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EVALUATING WATER APPLICATION EFFICIENCIES OF SURFACE IRRIGATION METHODS AT FARMER'S FIELD

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ABSTRACT

Study regarding water application efficiencies of surface irrigation methods was conducted in the command area of Nara Canal Area Water Board Command. In-situ, water application efficiencies were measured for Border and Furrow irrigation methods. Necessary data regarding moisture content, field capacity, discharge released and time were recorded for three to four irrigations to different Rabi and Kharif crops. Seed bed was prepared for border irrigation method through tractor, and furrows were made manually after levelling. Water applied was measured with cutthroat flume. The results revealed that the average water application efficiency under border irrigation method during first, second, third and fourth irrigation was 68%, 67%, 68% and 70%, respectively, which yielded the grand average value of all 4 irrigations as 67%. Whereas, in Furrow irrigation method, the average water application efficiency in first, second and third irrigation was 75%, 74% and 74.5%, respectively, which yielded the grand average value of all 3 irrigations as 74%. The comparison shows that there is considerable difference between the water application efficiencies in Border and Furrow irrigation methods ($P<0.05$). The analysis of variation in water application efficiencies during number of irrigations in both irrigation methods shows no clear trend of increasing or decreasing the water application efficiencies; however on average basis the water application efficiency of furrow irrigation method is 7% higher than border irrigation method. The values of water application efficiencies decrease as depth of application increases. This trend is almost similar in Boarder as well as in Furrow irrigation systems. There is very less variation in the values of each depth of application. The coefficient of variation (CV) value is less than 0.07, which shows consistency in the water storage throughout root zone in soil profile.

Keywords: Area water board, border irrigation, coefficient of variation, cutthroat flume, furrow irrigation.

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INTRODUCTION

In Pakistan, irrigated agriculture is the main user of surface as well as groundwater resources. The management of surface water resources in Pakistan is considered at critical stage. It is seventh-most important country which is under serious challenge that requires improvement in terms of both “hardware” and “software” of agricultural water management. The water scarcity is growing rapidly because of increasing demand from all water consuming sectors (Ringler and Anwar, 2013). According to the Pakistan Bureau of Statistics, the total cropped area of the country is about 23 million hectares for the last ten years, out of which approximately 80% is irrigated (Pakistan Bureau of Statistics, 2013). The available water resources, surface and ground, are insufficient to support irrigated agriculture due to the increasing population and food requirements. For agricultural extension in the country, the limited water resources become a major constraint. The main causes of such decrease are beyond the control of human, therefore, water research is required to study such variables to ensure its efficiency in-terms of precise application of water and optimum productivity per drop of water for sustained food security (Shaikh *et al*., 2015). It is essential to save every drop of water and utilize it judiciously for the production of crops. The climate change has affected the normal evaporation and transpiration from a cropped soil. It is not only dependent on the meteorological factors but also on factors related to crop and to the available amount of soil moisture in the soil (Shirazi *et al.*, 2011).

The critical measure of irrigation performance for irrigating fields at farms and irrigation units is termed as irrigation efficiency. Especially below the outlet the irrigation application efficiency is of utmost importance as it is totally managed by farmer itself. Application efficiency relates to the actual storage of water in the root zone to meet the crop water needs in relation to the water applied to the field. It might be defined for individual irrigation or parts of irrigations.

The surface irrigation methods have been practiced since several decades in terms of border, flood and furrow irrigations and farmer has easily adopted procedures and established criteria for cultivation. There is need to help them for optimum design and efficient management and operation of applying water to the fields to get maximum possible yield and produce considerable water saving. The furrow irrigation method has more importance in comparison with high cost of power in micro irrigation methods with less know how to the common farmer regarding its automation and operation (Shirazi *et al*., 2014). The selection of the method and approach depends on factors such as water availability, crop type, soil characteristics, land topography and associated cost (Holzapfel *et al*., 2010).

The irrigation efficiency is a crucial aspect for irrigated agriculture and a key factor due to the competition for water resources. The common methods for water application efficiency measurement is employed which either require irrigation advance data for the volume balance based and hydrodynamic models as demonstrated by Iqbal *et al*. (1994) and Walker, (1989) or pre and post irrigation soil moisture measurements from different techniques (Isrealson *et al.*, 1944 and Imark *et al.,* 2011). Besides that, irrigation surveys are also used to estimate application efficiencies (Shaikh *et al*., 2015). The determination of the water application efficiency by soil moisture measurements require two components of water balance, i.e. volume of water applied, volume of water stored in the root zone plus beneficially used volume of water. The measurement of volume of irrigation water delivered to a farm or plot for a particular irrigation can be made by measuring flow of irrigation stream and time for which water is applied. The stored volume is measured in terms of soil moisture status and can either be measured by taking soil samples before and after irrigation.

On large scale, no current study was conducted to measure water application efficiencies to document losses pattern for a particular irrigation method. It does not mean that there is no database with regard to such information, but in several countries such database is however maintained using surveys on irrigation methods. In developed countries like America, such database is prepared and maintained by survey information. The developing countries which are already under deficient financial power can adopt such methods to evaluate the water losses in the farmer's fields.

It is relatively easy to bring possible improvements in traditional surface irrigation methods in irrigated agriculture since they are low cost, easily implemented and do not require skilled labor and cumbersome techniques. It is estimated that more than 82% of total irrigated lands being irrigated under conventional methods having efficiency of water uses from source to the point of application is not more than 50%. Through the traditional methods of irrigation (border and furrow) with additional techniques of land levelling and optimum furrows dimensions, considerable portion of irrigation water can be saved.

In view of above facts, the research was conducted for determination of water application efficiency for flood (border) and furrow irrigation system at farmer managed field to evaluate the water application losses.

MATERIALS AND METHODS

Study area

The study was conducted on the farmer's field in the command area of Mirpurkhas subdivision of Nara Canal Area Water Board, Mirpurkhas, Sindh Pakistan. Four farms in the command areas were selected for four crops (two on furrow and two on border irrigation method). Two fields were selected on Cheema Farm and two on Belharo minor on Jamrao canal command. The location of study area is shown in Figure 1.

Crop fields under study

Field irrigation application efficiencies were evaluated on farmer's fields. Four farms were selected for four crops (two in the Rabi and two in Kharif season) to determine water application losses. Field plots were leveled with tractor blade and were irrigated with canal water on warabundi basis (water turn at every 7^{th} days on watercourse). Soil samples from different depths were randomly taken before and after irrigation. The details of selected crops, irrigation method, plot size and number of samples under observation are summarized in Table1.

Table 1. Summary of crop fields selected for water application efficiencies.

Crop	Season	Irrigation Method	Plot size (hectare)	No. of Samples	No. of Irrigations under observation
Maize	Kharif	Border	0.19	72	4
Wheat	Rabi	Border	0.17	54	3
Cotton	Kharif	Furrow	0.18	54	3
Tomato	Rabi	Furrow	0.16	54	3

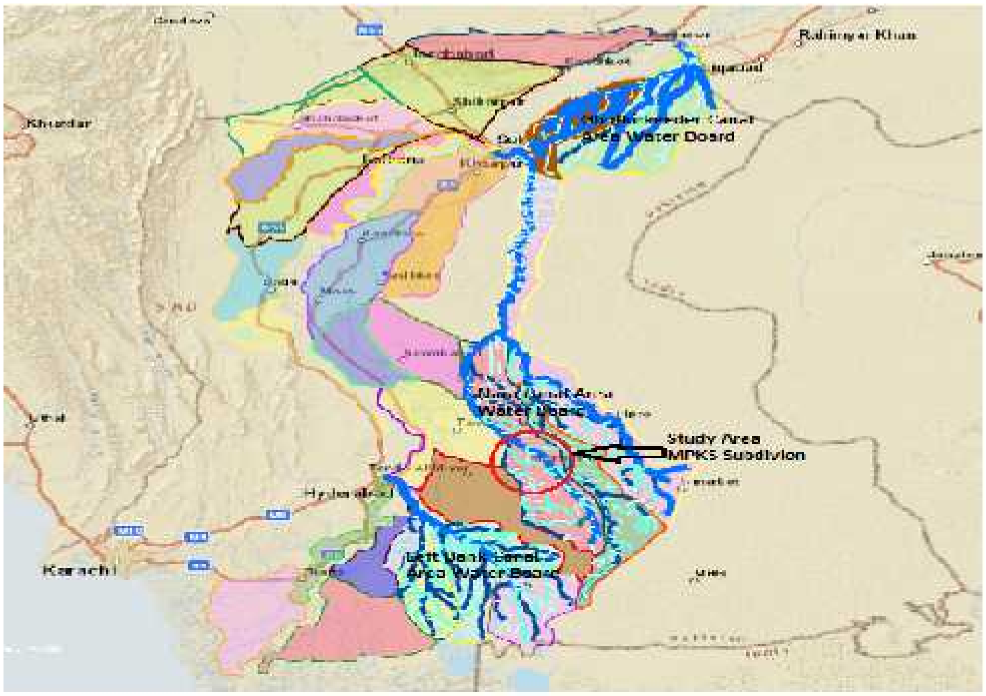

Figure 1. Location of study area in Nara Canal Area Water Board, Pakistan

Data collection and calculation

Volume of water delivery

The quantum of water released at farmers' selected plot was measured by cutthroat flume (20 cm x 92 cm). Before using, flumes were calibrated as per guidelines of Skogerboe *et al.* (1967) and relevant equation was used under free or submerged flow conditions. The volume of water applied was determined by multiplying the discharge observed and irrigation application time.

Rootzone depth of crops

Usually root zone is either assumed or estimated because its accurate measurement is not easy due to several varying conditions. For the current research, the root zone depth for crops under study were taken from the literature (FAO) depending on soil type depth to water tables, etc. and research institutions, which are used for designing and scheduling of the irrigation plan. The root zone of some mature crops (wheat, cotton, maize, tomato) was measured practically in the experimental field by slicing out the randomly selected plants taking into account the expected depth and radius.

Depth of applied water in the field

The depth of applied water (D_a) was calculated by dividing area of plot to the volume of water applied.

Depth of water stored in the rootzone

Pre and post irrigation soil moisture analysis method was employed for calculating water stored in the crop rootzone. The soil samples for moisture content before and after irrigation were taken at three randomly selected points in each plot. The samples were collected at three depths i.e. 30, 60 and 90 cm. The maize crop has root depth greater than 1m, therefore, soil samples were collected down to 120 cm depth. Moisture content of samples was measured on dry weight basis. The depth of water stored in the rootzone was calculated by equation given in the procedure adopted by Isrealson *et al.* (1944) and Imark *et al.* (2011).

$$D_S = (M.C \times Sp.G \times Rz)$$

Where:

Ds = Depth of water stored in root zone
M.C = Moisture content of soil (%)
Sp.G = Apparent specific gravity of soil
Rz = Depth of root zone of crop, m

Similarly total depth of water stored in the rootzone was calculated by addition of fraction of consumptive use by crop till the time to get soil sample after irrigation and is given as under:

$$D_T = D_S + Etc$$

Where:

Etc = Consumptive use of crop for the period between sample time before and after irrigation.
D_T = Total depth of water stored in the rootzone.

Water application efficiency

The water application efficiency was calculated by using following relation.

$$¦_a = \left(\frac{D_T}{D_a}\right) \times 100$$

Where:

$¦_a =$ Water application efficiency (%)
D_T = Depth of water stored in root zone (m)
D_a = Total depth of water applied in the field (m)

T test statistics (Field, 2005) was applied to determine the efficient method at the significance level of 5%. The depth wise variation in water application efficiencies were evaluated by calculating coefficient of variation as measured by Shirazi *et al.* (2011).

RESULTS

The results are shown in Table 2. Irrigation application efficiencies under border irrigation method were 68% and 65% during Kharif and Rabi seasons, respectively with average of 66.5%, whereas, values under furrow irrigation method were 75% and 70% for respective seasons with average of 72.5%. The T-test result depicted significant difference between furrow and border water application efficiencies ($t= 9.55$; $P< 0.05$). The results show that irrigation application efficiency under furrow irrigation method was higher by 7% as compared to border irrigation method as the water is applied in furrows only. The wetted perimeter of furrow supplies moisture to rest of the area (ridge) on which crop stands. Hence, furrow irrigation method saves a considerable volume of water. The seasonal trends of irrigation application efficiencies for a given irrigation method suggest that Kharif season has higher efficiency. It reflects that farmers are very careful in Kharif than in Rabi. This is attributed to limited availability of supply from the system or the less water to their fields in Kharif in order to irrigate more fields with a given volume of water.

The results shown in Table 2 are the average values of water application efficiency calculated separately for each irrigation. A total of 3 irrigations under each crop were considered during observations. Water application efficiencies under border and furrow irrigation methods for different irrigation numbers are shown in the Figure 2. The trend of curves reveals that for all crops the water application efficiency increases after 1st irrigation in both application methods. This is attributed to decrease in infiltration rate and increase in evapotranspiration rate. It has been observed that the infiltration rate of dry soil is higher than that in wet soil. Consequently there is an increase in water application efficiency.

Table 2. Summary of irrigation application efficiency of crops in Mirpurkhas subdivision.

Crop	Season	Irrigation method	Plot size (ha)	No. of samples	Irrigation No.	Water application efficiency (η_a)	Average	Overall average (η_a) (%)
Maize	Kharif	Border	0.47	72	1st	68	68	67
					2nd	67		
					3rd	68		
					4th	70		
Wheat	Rabi		0.43	54	1st	67	66	
					2nd	66		
					3rd	65		
Cotton	Kharif	Furrow	0.45	54	1st	75	75	74
					2nd	74		
					3rd	76		
Tomato	Rabi		0.40	54	1st	72	73	
					2nd	73		
					3rd	73		

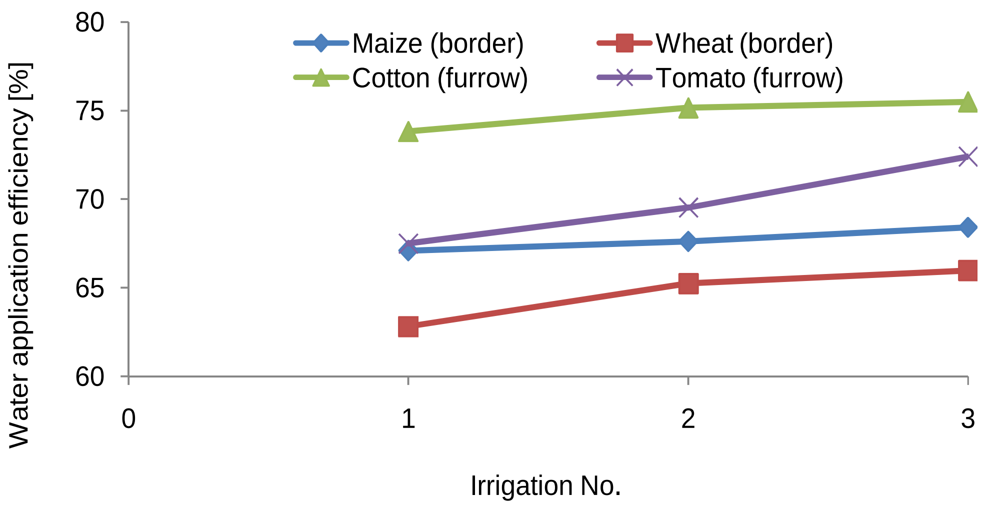

Figure 2. Irrigation application efficiency under border and furrow irrigation methods.

Increasing trends in water application efficiency was observed for all crops under both irrigation methods during Rabi and Kharif seasons. Summarized result of depth wise water application efficiency is shown in Table 3. There is no clear trend in depth wise variation in water application values.

Table 3. Depth wise variation in water application efficiency in surface irrigation method.

Depth (cm)	Variation in water application efficiency values [%]	
	Border irrigation method	Furrow irrigation method
30	3.8	4.5
60	6.4	5.4
90	2.8	5.8

DISCUSSION

Water application efficiencies were determined under different crops irrigated with border and furrow irrigation methods. The results show that irrigation application efficiency under furrow irrigation method was higher by 7% as compared to border irrigation method under clay loam soil. The results of this study are in close agreement with Zaman *et al*. (2000). They concluded that application efficiency was higher by 7 to 8% under border and furrow irrigation. According to FAO (1989), the water application efficiency for border and furrow irrigation methods is up to 60%. Rogers *et al*. (1997) concluded that furrow and border irrigation methods have wider range i.e. 50-90% and 60-90%, respectively. Almost all researchers have shown the different ranges of water application efficiencies depending on the soil types and irrigation modes. Solomon (1988) observed the range 60-75% and 70-85% for furrow and border irrigation methods, respectively. The study carried out by Shaikh *et al*. (2015) in the same area using irrigation surveys reveals that application efficiencies for border and furrow irrigation methods are within the ranges of 65-68% and 78-82%, respectively under medium textured soil. This shows the higher value of water application efficiency for furrow irrigation method whereas the border irrigation method has almost same value.

On overall basis, the values of water application efficiency under furrow and border irrigation methods are within acceptable ranges as described by the other researchers. The average ¦$_a$ values have been used to calculate irrigation demand for number of irrigations. Martin (2006) has given the values calculated on seasonal averages as well as on peak use period separately. The water application efficiencies under furrow and border irrigation methods for peak season are higher than the seasonal averages.

Where seasonal trend of irrigation application efficiencies for given irrigation method is required, the values are generally higher in Kharif season. It reveals that farmers try to irrigate fields very carefully in the Kharif than in Rabi. The limited availability of supply from the system or apply limited water to fields in Kharif compel them to irrigate more land for a given volume of water.

The water application efficiency has similar trends for all crops under both irrigation methods in Rabi and Kharif seasons. The variation of water application efficiency values in 1st foot depth was 3.8 and 4.5% for border and furrow irrigation method, respectively. Similarly, for next 2 depths the variation remained less than 10%, this proves that moisture distribution was uniform in the soil profile up to the crop rootzone. However, there is no clear trend in depth wise variation of water application values.

CONCLUSION

Water application efficiencies under border and furrow irrigation methods were determined on the farmer's field through conventional method with addition of land leveling and changed furrows size and length. The water application efficiency of border irrigation method under the Rabi and Kharif crops were observed 66 and 68%, respectively with an average value of 67%; whereas for furrow irrigation method the values of water application efficiencies remained 73 and 75% for Rabi and Kharif, respectively with average value of 74%. It is concluded that surface irrigation methods are also efficient if they are managed in well manner even under conventional way. The water application efficiency of furrow irrigation method is 7% more than the border irrigation method. There is very less variation in the values of each depth of application. The CV value is less than 0.07, which shows consistency in the water storage throughout the field under study. If the land is prepared through precision land leveling, the efficiency of irrigation can be increased more.

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