SIMULATION OF WATERTABLE LEVEL BY REGRESSION MODEL

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A simulation model was developed and applied to determine the irrigation scheduling in order to keep the watertable below a specified level. The regression models were used in the simulation to predict the weekly watertable under effective rainfall, predicted canal and tubewell supplies and selected cropping pattern. Weekly data of past ten years were used in the regression. Two regression models were developed for the Rabi and Kharif seasons separately. Thus, irrigation management alternatives were found to minimise waterlogging.

INTRODUCTION

Too much emphasis on developing more water supplies and total neglect of efficient water use has resulted in waterlogging and salinity problems in the Indus River Basin. Drainage is lacking in most of the Indus Basin. Water is being lost by seepage from canals and water courses and deep percolation from croplands which resulted in high ground water levels, degradation of down stream water supplies and salt accumulation the ground surface (Bokhari, 1980).

One of the important elements in the new strategy for waterlogging and salinity control in the Indus River Basin is attention towards efficient water utilisation and its proper management on croplands.

Second ignorance was revealed in the application of water in excess of the normal irrigation requirement to wash the salts, down and out of the root-zone keeping it free of dangerous salt buildup. Over-irrigation disturbed the natural hydrologic balance by increasing the groundwater table causing problems of waterlogging and salinity (Shafique and Skogerboe, 1984).

The increasing problem of waterlogging has resulted in need for information on groundwater fluctuation due to recharge and discharge parameters. The process of variation of the water table level due to recharge and discharge parameters is a complex one. The rate of infiltration depends upon several parameters. However, the main controlling factors are based on the amount and timing of irrigation water. Hence it is desirable to identify the significant factors causing water table rise and the magnitudes of their effects (Draper and Smith, 1981).

AVAILABLE DATA

The study described here is strictly a modelling exercise. The model used weekly data of ten years from Mona Reclamation Experimental Project. Since the characteristics considered are specific to the study area, the relationship hence established will only be applicable directly to the area considered.

ANALYSIS

The analysis used the stepwise regression method to develop a linear model for

Table 1. Resultant water table (supply = Dem) for Rabi season

Week	Qc (cm)	RF (cm)	TW (cm)	Dem (cm)	TI (cm)	Wt (cm)	TI - Dem (cm)
1	0.11	1.95	2.60	4.57	4.66	102	0.09
2	0.80	1.29	3.11	5.20	5.20	112	0.00
3	0.34	1.49	3.50	5.15	5.33	109	0.18
4	0.34	0.82	3.50	4.77	4.66	108	-0.11
5	0.64	0.00	4.23	4.87	4.87	124	0.00
6	0.94	0.00	3.34	4.40	4.28	134	-0.12
7	0.90	0.42	3.55	4.87	4.87	138	0.00
8	1.14	0.63	3.50	4.99	5.27	154	0.28
9	1.14	0.37	3.27	4.97	4.78	160	-0.19
10	1.01	0.26	3.27	4.33	4.54	161	0.21
11	1.02	0.00	3.27	4.29	4.29	159	0.00
12	0.52	0.53	3.27	4.34	4.32	162	-0.02
13	0.52	0.53	3.30	4.54	4.35	163	-0.20
14	0.76	0.77	3.27	4.48	4.79	163	0.30
15	0.78	0.74	3.27	4.48	4.79	163	0.30
16	0.96	0.00	3.90	4.52	4.68	170	0.16
17	0.78	0.76	3.94	4.80	5.47	173	0.67
18	0.77	0.76	3.94	4.80	5.47	173	0.67
19	0.63	0.82	3.94	5.04	5.39	182	0.35
20	0.63	0.79	3.94	5.34	5.36	180	0.02
21	0.81	1.14	3.94	5.59	5.89	179	0.30
22	0.63	1.57	3.91	5.15	6.11	180	0.96
23	0.80	0.95	4.35	6.09	6.10	178	0.01
24	0.90	1.24	4.30	6.40	6.44	183	0.04
25	0.66	1.92	4.50	6.82	7.08	190	0.26
26	0.64	1.64	4.90	7.12	7.18	204	0.06

determining the most significant factors causing waterlogging. The results will provide guideline for developing methods to reduce the waterlogging by:

1. Retiming the surface irrigation system.
2. Rescheduling tubewell operation.
3. Proposing suitable cropping patterns.

The analysis of the fluctuation of the water table was done with the help of the following water balance equation:

$$\text{Input} - \text{Output} = \text{Change in storage}$$

$$(Pr + Qc) - (Tw + ETc) = S$$

where

Pr = Recharge by precipitation (cm)
Qc = Recharge from canal water (cm)
Tw = Discharge from tubewell (cm)
ETc = Evapotranspiration (cm)
S = Charge in storage (cm)

REGRESSION EQUATION

Two equations were obtained, each for Rabi and Kharif seasons. The basic variables used were on weekly basis, rainfall (cm), tubewell discharge (cm), evapotranspiration (cm), and canal discharge (cm^3 sec^{-1}). The independent variables in the regression model were formed as below:

$$WT_t = f\,(R_t, R_{t-1}, R_{t-2}, R_{t-3}, TW_t, TW_{t-1}, TW_{t-2}, TW_{t-3}, QC_t, QC_{t-1}, Qc_{t-1}, Qc_{t-2}, Qc_{t-3}, ETc_t, ETc_{t-1}, ETc_{t-2}, ETc_{t-3})$$

where

WT_t = Water table level of current week
R_t = Rainfall (RF) of current week
TW_t = Tubewell discharge of current week
Qc_t = Canal discharge of current week
ET_{ct} = Evapotranspiration of current week

and the t, t_{-1}, ... t_{-3} refer, respectively, to the current week, a week preceding the current week and so on up to third week preceding the current.

SIMULATION METHOD FOR IRRIGATION SCHEDULING

The simulation process is described by the flow chart shown in Fig. 1. The sequence of computation and description of various steps is provided below:

1. Read the constants C, variables ($X_{(1)}$.........$X_{(n)}$) and coefficient of the regression equation ($B_{(1)}$..........$B_{(n)}$).
2. Read the variables for all the weeks such as rainfall, canal and tubewell discharges (TW) and evapotranspiration (ETc).
3. Assume or define a cropping pattern.
4. Assume canal (Qc) and tubewell discharge.
5. Call for evapotranspiration and rainfall data to compute demand (DEM).
6. Compute total irrigation by dividing the demand with application efficiency.
7. If the total supply (TI) assumed in step 4 meets the demand then calculate new water table (Wt), otherwise adjust the supply and repeat from step 4.
8. Print the result.
   (Simulation was run for both wet and dry seasons).

PARAMETER ESTIMATION

The results of the backward elimination are presented in Akbar (1988). At each step the least significant variable was deleted and as a result the multiple correlation coefficient declined while the significance of the equation increased. The resulting equations for "Rabi" and "Kharif" are:

For Rabi:

$$WT_t = 82.62 - 5.62\,R_{t-1} - 4.67\,R_{t-2} - 2.73\,R_{t-3} + 6.05\,Tw_{t-1} + 5.45\,TW_{t-2} + 9.48\,Tw_{t-3} - 0.0082\,Qc_t - 0.0091\,Qc_{t-3} + 12.7\,ETc_t$$

For Kharif:

$$WT_t = 145.85 - 3.54\,R_{t-1} - 3.35\,R_{t-2} - 2.77\,R_{t-3} + 10.78\,Tw_{t-2} + 16.30\,Tw_{t-3} - 0.018Q_{ct} - 0.016Qc_{t-1} - 0.015Qc_{t-2} + 6.10ET_{ct}$$

The cross correlation of water table (Wt) with rainfall (RF), tubewell discharge (TW), canal discharge (Qc) and with evapotranspiration (ETc0) shows significant positive and negative lags, indicating the direct dependence of water table on rainfall

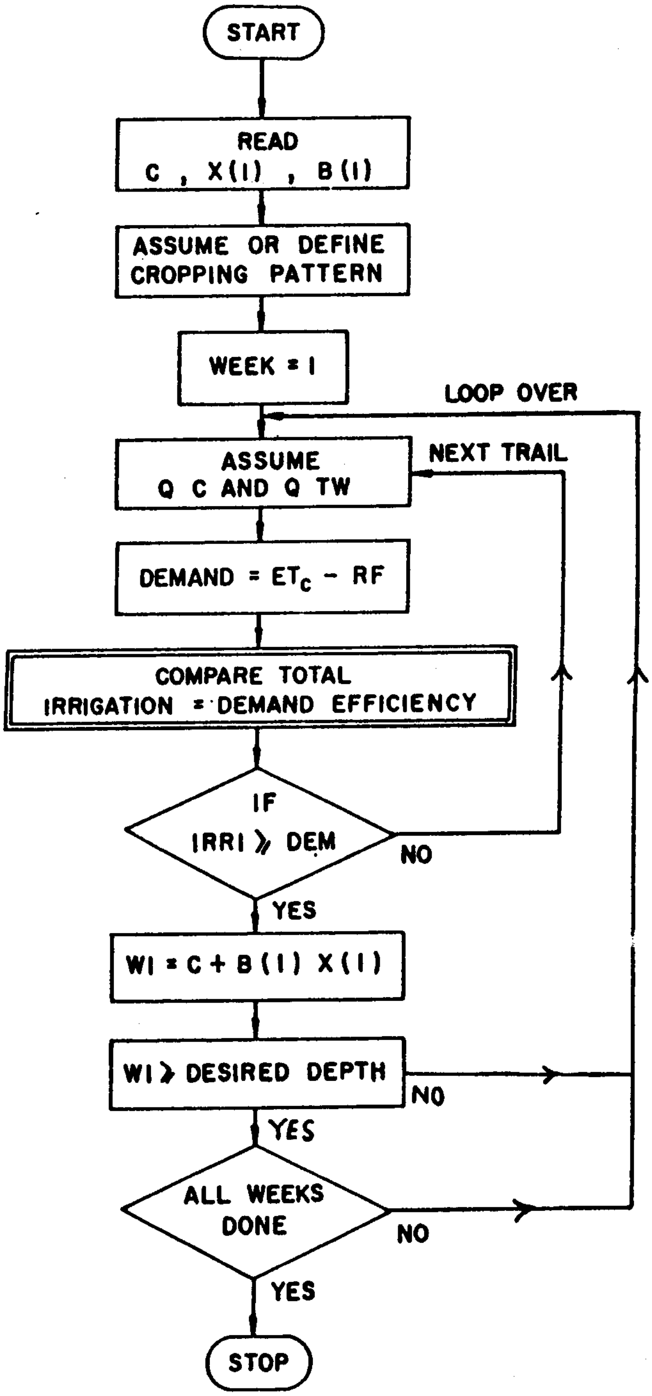

Fig. 1. Flow chart of the Simulation Model for irrigation scheduling

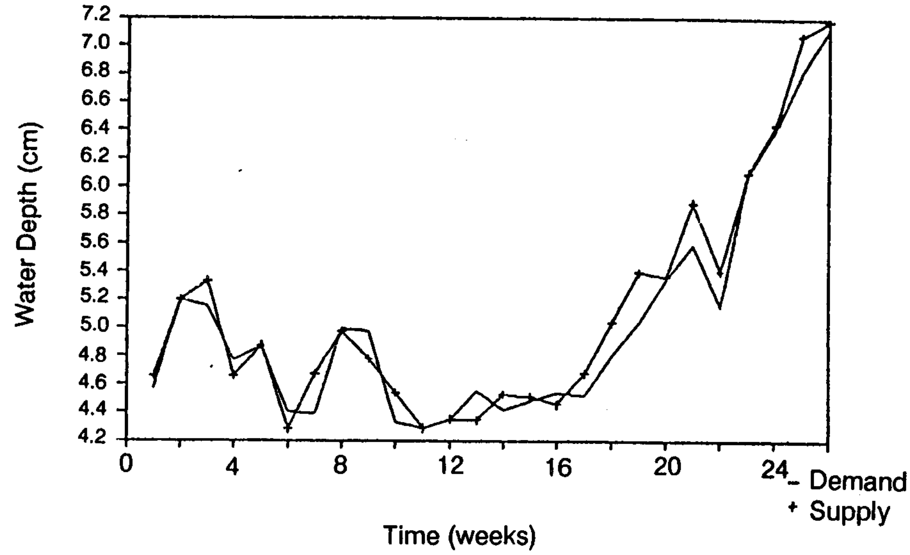

Fig. 2 a. Demand versus equal supply for Rabi season.

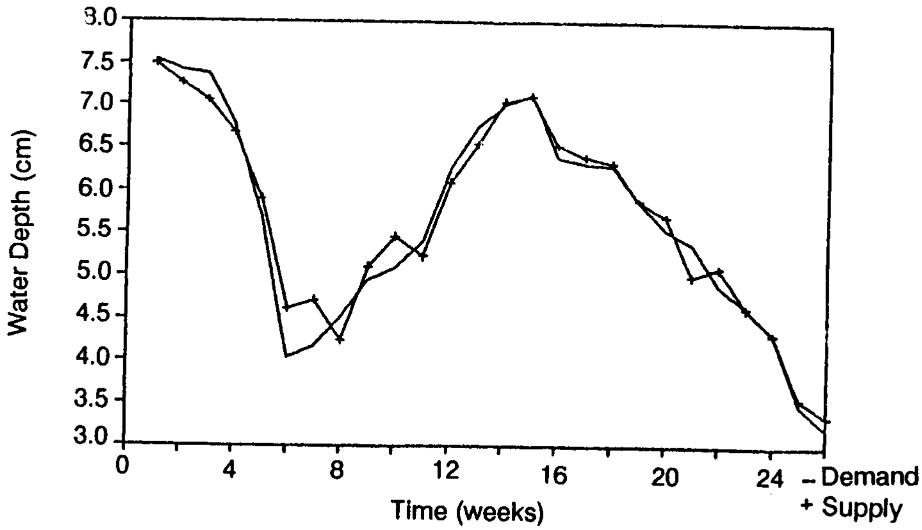

Fig. 2 b. Demand versus equal supply for Kharif season.

recharge and pumping on weekly basis. Total demands calculated for Kharif and Rabi season are given in Tables 1 and 2 which show complete picture of the results. In view of the results, it can be noticed that if we apply a total supply (TI) equivalent to demand (DEM) (Fig. 2 a and 2 b), the average water table depth cannot be controlled up to or more than 200 cm because of high water table elevation below the ground surface.

Table 2. Resultant water table (supply = Dem) for Kharif season

Week	Qc (cm)	RF (cm)	TW (cm)	Dem (cm)	TI (cm)	Wt (cm)	TI - Dem (cm)
1	0.86	1.13	5.50	7.54	7.49	192	-0.05
2	1.25	1.01	5.00	7.42	7.26	200	-0.16
3	0.48	1.57	5.00	7.37	7.05	202	-0.32
4	0.37	2.30	4.01	6.77	6.68	191	-0.09
5	0.11	2.54	3.26	5.67	5.91	156	0.24
6	0.11	1.26	3.26	4.03	4.63	141	0.60
7	0.11	2.37	2.24	4.17	4.72	141	0.55
8	0.11	0.88	3.26	4.52	4.25	145	-0.27
9	0.11	1.74	3.26	4.95	5.11	153	0.16
10	0.60	0.58	4.28	5.09	5.46	162	0.37
11	0.60	0.35	4.28	5.40	5.23	170	-0.17
12	0.60	1.22	4.28	6.27	6.10	176	-0.17
13	0.43	0.84	5.28	6.75	6.55	204	-0.20
14	0.11	3.94	3.00	6.39	6.53	171	0.14
15	0.42	3.59	3.10	7.13	7.11	184	-0.02
16	0.11	3.42	3.00	6.39	6.53	171	0.14
17	0.54	4.6	1.80	6.32	6.40	152	0.08
18	0.18	4.95	1.20	6.30	6.33	140	0.03
19	0.18	3.91	1.80	5.87	5.89	135	0.02
20	0.18	3.11	2.40	5.54	5.69	131	0.15
21	0.12	2.88	2.00	5.37	5.00	120	-0.37
22	0.11	3.98	1.00	4.89	5.09	118	0.20
23	0.80	1.83	2.00	4.63	4.63	116	0.00
24	0.17	2.15	2.00	4.33	4.32	115	-0.01
25	0.34	1.43	1.80	3.49	3.57	114	0.07
26	0.11	2.44	0.80	3.22	3.35	110	0.13

CONCLUSIONS

The most significant parameters towards water table fluctuation were obtained by using multiple linear regression. The parameters were predicted by minimisng the mean square error between the predicted and observed water table levels. Two sets of independent variables were used to model for Rabi and Kharif seasons. Results obtained were used in the simulation of irrigation scheduling. In the water table fluctuation measurement all parameters were treated as time dependent variables.

For the simulation results it is concluded that when the total supply equals the demand it is not possible to lower the water table up to the desired depth. More water has to be pumped out to achieve the required depth of water table.

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