Appraisal of Economic Impact of Zero Tillage, Laser Land Levelling and Bed-Furrow Interventions in Punjab, Pakistan

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Abstract

Irrigation is inevitable for profitable farming in arid and semi-arid regions. Water shortage is augmenting all over the world including Pakistan, due to which agriculture sector is facing critical challenges. For sustainable and feasible agriculture production, the cost of crop inputs needs to be reduced and at the same time the efficiency of resources must be enhanced. Resource conservation interventions (RCIs) play a vital role to achieve these goals. The RCIs include laser land levelling (LLL), zero tillage (ZT) and bed-furrow (BF). A survey was conducted in year 2011-12 in ten districts of Punjab for data collection regarding the agriculture inputs and outputs of RCIs and traditional irrigation system. The study area lies in rice-wheat cropping zone in Punjab, Pakistan. The analysis of data concluded that these interventions have enhanced the crop yield; saved significant irrigation water and increased the income of the farmers. Irrigation water saved by laser land levelling, zero tillage and bed-furrow was 31, 49 and 40 percent per hectare respectively in the selected irrigated areas. Water productivity was higher for zero tillage farms (2.02 kg/m^3) followed by bed-furrow (1.59 kg/m^3) and laser land levelling farms (1.58 kg/m^3). Fertilizer use efficiency by zero tillage, bed-furrow and laser land levelling was 19.1, 18.19 and 17.7 percent per hectare respectively as compared to traditional farming (13.98 percent). Therefore, the resource conservation interventions provide excellent tool for making development towards improving and sustaining agriculture production, ensure food security and poverty empowerment in Pakistan and elsewhere under similar socio-environmental conditions.

Key Words: Resource conservation interventions; Economic Impact; Irrigation water; Water productivity; Income

1. Introduction

Irrigation is the mainstay of Pakistan's agriculture and the irrigated area spreads over 17 million hectare (ha). Nearly 90% of food production is contributed by the irrigated area in the country [1]. The irrigated wheat systems contribute over 40% of wheat production in the developing world [2, 3]. To meet the growing wheat demand, the global production needs annual growth rate of 1.6% to 2.6% which can be mainly achieved through improvement in input use efficiency [2]. There are clear-cut differences between developed and developing countries regarding how wheat and other crops are grown and who grows the crops. Less than 5% of the total wheat produced in developed countries (and also in Argentina, Brazil, and Paraguay) comes from irrigated conditions, whereas large-scale farmers are by far the most important wheat producers. In contrast, well over 50% of wheat production in developing counties (especially for large producing countries in south Asia and China) comes from irrigated conditions, and the vast majority of these farmers are very small-scale [4]

Wheat is the vital basic food of the people of Pakistan. Except a few years, wheat is often imported to cater the needs of the population. For example, in 1998, 4.11 million ton wheat was imported in the country. The demand of wheat will be 25 to 30 million ton in the next ten years. Such a huge requirement could only be met by vertically enhancing the yield [5]. In Punjab, 34% of the total cultivable area is devoted for wheat. The districts of Lahore, Sheikhupura, Gujranwala, Narowal, Hafizabad, Kasur, Gujrat and Sialkot cover an area of 1.1 million ha for rice-wheat zone in Punjab. In these areas, 72% of wheat is cultivated in rotation with rice. However, its yield is low as compared to other cropping zones in Pakistan [6].

Yield levels of bed-furrow are comparable to ZT treatments while residue retention is equally crucial. Planting wheat on raised beds is an innovative option that improves rainwater use efficiency and reduces soil erosion [7]. The Bed and furrow technology applied in the irrigated areas of northwest Mexico, with serious shortage of water in the reservoirs. Most farmers of the area still use conventional tillage. However, those farmers who grow wheat using planting system on beds obtain 10% higher yield with 25% less irrigation waterand 25% less operational cost. The average wheat yield for the Yaqui Valley is over 6 tons per ha for the past several years [8].

Laser land levelling (LLL) was first introduced in India in 2001 in western Uttar Pradesh. However, the number of laser land levellers rose to 925 and the acreage under LLL grew to 200,000 hectares in 2008. A series of studies on LLL in rice-wheat systems of the IGP have found 10-30% irrigation water savings, 3-6% effective increase in farming area, 6-7% increase in fertilizer use efficiency, and 3-19% increase in yield [9]. Review of existing literature on land levelling indicated positive impact on water saving, crop and farm productivity [10]. A reduction of 75 % in labour requirement for weeding was reported due to LLL. There is a strong correlation between the levelness of the land and crop yield. Considerable increase in yield of crops is also possible due to LLL [11]. It was concluded that the laser land levelling saves farm inputs like water and fertilizers, improves crop stand and encourages uniform germination [12].

Experimental data have shown that water saving with zero tillage (ZT) in wheat could be 36 percent, on an average. Reduction of water use in first irrigation varied from 30-50 percent while for subsequent irrigations it ranged between 15-20 percent. Water use could be further reduced if ZT is used in combination with other technologies like raised bed planting and laser land levelling [13]. The results of adoption of resource conservation interventions (RCIs) for rice-wheat system (RWS) showed that there is significant reduction in the cost of production of wheat [14-15].

Some studies concluded that farmers had favourable attitude towards zero tillage intervention (ZTI), but non adopters need to be motivated to adopt ZTI. The ZTI has been rapidly accepted by farmers due to its contribution in reducing cost of production, conservation of resources, and improving yields [16]. In ZTI, land is left undisturbed after harvesting of the previous crop to sow the next crop. However, the only minor soil disturbance is due to small furrows for sowing of seeds [17]. It is evident from different studies that evaporation losses could be reduced by reduction in duration of land preparation and by adopting ZTI. [18].

In Pakistan, approximately 80% of wheat area is irrigated by canal irrigation system, supplemented with tubewell water. Because of continuous dry spell over the previous years, both ground and surface water resources are decreasing [19]. Moreover, almost 50% of the total available irrigation water is lost during conveyance in the irrigation system and at the farm level during application to crops. Uneven fields and unlined irrigation channels also cause loss of huge irrigation water. [20].

There is adequate residue soil moisture after harvesting of rice. If the land is ploughed by traditional method, it will not merely dissipate the moisture retained in the soil but also causes further monetary and physical problems for the cultivators in terms of ploughing, planking and ‘rauni’ (irrigation before sowing). Moreover, it further delays sowing of the wheat crop which may reduce the crop yield. According to some studies, sowing after mid of November in Pakistan may reduce wheat yield at the rate of 1% per day [21]. Delay planting not only decreases yield but also curtails the effective usage of fertilizers [22].

In Brazil, sizable yield increase and income stability for the farmer lead to a wide adoption of the ZT technique [23]. In Australia, it was reported that there is consistent advantage in wheat grain yield for ZT compared to convention tillage (CT) in all four years of their experiments [24]. Similarly, a study in west-central Saskatchewan, Canada has shown that wheat yield can be improved with ZT, providing there is an adequate weed control and crop stands [25]. Crop residues accumulating on the soil surface form a barrier to water loss by evaporation and decrease of soil temperatures. More stable soil aggregate structure is present under zero tillage (ZT) compared to CT [26].

Technological advancements like RCIs for efficient use of irrigation water deserve high priority. Some efforts have been made in this direction and the success is confined to zero-tillage and raised bed planting in wheat [27]. Experimentation is underway to further enhance incorporation of paddy residue through use of improved ZT drill with disk furrow opener. In this method entire paddy straw can be left on surface and wheat can be sown under ZT. This has several added advantages. Firstly, the covered land surface reduces evaporation losses and therefore maintains soil moisture and temperature which are conducive for plant growth. Secondly, mulching effect suppresses weed growth (about 40 percent less weed growth) and increases plant population. Also there is saving of weedicide, resulting in additional economic and environmental benefits. Finally, farmers may not burn paddy straw for sowing of wheat, as done under conventional technique (CT) and therefore significant environmental benefits are added [13].

The latest performance appraisal studies in term of water application have recognized that laser land levelling, zero tillage and bed-furrow interventions can be prosperous in ameliorating field level efficiency and irrigation water saving [28-29]. The RCIs interventions lead to augmentation of wheat yield and reducing its production cost [30] . The water productivity of wheat is highest under bed-furrow intervention whereas flat basin irrigation technique has the lowest yield and maximum water consumption. The water saved by bed-furrow intervention, can be used to enhance the cropping intensity and leaching salts. Based on the water productivity, the bed-furrow intervention is the best effective surface water use intervention [31]. The Rice-Wheat consortium has shown water savings of 30 percent due to adoption of zero tillage in rice-wheat zones [32].

Bed-furrow planting of wheat has special role in Pakistan. In the low-lying areas having poor drainage, the bed-furrow planting intervention is more favourable than the zero tillage [33]. On raised beds, wheat planting with two or three rows is practiced on the whole region of north-western Mexico [34].

In 2007, the wheat area, average yield and production of China was 23.4 million ha, 4487 kg ha^{-1} and 105 million tons (mt) respectively [35]. Timely planting of wheat is essential, since yield can be greatly reduced with delays of 7–14 days after the optimal sowing time. Increased seed rates and modified applications of fertilizers and irrigation water are required to achieve high grain yields following late sowing [36].

The retention of crop residues on the soil surface normally associated with conservation agriculture-based no-till system has an important influence on soil water storage [37-38]. Four-year average net economic returns for wheat grown in the zero tillage system increased about 30% as compared with the traditional tillage system. It also resulted in higher yields and lower production costs [39].

In the recent years, planting of wheat on raised bed is being advocated in South Asia for improving resource use efficiencies i.e., water use efficiency (WUE). Significant increase in WUE on laser level fields has been reported by several researchers under different soil and climatic conditions [40-43]. A raised bed-planting technology for wheat-based cropping systems was developed in Mexico. In raised bed-planting the wheat rows are planted on the top of beds with furrow irrigation between the beds. It overcomes some of the disadvantages of flood irrigation such as low potential irrigation water use efficiency, inefficient use of fertilizer, crusting of the soil surface, degradation of some soil properties, and more lodging of the crop [44]. The cumulative effects of the various advantages resulted in improved wheat quality and increase wheat yield by more than 10% [45].

The comparison of three RCIs under different circumstances is given in Table 1. Whereas, their definition, merits and de-merits are summarized in Table 2.The rising prices of tillage inputs like seeds, production cost, less use of chemicals and enhance in the efficiency of irrigation water and fertilizers for the improvement of economically feasible and environmentally enhanced wheat production system. Hence, resource conservation interventions would greatly help to achieve these goals irrigation water, weedicide and fertilizers have aggravated the situation. So, strategies must be implemented to augment the soil fertility, curtail the.

The main objective of the current study was to appraise the economic impact of resource conservation interventions to augment in yield and net farm income and curtail in cost of production of wheat crop.

2. Methodology:

This study presents an appraisal of economic impact of Resource Conservation Interventions (RCIs). As a case study ten districts of Punjab, Pakistan were selected for the study, where RCIs have been implemented. A questionnaire was developed to collect data from the farmers of the selected areas. Fifty nine farmers, who have implemented RCIs for sowing of wheat, were purposively selected for data collection. The questionnaires were filled by interviewing the farmers of the selected areas. The survey was conducted in year 2011-12 for collection of data from the farmers through questionnaire to appraise the economic impact of RCIs. The questionnaire developed for data collection for the study was redesigned and modified through discussion with the local supervisor and some relevant personnel of On Farm Water Management. Before the tangible interview, questions were translated into local language.

The irrigated area selected for evaluation of RCIs includes rice-wheat cropping zone. The data collected through questionnaire included the agriculture inputs and outputs of RCIs and traditional irrigation system i.e. tillage, seed rate, irrigation water, weed intrusion, fertilizer use, FYM, herbicide, cropping intensity, crop yield, total cost of cultivation, gross farm return and net farm return.

The economic analysis was carried out on the basis of agriculture inputs and outputs. The results of economic analysis of RCIs were compared with traditional irrigation system to appraise the impact of enhancing the crop yield and reducing the agriculture inputs. In addition to economic analysis the water productivity (WP) and fertilizer use efficiency was also calculated for RCIs and traditional irrigation system.

2.1 Sampling Procedure and Data Collection

intervention of bed-furrows planting and laser land levelling in three districts (Sialkot, Nankana, Khanewal) and 6 respondents implemented the two interventions of bed -Furrow planting and zero tillage in the district Sahiwal. Impact appraisal of the Resource Conservation Interventions was done using ‘with’ and ‘without’ intervention approach.

2.3 The study area:

The study area lies in central Punjab. Dissemination of farm area concealed by ‘with’ and ‘without’ interventions, which was surveyed, is given in Table 4. In the current study, an effort was made during the field survey that only those fields were selected where single RCI was implemented. Hence those fields were selected for the study where the improvement in benefits was only due to single RCI as shown in Table 4.

2.4 Economic Analysis

The impact assessment by economic analysis was carried out in the present study for the rice-wheat cropping zone. The economic impact indicators were assessed for RCIs and traditional irrigation system. During economic analysis, all the indicators were converted to equivalent monetary units i.e. in rupees per unit area for the purpose of comparison of the results. In addition to economic analysis the water productivity (WP) and fertilizer use efficiency were also calculated.

2.5 Limitations of Research Method

The limitations of research method are i) Results are based on data collected through survey of ten districts in Punjab. ii) Only respondents/farmers were interviewed in each district through survey instrument. iii) Only those areas were included in the study which were subject to single RCI for improvement in benefits. iv) RCIs were evaluated for only rice-wheat cropping zone. v) Research work is only carried out for economic evaluation and no socio parameters have been included.

Table 1: Comparison of Three Techniques

Circumstances		Techniques		
		Zero tillage	Laser levelling	Bed- furrrow
Topography	Low-lying regions	-	-	more preferable for Low-lying regions with weak drainage system
	Plane regions	-	Best because economical w. r. t. levelling	-
Soil type	sandy soil	Best due to soil is already loose	-	-
	Silt clay loam	Best because no salinity and well drained	-	-
	saline and sodic soil	-	-	Best because negative effects of salinity can be avoided
Dominant irrigation method	Furrow irrigation method	-	-	Best because 45% water saving
	flood/surface irrigation method	-	Best because water is uniformly distributed	-
Crop type	wheat	Best due to less planting time, reducing weed infestation.	-	-
	cotton	-	-	best for row crops
	Sugarcane	-	Best due to equal distribution of water and fertilizer	
Water logged region		-	-	Best because furrows performs as drainage channels
Economy		Best due to the reduced number of tillage operations prior to seeding and reduced number of irrigations.	-	-
Crop yield		-	Best because maximum land use intensity than others	-
Fertilizer use efficiency (FUE)		-	-	Best due to light irrigation and top dressing on bed.
Weed control		Best because less soil distur-bance which could not help to germinate the weed seed.	--	-
Water use efficiency (WUE)		-	-	Best because water is applied in furrow only and not to the entire field
Saving in water		-	-	Best because 45 percent water saving
Timely/Early sowing		Best due to sowing is completed within 2 weeks.	-	-
Moisture conservation		Best because of better infiltration of surface water and reduction of surface evaporation	-	-

Compiled from reference No. 46. 47, 48, 49.

Table 2: Definition, Merits and De-merits of three Techniques.

Interventions	Definition	Merits	De-merits
Zero tillage (ZT)	The cultivation intervention in which soil is disturbed only in the slit or hole where seed is to be planted.	• Conserve moisture. • Earlier sowing of crop possible • Reduce erosion. • Use less labour. • Consume less fuel. • Increase soil organic matter.	• Require a zero tillage planter. • Rely on herbicides for weed control. • May cause soil compaction in upper soil zone.
Laser land levelling (LLL)	Laser levelling is a process of smoothing the land surface (± 2 cm) from its average elevation using laser-equipment.	• A levelled surface leads to uniform soil moisture distribution, resulting in good germination, enhanced input use efficiency and improved crop yield. • Laser levelling allows for control of water distribution with negligible water losses. • Laser levelling improves irrigation efficiency and reduces the potential for nutrient loss through better irrigation distribution efficiency and less runoff, if any. • Land levelling reduces weed, pest, and disease problems. • Leads to reduced consumption of fuel, seeds, fertilizers and chemicals.	• High cost of the laser instrument. • Need for skilled operator to adjust laser settings and operate the tractor. • Less efficient in irregular and small sized fields.
Bed - furrow (BF)	It is a process in which the field is divided into narrow strips of raised beds / ridges separated by furrows. The crops are planted on the bed surface and irrigation water is applied through the furrows.	• Saving of about 30% irrigation water. • Less reduced chances of plant submergence due to excessive rain or over-irrigation. • Lesser crusting of soil around plants and therefore, more suitable for saline and sodic soils. • Adaptable for various crops without changing basic design / layout of farm. • Enhanced fertilizer use efficiency due to local application.	• It requires land grading so as water can travel the entire length of furrow without ponding. • It requires continual slope by removing low and high spots. • It is not suited to all crops.

Table 3: Detail of number of Farmers interviewed during survey in different districts:

Sr. No	Name of District	No. of Farmers interviewed	Percent of total sampled farmers
1	Gujranwala	9	15
2	Hafizabad	5	8
3	Kasur	8	14
4	Khanewal	4	7
5	Lahore	5	8
6	Nankana	4	7
7	Okara	6	10
8	Sahiwal	6	10
9	Sheikhupura	8	14
10	Sialkot	4	7

2.5 Sources of uncertainty

In the absence of proper farm records, there was no alternative except to rely on the memory of the farmers. Therefore, the uncertainty may be in crop yield, number of irrigations, fertilizer and seed rate used.

3. Results and Discussion:

The economic analysis was carried out to find out augment in yield and net farm income and curtail in cost of production of rice-wheat cropping zone using RCIs as compared to traditional irrigation system. The results of economic analysis of each indicator for RCIs and traditional irrigation system are discussed below.

3.1 Tillage (Soil preparation and sowing) cost:

At the time of sowing, cultural practices like levelling, ploughing and planking were applied for preparation of the fields. The data revealed that field preparation for sowing of wheat was commonly carried out by tractor. Bullocks were rarely used for cultivation. Some advanced respondents had rotavators and disc harrow plough. Table 5 shows the number of ploughing and planking for wheat fields in the selected areas.

The items that are included in the cost of soil preparation and sowing are leveling, ploughing, planking and sowing/planting of seeds. Lumpsum rate is charged for cost of soil preparation and sowing (Leveling, Ploughing, Planking and Sowing/planting of seeds) which also includes the labour cost. Therefore, no separate labour cost was collected.

For wheat sowing, ZT is the utmost effective intervention. In this intervention, wheat is implanted with a special drill without any preparation after harvesting rice crop. This intervention not only curtails the agriculture cost to a substantial amount but also saves time by approximately 15-20 days. Laser land levelling permits for uniform application of irrigation water, saving of land and fertilizers. For example, results of some studies showed that cultivable land has increased from 3 to 5 % by LLL because of reduction in number of field channels [50-51].

Bed-furrow is an intervention for efficient water saving. Under this technique, the wheat crop is planted on bed in different rows. Floras on these beds acquire moisture from the furrows. Traditional irrigation technique uses ancient farm intervention i.e. Flood irrigation. This technique produces less net returns than improved interventions. The average, median and range of cost of ZT, LLL and BF are mentioned in Table 6. The survey was carried out for adjacent and nearby districts of Punjab. Only minor difference in cost of RCI was observed for the selected districts.

3.2 Seed rate:

Application of improved seed was more inspiring in the selected areas. Some respondents used seed obtained from Government Seed Corporation and private companies while the other used seed retained from the previous crop. Average seed rate in areas where RCIs have been adopted varied from 121 to 128 kg per hectare, whereas 148 kg per hectare seed was used in traditional irrigation farm. The seed rate in traditional farm is more than the RCIs adopted farms. Recommended seed rate should be 116-126 kg per hectare for wheat (OFWM, Punjab, Pakistan 2003). Wheat varieties mostly planted in the study region included Sahar 2006, Shafaq 2006, Fareed 2006 and Inqilab 91. The cost of seed for wheat was Rs.2000/50kg and its range is given in box plot 1. The seed rate for both ‘with’ intervention (RCIs) farms and ‘without’ intervention farms is presented in table 7. It is apparent from these data that seed rate and its cost are lower for all the RCIs than traditional.

Table 4: Dissemination of farms area by different interventions.

Location (Districts)	Village	Total area (ha)	Dissemination of farms area by different interventions (hectares)							
			Bed-furrow		Laser land levelling		Zero tillage		Traditional	
			(ha)	%	(ha)	%	(ha)	%	(ha)	%
1) Lahore	**-**	**20**	**-**	**-**	**8**	**40**	**4**	**20**	**8**	**40**
(i)Lahore cantt	Hair	20	-	-	8	40	4	20	8	40
2) Sahiwal	**-**	**24**	**4**	**16.67**	**-**	**-**	**10**	**41.67**	**10**	**41.67**
(i)Sahiwal	113/9L	24	4	16.67	-	-	10	41.67	10	41.67
3) Okara	**-**	**32**	**8**	**25**	**8**	**25**	**8**	**25**	**8**	**25**
(i)Depalpur	Pipli mehtab ray	32	8	25	8	25	8	25	8	25
4) Kasur	**-**	**68**	**-**	**-**	**24**	**35.29**	**20**	**29.41**	**24**	**35.29**
(i)Kasur	Weerum Hittar	36	-	-	12	33.33	12	33.33	12	33.33
(ii)Pattoki	Narohi thatta	32	-	-	12	37.5	8	25	12	33.33
5) Hafizabad	**-**	**24**	**-**	**-**	**8**	**33.33**	**8**	**33.33**	**8**	**33.33**
(i)Pindi Bhattia	Bhopa Lodhika	24	-	-	8	33.33	8	33.33	8	33.33
6)Gujranwala	**-**	**70**	**7**	**22.67**	**22**	**32**	**28**	**-**	**13**	
(i)Kamokee	Kallu kalan	40	4	10	12	30	16	40	8	20
(ii) Gujranwala	Hambokey	30	3	9.33	10	34.67	12	40	5	16
7) sheikhupura	**-**	**60**	**8**	**-**	**16**	**-**	**16**	**-**	**20**	
(i) sheikhupura	Manawala	40	6	-	10	-	10	-	14	
(ii) Ferozwala	Kotpindi Das	20	2	-	6	-	6	-	6	
8) Sialkot	**-**	**20**	**4**	**20**	**8**	**40**	**-**	**-**	**8**	**40**
(i)Daska	Dholanwali	20	4	20	8	40	-	-	8	40
9) Nankana	**-**	**24**	**4**	**16.67**	**10**	**41.67**	**-**	**-**	**10**	**41.67**
(i)Nankana	Bunga	24	4	16.67	10	41.67	-	-	10	41.67
10)Khanewal	**-**	**20**	**6**	**30**	**8**	**40**	**-**	**-**	**6**	**40**
(i)Kabeerwala	Kohiwala	20	6	30	8	40	-	-	6	40
Total		362	41	11.32	112	30.94	94	25.97	115	31.77

Table 5: Number of Ploughing and Planking for wheat Fields:

Intervention	Traditional	Zero tillage	Laser land levelling	Bed-furrow
Ploughing	5	0	3	3
Planking	4	1	1	2

Table 6: Soil preparation and sowing costs (Rs Per ha)

Items	Interventions											
	Traditional			Zero tillage			Laser land levelling			Bed-furrow		
	Range of Cost value	Avg. value	Median cost value	Range of Cost value	Avg. value	Median cost value	Range of Cost value	Avg. value	Median cost value	Range of Cost value	Avg. value	Median cost value
Levelling (per Hectare)	….		….	…		….	3309-3605	3457	3469	….		….
Ploughing (one time)	1790-2049	1926	1938	….	….	….	1802-2099	1975	2000	1753-2148	1975	1988
Planking (one time)	1012-1185	1111	1111	716-938	864	889	889-1062	988	1000	864-1062	988	1012
Sowing (per Hectare)	1062-1333	1234	1259	1951-2272	2099	2099	1568-1901	1728	1753	3173-3506	3333	3358

Table 7: Sowing dates and average seed rate (kg per ha) for wheat crop

Sowing dates	Traditional	Zero tillage	Laser land levelling	Bed-furrow
22 Oct to 7 Nov.	143	118	123	121
8 Nov to 15 Nov.	146	121	128	123
16 Nov to 30Nov.	156	123	133	126
Average seed rate	148	121	128	123
Percentage	100	82	86	83

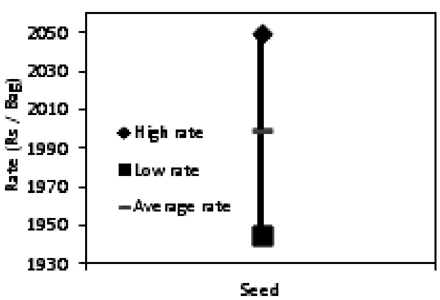
Table 8: Total Depth of Irrigation and water saved for wheat crop (2011-12)

Intervention	Traditional	Zero Tillage	Laser Land Levelling	Bed-Furrow
No. of irrigations applied.	5	3	4	3
Average depth per irrigation (cm).	8.9	7.6	7.6	8.9
Total depth of irrigation applied (cm) per ha.	44.5	22.9	30.5	26.7
Water saved per ha (cm).	-	21.6	14	17.8
Water saved in percent	-	49	31	40
Cost of total irrigations (Rs/ha)	4716	3501	3975	3390

3.2 Irrigation Water:

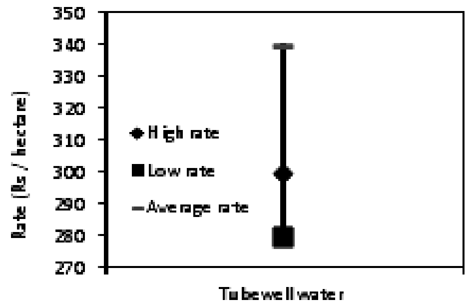
In the study area, sources of irrigation water are canal and tubewell. In the study area, the common practice is the conjunctive use of irrigation due to insufficient canal supplies. The number of irrigations, average depth per irrigation and total depth of irrigation for farms where RCIs have been implemented and total cost of irrigation water per hectare of wheat crop are given in Table 8. Number of irrigations applied and depth per irrigation were collected from the respondents during the field survey. Accordingly average depth per irrigation was multiplied by number of irrigations to calculate total depth (Δ) of irrigation applied. The volume of water applied was estimated by multiplying the total irrigation depth and the area irrigated.Water saved in RCIs varied from 49 to 31 percent (Table 8).

Box Plot 1: Seed Rate Range



In Punjab, the canal water rate (abiana) is nominal and at the time of data collection it was Rs. 200.0 per hectare for the whole season of Rabi crops (e.g. wheat) and tublewell water rate was Rs. 300 per hour (range given in box plot 2). Due to conjunctive use of irrigation, total cost of irrigation per hectare was taken through feedback of respondents for each intervention (Table 8). Thus, total irrigation cost includes cost of canal water (Rs. 200) plus Rs. 300 multiplied by total number of t/w water (hours) applied. Total cost of irrigation per ha for traditional farming was Rs 4716 whereas for the RCIs it varied from Rs 3501 to Rs 3975 (Table 8).

Box Plot 2: Tubewell Water Rate Range



3.3 Fertilizer:

Farmers habitually trust on commercial fertilizers to revive fertility of their soils. Farm Yard Manure (FYM) was also a source of fertility but it was applied to a limited extent. Data did not show about the use of green manuring on the sampled farms. According to farmer's perceptions, the use of nitrogenous fertilizers was superior to phosphate and potash fertilizers. Phosphate and potash fertilizers were applied at the time of sowing of the crops whereas nitrogen was applied mostly in two to three dozes i.e. with Ist, 2nd and 3rd irrigations. The major hindrance jagged by the farmers were low purchasing power against extremely high fertilizer prices, its uncertain supply, adulteration and less weight. In spite of these, the farmers used suitable and sufficient quantity of fertilizer in 'with' intervention farms as compared to 'without' intervention farms, because more use of fertilizers gave more yield which compensate the expenditure of the fertilizers as shown in Table 9. The prevailing costs of phosphate and nitrogen. fertilizers were Rs.4000/bag (50kg) and Rs.1750/bag respectively whereas the cost of FYM fertilizer was Rs.4/kg.

Table 9: Average fertilizer use for wheat crop (2011-12) under different interventions: (kg per ha)

Intervention	Traditional	Zero tillage	Laser land levelling	Bed-furrow
Nitrogen (N)	173	143	160	146
Phosphate (P_2O_5)	111	99	104	96
FYM	1037	765	963	889
Total Cost (Rs/ha)	19086	15975	17765	16198

3.5 Weed Eradication.

Weeds and crop plants grow under the same environment and have the same requirement for development and growth. Equally extrovert moisture and soil nutrients from the same medium of soil take CO2 and light for photosynthesis from the same atmosphere and accommodate their build up within the same space. Due to this reason, weeds effect adverse on the yield of crop and consequently, crop yield is curtailed. Chemical was applied to eradicate the weeds. Weed densities before and after application of herbicides and its cost per hectare are given in Table 10. It is apparent from the table that cost of weed eradication is more for traditional intervention as compared to the RCIs.

3.6 *Harvesting /Threshing*:

During survey, the data was collected from the respondents about harvesting/threshing. Most of the farmers preferred harvesting rather than threshing because, during threshing, 8-10 maund (one maund = 37.4 kg) wheat was wasted as reported by the farmers. The rate of wheat crop harvesting in the study areas was 7.5 maund per ha. So the average prevailing rate of wheat crop harvesting for zero tillage, laser land levelling and bed-furrow interventions and traditional technique was Rs.7802, Rs.7778, Rs.7679 and Rs.7931 per hectare respectively depending on yield of the crop.

Table 10: Weed eradication and use of herbicide for wheat crop

Interventions		Traditional	Zero tillage	Laser land levelling	Bed-furrow
Weed density (Number/m^2)	Before herbicide	99	65	87	62
	After herbicide	14	11	12	10
herbicide cost (Rs/ha)		3778	3037	3383	2765

Table 11: Impact of different Interventions on Inputs (Rs Per ha):

Name of inputs	traditional	zero tillage	laser Land levelling	bed - furrow	cost reduction in percent		
					Zero Tillage	laser Land levelling	Bed-furrow
Tillage& sowing	15308	2963	12099	11234	-80.64	-20.96	-26.61
Seeds	5920	4840	5120	4920	-18.24	-13.51	-16.89
Irrigation water	4716	3501	3975	3390	-25.76	-15.71	-28.12
Fertilizer	19086	15975	17765	16198	-16.30	-6.92	-15.13
Herbicide	3778	3037	3383	2765	-19.61	-10.46	-26.80
Total	48808	30316	42342	38507	-37.89	-13.25	-21.10

3.7 *Impact of Interventions on inputs*:

The impact of the three RCIs on overall field level agricultural inputs are given in Table 11. All three interventions resulted in significant savings in tillage and irrigation water costs. However, impacts of fertilizer and herbicide use were relatively small in laser land levelling. Reduction in production cost was approximately 37.89, 13.25 and 21.10 percent in zero tillage, laser land levelling and bed-furrow interventions respectively.

3.8 Crop Yield:

Soil management, soil fertility, application of fertilizers, quality of seeds, timely sowing of crops and adoption of better cultural practices all affect yield of wheat crop. There is a close relationship between all these inputs and high crop yields. All the agriculture inputs play an important role in enhancing the crop yield. To appraise the impact of these interventions on wheat yield, yield data was analysed separately for each intervention (Table12). Yield increase of 16, 21 and 7 percent was recorded for ZT, LLL and Bed-furrow interventions respectively.

3.9 Cropping Intensity:

The cropping intensity has increased 'with' RCIs as compared to the 'without' RCIs as shown in Figure 1. According to the farmers' response, there is a significant increase in cropping intensity on zero tillage, laser land levelling and bed-furrow farms. The Figure 1 also shows that a marginal increase in cropping intensity in zero tillage intervention because in general it saves rauni (pre-sowing irrigation) and tillage and does not require irrigation water and labour as compare to laser land levelling and bed-furrow.

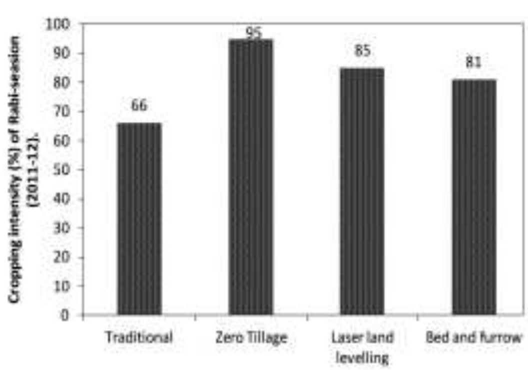


Fig. 1: Cropping Intensity (%) of Rabi season (2011-12)

3.9 Water productivity (WP):

Water productivity is ratio of crop yield to depth of water applied. Water productivity is a simple appraise to measure how effectively irrigation water has been used for crop production. Any effort which tends to augment crop yield or curtail the amount of water required, without disturbing crop yield, will enhance the water productivity. In this study, water productivity has been worked out as Kg per cubic meter of water applied. Table 13 shows that water productivity achieved by RCIs are much higher than traditional farms. It is highest for ZT followed by bed-furrow and LLL farms. Water saved by ZT, LLL and bed-furrow are 49, 31 and 40 percent per hectare respectively w.r.t traditional farming.

3.10 Fertilizer use Efficiency (FUE):

Fertilizer use efficiency is the ratio of crop yield to total fertilizers applied. The efficiency of Manure/Fertilizer use for farms 'with' RCIs was greater than 'without' RCIs farms. Effective use of fertilizer for RCIs farms resulted in augmented yield. Table 14 shows that the fertilizer use efficiency of RCIs farms is higher than traditional farms. Higher fertilizer use efficiency revealed that these interventions are more helpful for optimal use of fertilizers.

3.11 Gross and Net Benefits:

The goal of economic analysis was to appraise the impact of zero tillage, laser land levelling and bed- furrow on yield, net farm income and cost of production for wheat crop. Table 15 shows that ZT intervention for wheat sowing is the utmost cost effective intervention with aggregate cost of production of Rs.38118 per hectare. The key reason for less cost of production for this intervention is less cost of soil preparation for sowing of the crop. Bed-furrow was second cost effective intervention with aggregate cost of production of Rs.46138 per hectare.

The main reason for less cost of this intervention was the less expenditure incurred on herbicide and irrigation. Cost of production for LLL was more than the other improved interventions. The cost difference was endorsed mainly to cost of levelling on traditional farm.

Gross benefits were computed by multiplying yields (in Maund) with market rates (average

Table 12: Yield of wheat crop (2011-12) on the sample farms

Intervention	Traditional	Zero tillage	Laser Land Levelling	Bed -furrow
Yield (kg/hectare)	3970	4617	4802	4247
Bhoosa (kg/hectare)	4247	4338	4985	4432
Increase in Yield(Percent)	-	16	21	7

Table 13: Water productivity of wheat crop on sample farms (2011-12)

Depiction	Units	Traditional	Zero tillage	Laser land levelling	Bed-furrow
water applied	m^3/ha	4439	2284	3044	2664
Crop yield	kg/ha	3970	4617	4802	4247
water productivity	kg/ m^3	0.89	2.02	1.58	1.59
water saved	m^3/ha	-	2155	1395	1775
Water saved per ha w.r.t. traditional	in percent	-	49	31	40

Table 14: Fertilizer use efficiency of wheat crop on sample farms (2011-12).

Intervention	Traditional	Zero tillage	Laser land levelling	Bed-furrow
Total NP (kg/ha)	284	242	264	240
Crop yield (kg/ha)	3970	4617	4802	4247
Fertilizer UE (%)	13.98	19.1	18.19	17.7

Table 15: Total Cost of production, Gross Benefits and Net Benefit for wheat by various interventions (Rs Per ha)

Interventions	Traditional	Zero tillage	Laser land levelling	Bed-furrow
Levelling	-	-	3457	-
Ploughing	9876	-	5926	5926
Planking	3951	988	988	1975
Sowing	1481	1975	1728	3333
Seeds	5920	4840	5120	4920
Irrigation	4716	3501	3975	3390
Fertilizer	19086	15975	17765	16198
Herbicide	3778	3037	3383	2765
Harvesting/threshing	7931	7802	7778	7631
Total Cost of Production	56739	38118	50120	46138
Gross benefits	143552	161948	171534	150734
Net benefits	86813	1238302	121414	104596
Increase in net benefits	-	37017	34601	17783

prevailing rate Rs.1050/maund) of wheat crop in 2012. Gross revenue for wheat also included gross benefits of wheat by- product (i.e. bhoosa) which was computed based on average prevailing rates in the study region as Rs.250/40kg. Gross benefits of laser land levelling is highest followed by zero tillage and bed-furrow farms.

Economic well-being and agricultural achievement depends mainly on net revenue gained. Net benefits were calculated by subtracting the total cost from gross benefits as shown in Table 15. The net benefits of zero tillage are the highest followed by laser land levelling and bed-furrow farms. Hence, economic analysis concludes that the zero tillage intervention is the best feasible and attractive opportunity for agricultural community due to less cost of production inputs and enhanced water productivity, fertilizer use efficiency and net benefits.

3.12 Comparison of the Results with other countries:

The results of present study are compared with other studies from Pakistan, India, Mexico and China where these RCIs have been implemented (Table 16). The average wheat yield of present study is only 7% higher than the average wheat yield of Pakistan and compatible with India (only 4% lower). However, the yield is 23 and 12% lower than Mexico and China respectively. Similarly, water productivity (kg/m^3) is slightly higher and fertilizer use efficiency is 9% lower than Pakistan. The overall results conclude that the output parameters of the current studty are similar to regional countries like India and lower than the developed countries i.e., Mexico and China.

Table16 Comparison of results with other studies

Output parameters	Present study	Pakistan	India	Mexico	China
Wheat yield (kg/ha)	4555	4250	4758	5591	5137
Water Productivity (kg/m^3)	1.73	1.6	1.75	2.3	2.16
Fertilizer use efficiency (%)	18.33	20	25	30	28

Complied from references no.52-58.

4. Conclusions

Overall conclusion of this study is that all the RCIs lead to increase in crop yield and saving of irrigation water. Specific conclusions of the study are:

- Wheat yields obtained by using RCIs were 4802 kg/ha for laser land levelling followed by zero tillage (4617 kg/ha), bed-furrow (4247 kg/ha) and traditional farms (3970 kg/ha). The increase in crop yield varied from 7 to 21 percent in all the RCIs.
- The Rabi cropping intensity of wheat increased from 66% (traditional) to 95%, 85% and 81% by zero tillage, laser land levelling and bed-furrow respectively.
- Saving of irrigation water by Zero tillage, bed-furrow and laser land levelling was 49, 40 and 31 percent per hectare respectively as compared to traditional.
- Water productivity was higher for zero tillage farms (2.02 kg/m^3) followed by bed-furrow (1.59 kg/m^3) and laser land levelling farms (1.58 kg/m^3).

5. Recommendation

The study concludes that RCIs are favourable to enhance the crop production and net income, and their attractiveness is augmenting every day among the farming community. However, these are not used by most of the farmers in Pakistan due to high cost of equipment used for implementing RCIs. Government should reduce the costs of RCIs, so that these can be implemented by all the farmers and area under RCIs may be extended. Modern technology and machinery, delivery of zero-tillage drills and laser levellers should also be made available to farmers at subsidised rates.

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