity. The reduction is probably caused by applying good quality of canal-water, rainfall, as well as seepage from the whole system and lowering of the groundwater-levels by the drainage- system deeper to the drain depth and also the reclamation measures adopted in the area.

The simulated results regarding quality of drainage water shows the same decreasing trend from the initial value of 3.5 dS/m to less than 1.5 dS/m for the predicted seasons. All this indicates the performance and continuous proper functioning of the drainage-system, flushing and draining out the saline-mixed water away from the area. The predicted results of declining root-zone and drainage-water salt-concentration clearly gives the picture for the future that more area could be made under cultivation again and the shortage of irrigation-supplies in the area can be met by using subsurface drainage-water as conjunctive-use supplement irrigation. As the tile-flow quality seems be declining to 1.5 dS/m and according to WAPDA standards, the good quality of water has the range upto this limit in terms of EC value.

CONCLUSIONS

Calibration of SALTMOD for four water-salt balance parameters shows the reliable validity of the model for the local conditions and so it could be applied with confidence for other project areas. Prediction shows that the area is approaching the safer limits regarding hydrosalinity status, indicating satisfactory performance of all reclamation measures. Also, the quality of drainage-water seems to be declined to 1.5 dS/m approaching towards good quality of irrigation water, according to WAPDA standards in terms of EC values. These results will be useful for planning projects related to the re-use of drainage-water as conjunctive use for supplement irrigation, to meet the shortage of irrigation requirement for that particular rural agriculture system of the area. The predicted hydrosalinity results clearly give the picture for future that more area could be brought under cultivation again, without causing scourge of waterlogging and salinization in the area.

SALTMOD offers many other possibilities of application for entirely different situations (with and without subsurface drainage), which are to be expected in the various other SCARP projects. It is hoped that SALTMOD application can provide reliable and valuable information on planning, design, and evaluation of the new projects to control the severeness of the problem in Pakistan.

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