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Performance evaluation of border irrigation by using NLREG Model*

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Field design and irrigation management practices have a significant impact on surface irrigation performance (Raine *et al*. 1998) but have received only limited consideration to date. Improper design and management of border irrigation system may result in water wastage in terms of over irrigation, waterlogging and losses of fertilizers and pesticides out of root zones. Study of the performance of border irrigation method can help improve the design and management of the system and provide information for the design of irrigation systems in future by developing relationship between the performance indices and the system variables. Holzapfel *et al.* (1985) developed relationships between performance irrigation parameters and surface irrigation design variables along with yield. A number of surface irrigation models were used by various researchers to simulate furrow and border irrigations, assuming that the simulated irrigations are representative for the season. Feyen and Zerihun (1999) assessed the performance of border and furrow irrigation systems and the relationship between performance indicators and system variables using software tools BORDEV and FURDEV. He concluded that the relationship between the performance indices and the system variable contains valuable information for the system design and management.

Navabian M *et al.* (2009) developed empirical functions for dependent variables in cutback furrow irrigation. This study employs sensitivity, dimensional and regression analysis in the development of empirical functions for application efficiency, deep percolation, runoff and distribution uniformity. The proposed functions were evaluated using a numerical zero-inertia model and field measured data. As the functions were general (not site and irrigation specific) and explicit, they could prove to be of practical significance in both conventional and optimal design and management of free-draining, graded furrow irrigation systems with cutback flows. Alazba (1999) assessed the effect of inflow rate on the performance of furrow irrigation system by using various performance irrigation parameters. Keeping in mind the previous studies, the present study was undertaken to study the relationship between irrigation performance parameters and their relationship to border irrigation design variables, crop yield and net returns. Crop yield was estimated on the basis of amount of water applied to the crop as differential irrigation along the run of the field, assuming that all other inputs and factors affecting production were held constant.

The study was carried out at Research Farm of Department of Soil and Water Engineering, Punjab Agricultural University, Ludhiana during the year 2006–07. The average rainfall in the region is about 600 mm-800 mm out of which 80 percent occurs during the months of July to September. Samples were taken from various places from the same field to get the average value of field capacity and permanent wilting point of sandy loam soil which were found out to be 11.70% and 4.0% respectively. The average bulk density of soil was found out to be 1.40 g/cm^3. The average soil slope of the field was found out to be 0.2%. The soil moisture content was measured by gravimetric method before and after each irrigation. There were three treatments, i e T_1(Border length 63 m, border width 5 m and inflow rate 7.5 l/s), T_2 (Border length 63 m, border width 5 m and inflow rate 8.5 l/s) and T_3 (Border length 63 m, border width 5 m and inflow rate 10.0 l/s) with three replications. The treatments were laid in a randomized block design. Wheat variety 502 was sown in the month of November after the pre sowing irrigation. Irrigation was planned on the basis on IW/CPE of 0.9. The total discharge available during each irrigation at the field was determined using Parshall Flume installed in the irrigation channel.

In the present study, water application efficiency (E_a), water storage efficiency (E_s) and water distribution efficiency (E_d) are the parameters that were analyzed. The selection of

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parameters was based on the fact that these take into account the depth of water required by the crop during irrigation as per the previous studies (Varlev 1976 and Seginer 1978). Irrigation performance parameters that measure the irrigation performance were analyzed for their relationship to surface irrigation design variables. The, non-linear regression (NLREG) model was used to obtain the equation (via multiple regression) for the irrigation performance parameters as a function of the design variables. The regression equation was as follows:

$$IPP = K\,(Q)^{a}\,(L)^{b}\,(T)^{c}\,(D)^{e} \quad (1)$$

where

IPP = irrigation performance parameter

Q = inflow rate, l/s

L = length of run, m

T = cut off time, min

D = depth of irrigation, m

K = constant for the equation

a, b, c and e = exponential coefficients of inflow rate, length, cutoff time and depth.

The irrigation efficiencies and yield of wheat crop were computed for all the irrigations during growing period of crop. Several combinations of the design variables were used to determine the values of the irrigation performance parameters. Multiple regression analysis was used to determine relationships between irrigation performance parameters and border irrigation design variables, yield and net returns.

Values of the constants for each irrigation performance parameter selected are presented in Table 1.

It is evident from the table that the water application efficiency had a higher coefficient of multiple determinations as compared to the other irrigation performance parameter. The relationship was

$$E_a = K\,(Q)^{-a}\,(L)^{b}\,(T)^{-c}\,(D)^{-e} \quad (2)$$

Indicating that E_a increased with decrease in inflow rate, time of inflow and depth and increased with increase in length of run. The water distribution efficiency correlated well with the design variable and the relationship developed was

$$E_d = K\,(Q)^{a}\,(L)^{-b}\,(T)^{c}\,(D)^{-e} \quad (3)$$

Shows that E_d increased when length of run and depth decreased and increased with inflow rate and cutoff time. Similarly the water storage efficiency equation also correlated well with the design variable and the relationship developed was

$$E_s = K\,(Q)^{a}\,(L)^{b}\,(T)^{c}\,(D)^{-e} \quad (4)$$

The above relationship indicates that E_s increased with decrease in depth and increased as the inflow rate, length of run and cutoff time increases. Based on the results analyzed, water application efficiency is the irrigation performance parameters best correlated with the design variables as compared to other irrigation performance parameters.

Based on the relationship between the design variables and irrigation performance parameters, water application efficiency (E_a) showed best correlation as compared to water distribution efficiency (E_d) and water storage efficiency (E_s). So water application efficiency was chosen as irrigation performance parameter for developing relation with relative yield. The NLREG, non-linear regression model was used to find the parameters. The regression equations are:

$$Y_R = K_A\,(IPP) + K_B \quad (5)$$
$$Y_R = K_C\,(IPP)^{K_D} \quad (6)$$
$$Y_R = K_E + K_F\,(IPP) + K_G\,(IPP)^{2} \quad (7)$$

Where

Y_R = relative yield, (%)

$Y_R = Y_a/Y_{max}$ (8)

Y_a = actual yield, q/ha

Y_{max} = potential yield under optimum conditions, q/ha

IPP = irrigation performance parameter

K_A, K_B, K_C, K_D, K_E, K_F and K_G are regression coefficients of equation

Table 2 shows the values of the constants for each parameter selected.

From the Table 2 it is clear that water application efficiency correlated well with relative yield for quadratic function.

The water application efficiency (E_a) is the irrigation

Table 1 Values of constants for exponential function

IPP	K	a	b	c	e	R^2
E_a	2241.30	–0.29	0.898	–0.57	–0.66	0.742
E_d	4.83	0.93	–0.03	0.706	–0.52	0.716
E_s	215.31	0.106	0.25	0.04	–0.54	0.723

Table 2 Values of constants for linear, exponential and quadratic functions in relationship between relative yield and water application efficiency

Functions	K_A	K_B	K_C	K_D	K_E	K_F	K_G	R^2
Linear	0.393	64.53						0.632
Exponential			29.25	0.269				0.65
Quadratic					356.00	–8.75	0.071	0.741

Table 3 Values of constants for linear, exponential and quadratic function in relationship between net return and water application efficiency

Functions	K_H	K_I	K_J	K_K	K_L	K_M	K_N	R^2
Linear	483.18	11663						0.65
Exponential			2087.84	0.72				0.68
Quadratic					276314.0	-8006.30	67.91	0.75

performance parameter that was analyzed to find relation between net returns and irrigation performance parameter based on relationship between design variables and IPP. The NLREG, non-linear regression model was used to find the parameters. The regression equations are:

$$NR = K_H (IPP) + K_I \quad (9)$$

$$NR = K_J (IPP)^{K_K} \quad (10)$$

$$NR = K_L + K_M (IPP) + K_N (IPP)^2 \quad (11)$$

Where

NR = net returns, Rs/ha

IPP = irrigation performance parameter

K_H , K_J , K_K, K_L, K_M and K_N are regression coefficients for equation

Tables 3 shows the values of the constants for each parameter selected.

From the Table 3, it is clear that water application efficiency correlated well with net returns for quadratic function.

SUMMARY

The study was conducted at Research Farm of Department of Soil and Water Engineering, Punjab Agricultural University, Ludhiana to determine the performance of border irrigation method during the year 2006–07. It was based on irrigation performance parameters, such as water application efficiency, water storage efficiency and water distribution efficiency. Irrigation performance parameters that measure the irrigation performance were studied and analyzed for their relationship to surface irrigation design variables, i e inflow rate, length of run, cut off time and depth with the help of non-linear regression (NLREG) model. Water application efficiency is the irrigation performance parameter that correlated well with the design variables as compared to other irrigation performance parameters for exponential function. The quadratic function was best fit between water application efficiency and relative yield as well as net returns.

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