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Simulation of Watertable Depth for Different Drain Depths and Levels of Drainage Rate

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ABSTRACT

Simulation for watertable depth can be done for different levels of drain depths and drainage rate. Important consideration in the selection of minimum depth to watertable is to provide sufficient aeration in the root zone of the plants and to restrict the upward capillary flow to an amount so that the yield of crops is not severely affected. These are primarily related to soil type, climate, crops, cropping intensity and ground water quality. Modified Chieng model was applied to simulate the watertable depths. The simulation was done for both different drain depths and different levels of drainage rate. The simulation of watertable depth indicated that 3.2 mm/day of drainage rate is required for 2.4 meters of average drain depth in the study area.

Key Words: Drains; Watertable depth; Drainage rate

INTRODUCTION

Waterlogging and salinity, widely spread throughout the Indus plains, is one of the major problems besetting agriculture in Pakistan. At least 20% of the irrigated area is affected (Ahmad & Chaudhry, 1988). Amongst other measures, drainage systems are constructed to alleviate these problems. With the aid of drainage system the watertable can be maintained below the root zone. This reduces not only the danger for waterlogging but also the danger of salinization through capillary rise.

The main objective of this study is to determine the optimum depth to the watertable for crop production under local conditions, as the information on the optimum watertable depth for different crops is necessary for the calculation of best drainage design. The required aeration needs a watertable depth of one meter for field crops and vegetables when using steady state formula (FAO, 1980).

Van Dam (1992) used the preliminary calibrated model to simulate different scenarios. He studied the effects of alternative irrigation management and different rainfall conditions. Later Beekma (1993) improved the calibration for field adjusting the soil hydraulic properties. Hussain (1994) calibrated the model on lysimeter that contained a silt loam soil. Depth to watertable was maintained constant throughout the calibration period.

Study area. The study area (area of Sump No.SIIA 8) is part of Faisalabad Fourth Drainage Project (FFDP), also referred to as the Lower Rechna Remaining Sub-Project. It lies between longitudes 70° 45' to 73° 22' E and latitudes 31° 02' to 31° 45' N. The Rechna Doab consists of all land between Ravi and Chenab rivers. The first sub-surface drainage work was started in this area. The area was highly productive previously but menace of waterlogging and salinity has declined the productivity. The location of this study area differed from the rest of the area as the area was enclosed from its all sides by canals and a road. So the water balance study was expected to be easily carried out in this area. Moreover sufficient reliable data was available since a project related to drainage efficiency was already going on in this area.

Model application. Modified Chieng model was applied to simulate the watertable depths for the project area. The validity of modified chieng model was verified by comparing the calculated watertable changes with the observed one in the study area. The verification of the model in actual field situation was obtained by using the observed field data of groundwater depth, rainfall, irrigation, seepage and evapotranspiration for 29 months (Aug. 1987 to Dec. 1989). In order to determine the drainage rate for whole of the project area, it was necessary to simulate the watertable depth regime over a long period. The computer model was run using 20 years climatic data of rainfall, irrigation, seepage and evapotranspiration for the project area. Based on physical and hydraulic properties of the soil, permissible watertable levels, construction equipment and crops to be grown, drain depths were set at 2.0, 2.4, 2.6, 2.8 and 3.0 meters from the soil surface for model simulation. The soil profile was divided in to four zones of equal depth each. There were two main inputs to the model.

1. Data including the parameters of soil moisture contents, transient storage, field capacities, drainable porosities, drain depth and the watertable from the surface.

2. Data including the daily precipitation, daily evapotranspiration and daily irrigation. The model was operated on daily basis and simulation was started from 1970 and proceeded to 1989. Seepage water from the canals was allowed to be distributed into upper three zones in proportion of 2:4:4 respectively, while the distribution of precipitation and irrigation were limited to first zone only. Drainage of excess water from the transient storages of three zones was calibrated. The evapotranspiration was considered to be taken place from the upper two zones due to the limitation of the root zone of the crops. It was considered that 70 and 30 percent evapotranspiration has been taken place from the first and second zones, respectively.

The output includes the followings:

1- Available soil moisture in each zone,

2- Transient storage in each zone,

3- Monthly and yearly drainage in storage and

4- The daily watertable depths for a particular drainage rate.

RESULTS AND DISCUSSION

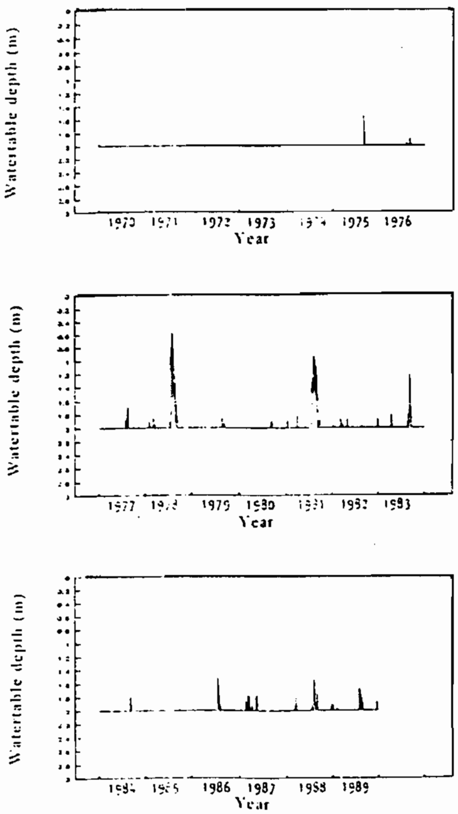
Simulation was done for both different drain depths and different levels of drainage rate. Selected results from the model output are plotted in the form of graphs (Fig 1 and 2). The figures show that the drainage rate is directly dependent upon the depth of the drains and the required watertable depth.

The important consideration in the selection of minimum depth to watertable is to provide sufficient aeration in the root zone of the plants and restrict the upward capillary flow to an amount so that the yields of the crops are not severely affected.

As the ground water of the area is highly saline and the salinity ranges between 300 to 13000 ppm with an average of 3000 ppm. Soils of the area are medium textured that is conductive for high capillary flow rate. So considering all the above mentioned factors, the minimum required watertable depth was selected as 1.8 meters.

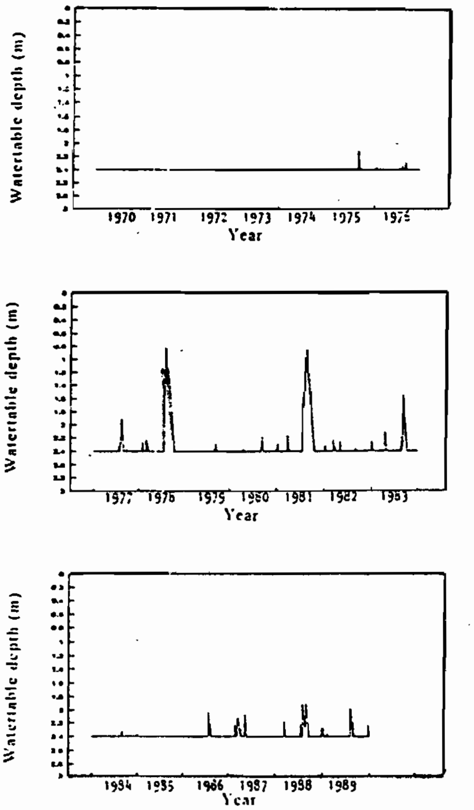
Fig 1 shows that for a shallow drain depth i.e. 2.0 meter below the surface, the drainage rate for a required watertable depth of 1.8 meter is very high and approaches to a value of 5.6 mm/day. Fig 2 shows that for a drain depth of 2.4 meter, the drainage rate for a required watertable depth of 1.8 meter is decreases to a value of 3.2 mm/day. Similarly the drain depth is set at a 2.6 meters depth from the surface and the drainage rate has attained a value of 2.4 mm/day. The effect of change in drain depth on the number of occurrences (high watertable positions) of a particular depth is illustrated as follow.

Fig. 1. Simulated daily water table change for drain depth 2.0 m & R 56 mm/day



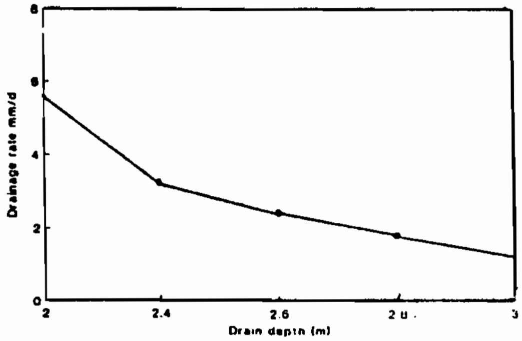
It was found that number of occurrence decrease as the depth of drain is increased. However, it was found that the decrease in the number of occurrences of a particular watertable depth was much greater when the drain depth was increased from 2.0 to 2.4 m than from 2.4 to 2.6 and 2.8 m. High watertable positions mostly occurred during monsoon months, i.e. during the months of July, August and September which are the rainy months in Pakistan. The figures 1 and 2 demonstrated that watertable approached to the surface during the year 1978 and 1981 in the month of July in both the cases. This watertable rise occurred due to high rainfall intensity. As the agricultural projects are designed for a return period of 5–10 years, therefore this high watertable position can be skipped in the determination of appropriate value of drainage rate.

Fig. 2. Simulated daily water table change for drain depth of 2.4 m & R 3.2 mm/day



Available soil moisture content has less influence on the watertable depth as compared to transient storage. Although the entire transient storage water is considered drainable. Also soil moisture content has less influence on the number of occurrences and the successive days duration than the drainable porosity for the specified watertable depth.

Fig. 3. Drain depth v/s required drainage rate



Effect of drain depth on the required drainage rate. The results showed that for a required watertable depth, if the depth of the drain is increased then the drainage rate is decreased and the rate of decrease of drainage rate is higher for shallow drain depth i.e. from 2.0 to 2.4 m as compared to the rate of decrease for the drain depth from 2.4 to 2.6 m and 2.8 m as shown in Fig.3 which is due to fact that as the available head increases the rate of decrease of drainage rate decreases.

Drainage rate for the drain depth of 2.6, 2.8 and 3.0 meters shows that for a deeper drain depth a little change in drainage rate causes a large fluctuation in the watertable depth. The combined effect of changes in the drainage rate with respect to drain depth are demonstrated in Fig 3. It is seen that the effect of increasing the drain depth is to make the watertable response initially more sensitive than the later with a small change in the drain depth, the change in drainage rate is long and later on a linear combination is maintained between the drain depth and the required drainage rate.

CONCLUSION

The simulation of watertable depth indicated that 3.2 mm/day of drainage rate is required for 2.4 meter of average drain depth in the study area. It is concluded from the simulation of watertable depth that the present system has not sufficient capability of subsurface drainage, compared with high recharge. Through the sensitivity analysis of the model it was found that the watertable movement is mostly affected by the value of the drain depth.

RECOMMENDATION

As the model used in the study is conceptual and lumped, a physically distributed model which may be able to improve the design parameters should be developed and examined.

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