3. Water and Energy Conservation at Source through Improved Surface Irrigation Techniques: A Case Study of Bahawalpur

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Abstract

Water is essential ingredient for sustaining life on the earth. Growing population and economies, changing lifestyles, and climate change are all increasing pressure on the Pakistan's freshwater resources. People and nature alike are threatened by the lack of responsible water management system. The water users, from agriculture, energy and industrial sector to cities and citizens, recognize the acute need of more sustainable management of water resources.
Agriculture is the backbone of Pakistan's economy. It accounts for 21% of the GDP and together with agro based products fetches 80% of the country. More than 90% of freshwater resources are utilized in the agriculture sector. Southern areas of Pakistan and Punjab facing multiple water related challenges due to the severe water scarcity. Due to the scarce surface water supplies groundwater abstraction is the common practice to full fill the crop water demand. Ground water contributes more than 50% water supplies for irrigated agriculture. Out of total irrigated area (18.63Mha) 3.79 Mha solely depends upon the tube wells. The use of tube wells water supplies for canal irrigated area is also very frequent due to the increase of cropping intensity up to 150% and deficit canal water allowance. The prime objective of the present study was to estimate the water and energy savings under different surface and agronomic practices.
Bahawalpur district is located in Punjab at 29'20'' latitude and 71'47'' longitude and elevation of 110m above sea level. The mean annual rainfall ranges from 147-226 mm. Cotton, wheat and sugarcane are the major crops of the area. Three different types of surface irrigation techniques and crop sowing methods were analysed during this study for cotton and wheat crop. Irrigation water supplies through tube wells and discharge measurement were made with cut throat flume. Basin and bed & furrow irrigation techniques were tested under different land preparation methods i.e. unlevelled, zero level and laser grade field. Experimental site located at agronomic research station (ARS) Bahawalpur. Three sets of each trail were performed and average the values during the calculation. Soil at experimental site was clay loam in texture for 0-60cm depth; average pH and organic matter was 8.0 and 0.73 % respectively. Following results were calculated for one acre field of cotton and wheat.
It was estimated that laser level field with traditional flat sowing of wheat and cotton saved 30% water and energy as compared to the unlevelled field, where as laser level field with bed and furrow sowing technique saved 42 % water and energy. It was estimated that laser graded (mild slope) field with traditional flat sowing technique saved 39%, 11% water and energy as compared to unlevelled and zero level field respectively. It was estimated that laser graded field with bed & furrow sowing technique saved 47%, 22% water and energy as compared to the unlevelled and zero level field respectively. It was concluded that laser grading is the most efficient and recommended for wheat, cotton, sugarcane and other fodder crops as well. It was also noted that during one crop calendar/acre (Wheat, Cotton) on average 2700 cubic meter water, 80 liter diesel fuel saved and reduced 212 Kg carbon emission.

Keywords: *Water and Energy Conservation, Groundwater sustainability, Groundwater Abstraction, COP 21, Carbon emission*

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1. Introduction

Pakistan's irrigated agriculture depends primarily on the Indus basin irrigation system. The IBIS is comprised of dams, headwork's/barrages and an extensive network of irrigation and link canals. These canals draw the majority of their surface water from rivers. Recently, the total surface water availability has been deviating from the annual mean flow, showing a trend of decreasing annual water availability due to climate change. Following the partition of the subcontinent, the Indus Water Treaty was passed in 1960, allocating the eastern rivers water rights to India. The command area water requirement of the eastern rivers was compensated by constructing link canals. The gap between water availability and consumption is overcome by extracting groundwater in Punjab and other parts of the Pakistan. Groundwater withdrawals have increased worldwide to meet the consumption gap. Currently, over 1.4 billion people are living in river basins, where the consumption of water exceeds the minimum recharge level. Water withdrawal is predicted to increase by 50 percent by 2025 in developing countries. Water is a critical resource in the agriculture. Without the water there is no concept of agriculture. Artificial application of water to the crops is called irrigation. Arid and semi-arid regions with less precipitation are mostly dependent on the irrigation. There are number of methods developed for this artificial application of water during centuries of irrigation. These methods are ranged from flood irrigation to drip, sprinkler and sub-surface drip irrigation methods. There are number of ways to enhance the overall irrigation efficiency. These methods are ranked on the basis of this efficiency term. In Pakistan high irrigation efficiency systems (HIES) are running but there scope remain limited still due to number of reasons. The large scale adoption of most efficient irrigation methods are still a dream to be achieved. Surface irrigation methods are still in practice over a large scale irrigated area. There are number of innovative ideas are practiced to enhance the irrigation efficiency of surface irrigation methods. Laser land leveling, bed and furrow irrigation and alternate furrow irrigation methods revolutionize the surface irrigation methods. "It is not the quantity of water applied to a crop, it is the quantity of intelligence applied which determines the result there is more due to intelligence than water in every case" (Alfred Deakin 1890)

Indus basin irrigation system is a largest irrigation network which continuously under pressure due to multiple issues and challenges. Surface supplies of irrigation are not enough that it fulfill the crop water requirements with ever increasing cropping intensity. So to meet the ever increasing demand of agriculture groundwater is pumped especially where groundwater is in fresh water zone. Pakistan and Punjab experienced an upward trend of groundwater extraction during the last three decades. Almost one million tube wells are reportedly installed in Punjab alone, and use of energy in pumping and other farm operation may account for up to one fifth of the province's energy consumption. So the water consumption in the agriculture is highly linked with the energy consumption too. More will be the water consumption more will be the energy consumption and more carbon emission consequently hampers the environment. Water savings at farm level not only reducing the pressure from groundwater but also reducing the carbon footprint of the agriculture farm. Management of each resource separately can lead to decisions that seemingly improve supply in one sector, but in reality, creates problems in others. If the linkages are incorporated in policy evaluation, then unintended consequences may be avoided while multiple problems may simultaneously get addressed (Afreen Siddiqi 2013). Understanding and accounting for these interconnections is important for resource use-efficiency, socio-economic growth, and long term sustainability of agriculture.

The impact of irrigated agriculture on water resources is significant. In Pakistan, irrigated agriculture uses more than 90% of fresh water resources. The Punjab Agriculture Department () stated that on an average 56 MAF water diverted to the canal irrigation networks annually and 33 MAF extracted from groundwater, which is almost 58% of the Punjab water budget. Pakistan's groundwater management is approaching or exceeding sustainable extraction limits in most of the fresh water groundwater zones. There is increasing competition between users, and growing recognition of the environment as a legitimate 'user' of water. Future progress in irrigation now rest on efficiency gains in existing practices, rather than further use of scarce water resources. Water use efficiency (WUE) concepts have evolved over a century of irrigation development. Brown (1920) introduced the term 'duty of water' defined as "the measure of the efficient irrigation work that water can perform, expressed in terms establishing the relation between the area of crop brought to maturity and the quantity of water used in its irrigation". Fortier (1928) used the term 'permissible waste', and observed that there would always be a limit to improvements that would be governed by economics. Israelsen (1932) defined irrigation efficiency as "the ratio of irrigation water transpired by the crops of an irrigation farm or project during their growth period to the water diverted from a river or other natural source into the farm or project canal or canals during the same period of time." Christiansen (1942) introduced a uniformity coefficient, which is a ratio of depths that represents the lower proportion of applied depth to the average applied depth across the field.

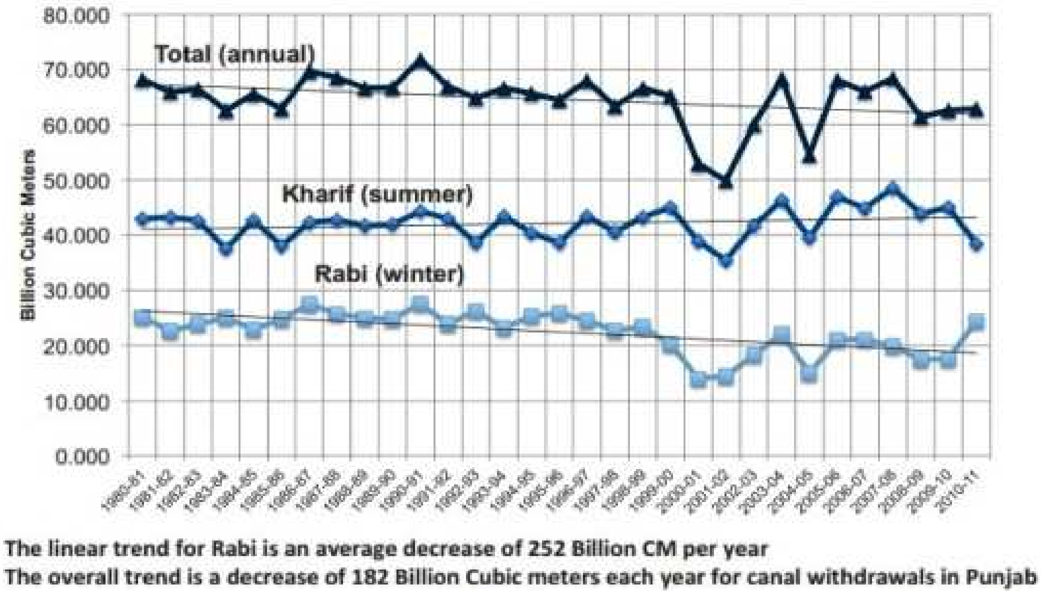

Fig. 1. Canal Withdrawal Trend in Punjab

2. Materials and Methods

Bahawalpur district is located in Punjab at 29'20'' latitude and 71'47'' longitude and elevation of 110m above sea level. The mean annual rainfall ranges from 147-226 mm. Cotton, wheat and sugarcane are the major crops of the area. Three different types of surface irrigation techniques and crop sowing methods were analyzed during this study for cotton and wheat crop. Irrigation water supplies through tube wells and discharge measurement were made with cut throat flume. Basin and bed & furrow irrigation techniques were tested under different land preparation methods i.e. unleveled, zero level and laser grade field. Experimental site was located at agronomic research station (ARS) Bahawalpur. Three sets of each trail were performed and average the values during the calculation. Soil at experimental site was clay loam in texture for 0-60cm depth; average pH and organic matter was 8.0 and 0.73 % respectively. Same variety of wheat and cotton were sow in each trial. Other inputs (fertilizer and pesticides) were also same. There were three plots with equal dimensions located in the experimental site. One plot is unlevelled; second one is zero leveled and third one laser grade. Grade of the field adjusted 0.0012 ft/ft. Grade of the plot were adjusted keeping in view the soil texture, infiltration rate and stream size. Software package WINSRFR can be used for the theoretical simulations to find out the optimal grade according to the concerned field conditions. The basin and bed &furrow irrigation techniques were tested for three above mentioned land preparation methods. The comparison of water, energy and monetary savings were calculated between the following pairs of sets is as under;

- Zero level field & unlevelled field with basin irrigation
- Zero level field & laser grade field with bed and furrow irrigation
- Zero level field & laser grade field with drill sowing

The calculations of water used, water savings, energy savings, monetary benefits and carbon emission for each sets of trials were calculated by measuring the discharges with cut throat flume once and then note down the minutes of irrigation applied to each sets. We may calculate the volume of water used, water savings, energy savings, monetary benefits and carbon emission with following equation and empirical formula as;

$$\text{Volume of Water Used (m3)} = Q \times \text{Irrigation Time} \times \text{No. of Irrigations} \quad (1)$$

Whereas Q is a discharge of the tube well in m3/sec, Irrigation time is seconds

$$\text{Water Savings (\%)} = \frac{\text{Volume of water Used X technique} - \text{Volume of water used Y technique}}{\text{Volume of water Used Y technique}} \times 100 \quad (2)$$

$$\text{Energy Saved (Litre)} = \text{Fuel used per hour water extracted} \times \text{Irrigation Time saved} \quad (3)$$

$$\text{Monetary Benefits} = \text{Amount of fuel saved} \times \text{Price of fuel} \quad (4)$$

$$\text{Carbon Emission (CO2)} = 2.63 \times \text{Amount of Dissel fuel consumed} \quad (5)$$

3. Results and Discussions

It was found that during the cotton crop season treatment T1, T2, T3, T4, T5 and T6 used volume of water 2571.42, 3714.28, 2285.71, 2000.04, 2571.42 and 2284.71 cubic meter respectively. It was observed that during the comparison of T1 and T2 treatment T1 saved 30.8 % water, around 33 litre dissel fuels and hence reduces 88 kg of carbon emission for one acre. In the comparison of T3 and T4 treatment T4 saved 12.5 % water, 12.5 litre of dissel and consequently reduce the 33 kg of carbon emission as compared to T3 treatment, whereas treatment T5 and T6 comparison T6 is more efficient than T5. More comparison pairs were also performed from the following table 1. The laser grading technique is most efficient from all the techniques.

Table 1. Water, Energy, Carbon (CO2) Emission and Monetary Savings / Acre for Cotton Crop

Surface Irrigation Methods	Volume of Water Used (m3)/Acre	Saving of Water (%)	Energy Saving Dissel (Litre)/Acre	Monetary Saving (PKR)/Acre	Reducing CO2 Emission (Kg/Acre)
Zero Level Field (Drill Sowing) T1	2571.42	30.8	33.33	2866.67	87.66
Un levelled Field (Drill Sowing) T2	3714.28	00.00	0.00	0.00	0.00
Zero Level Field (Bed & Furrow Sowing) T3	2285.71	11.1	12.50	1075.00	32.87
Laser Grade Field (Bed & Furrow Sowing) T4	2000.04	12.5	12.50	1075.00	32.87
Zero Level Field (Drill Sowing) T5	2571.42	0.00	0.00	0.00	0.00
Laser Grade Field (Drill Sowing) T6	2284.71	11.1	12.50	1075.00	32.87

It was found that during the wheat crop season treatment T1, T2, T3, T4, T5 and T6 used volume of water 1028.57, 1485.71, 914.28, 800.45, 1028.57 and 914.28 cubic meter respectively. It was observed that during the comparison of T1 and T2 treatment T1 saved 30.8% water, around 13 litre dissel fuels and hence reduces 35.06 kg of carbon emission for one acre. In the comparison of T3 and T4 treatment T4 saved 12.5 % water, 4.17 litre of dissel and consequently reduce the 10.95 kg of carbon emission as compared to T3 treatment, whereas treatment T5 and T6 comparison T6 is more efficient than T5.

Table 2. Water, Energy, Carbon (CO2) Emission and Monetary Savings / Acre for Wheat Crop

Surface Irrigation Methods	Volume of Water Used (m3)/Acre	Saving of Water (%)	Energy Saving Dissel (Litre)/Acre	Monetary Saving (PKR)/Acre	Reducing CO2 Emission (Kg/Acre)
Zero Level Field (Drill Sowing) T1	1028.57	30.8	13.33	1146.67	35.06
Un levelled Field (Drill Sowing) T2	1485.71	0.0	0.00	0.00	0.00
Zero Level Field (Bed & Furrow Sowing) T3	914.28	11.1	4.17	358.33	10.95
Laser Grade Field (Bed & Furrow Sowing) T4	800.45	12.5	4.17	358.33	10.95
Zero Level Field (Drill Sowing) T5	1028.57	0.0	0.00	0.00	0.00
Laser Grade Field (Drill Sowing) T6	914.28	11.1	4.17	358.33	10.95

It was estimated that laser level field with traditional flat sowing of wheat and cotton saved 30% water and energy as compared to the unleveled field, where as laser level field with bed and furrow sowing technique saved 42 % water and energy. It was estimated that laser graded (mild slope) field with traditional flat sowing technique saved 39%, 11% water and energy as compared to unleveled and zero level field respectively. It was estimated that laser graded field with bed & furrow sowing technique saved 47%, 22% water and energy as compared to the unleveled and zero level field respectively. It was concluded that laser grading is the most efficient and recommended for wheat, cotton, sugarcane and other fodder crops as well. It was also noted that during one crop calendar/acre (Wheat, Cotton) on average 2700 cubic meter water, 80 liter diesel fuel saved and reduced 212 Kg carbon emission.

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