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IMPACT OF LASER LEVELING TECHNOLOGY ON WATER USE EFFICIENCY AND CROP PRODUCTIVITY IN THE COTTON –WHEAT CROPPING SYSTEM IN SINDH

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ABSTRACT

The crop productivity in Pakistan is very low as majority of the farmers are still practicing traditional farming techniques. The existing crop production technologies do not offer effective and efficient utilization of natural resources, particularly that of water. Moreover, a significant amount of irrigation water is wasted due to uneven fields and ditches. Unevenness of the soil surface also has a major impact on the germination, stand and yield of crops through nutrient water interaction and salt and soil moisture distribution pattern. Therefore, the water use efficiency along with yield per acre could be increase by adopting resource conservation technologies like laser leveling. A sample of 120 growers including 60 wheat growers and 60 cotton growers were selected from Mirpurkhas & Tando Allahyar districts of Sindh province of Pakistan. Study results revealed that about 21 percent irrigation water saved by the adoption of laser leveling technology and also obtained higher yield and profit margins comparatively. Study concluded that adoption of laser leveling technology helps in reducing the farm input costs, improve water use efficiency and enhance crop productivity.

Keywords:
Laser leveling technology, water use efficiency, economic analysis, water saving.

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1. INTRODUCTION

Water is one of the most important inputs for crop production. Increasing water scarcity is also seen as major contributor to stagnating productivity of cropping system (Byerlee et al. 2003; Kumar et al. 2002). Due to the absence of efficient water-pricing mechanisms, the scarcity value of water is not reflected in water prices (Pingali and Shah 2001). In the face of unreliable canal water supplies, many farmers have increased their reliance on private tube wells placing tremendous pressure on groundwater supplies (Abrol 1999; Ahmed et al. 2007; Qureshi et al. 2003). Negative environmental effects related to irrigation are increasing as overexploitation of groundwater and poor water management lead to the dropping of water tables in some areas and increased waterlogging and salinity in others (Harrington at al. 1993; Pingali and Shah 2001; Qureshi et al. 2003). In edition tube-well irrigation has raised production costs in view of energy expenses incurred on electricity or diesel (Qureshi et al. 2003). Also significant amount of irrigation water is wasted due to undulated fields and due to field ditches. The crop productivity of the country is very low as majority of the farmers are still practicing traditional farming techniques. Moreover, cost of production has increased many times due to rising prices of fuel and other agricultural inputs. The existing crop production technologies do not offer effective and efficient utilization of natural resources, particularly that of water. Extremely low efficiency of input use has led to wastage and depletion of natural resources besides environmental degradation (Hobbs, et al. 1997). The importance of efficient use of this precious crop input increases as the world population increases. Qutab and Nasiruddin (1994) reported that the Pakistan Rabi Shortfall of 3.5 million acre foot (MAF) could increase to 13 MAF by the year 2019, at this stage; country would need more food and fiber to meet the needs of the growing population. This shortfall has to be met either by constructing new reservoirs or by improving the water use efficiency at the farm. The construction of new reservoirs has financial and environmental constraints. Whereas, the efficiency of the irrigation system could be improve easily by adopting proper technologies (Ashraf et al. 1999). However, the water use efficiency along with yield per acre could be increase by adopting resource conservation technologies like laser leveling.

Unevenness of the soil surface has a major impact on the germination, stand and yield of crops through nutrient water interaction and salt and soil moisture distribution pattern. Land leveling is a precursor to good agronomic, soil and crop management practices. Resource conserving technologies perform better on well leveled and laid-out fields. Farmers recognize this and therefore devote considerable attention and resources in leveling their fields properly. However, traditional methods of leveling land are not only more cumbersome and time consuming but more expensive as well. Thus in the process of a having good leveling in fields, a considerable amount of water is wasted. It is a common knowledge that most of the farmers apply irrigation water until all the parcels are fully wetted and covered with a thin sheet of water. Studies have indicated that a significant (20-25%) amount of irrigation water is lost during its application at the farm due to poor farm designing and unevenness of the fields. This problem is more pronounced in the case of rice fields. Unevenness of fields leads to inefficient use of irrigation water and also delays tillage and crop establishment options. Fields that are not level have uneven crop stands, increased weed burdens and uneven maturing of crops. All these factors tend to contribute to reduced yield and grain quality which reduce the potential farm gate income.

Effective land leveling is meant to optimize water-use efficiency, improve crop establishment, reduce the irrigation time and effort required to manage crop. The Manual for Laser Land Leveling seeks to explain the benefits of land leveling in fields, particularly rice fields, and help develop skills of farmers and operators in using laser technology to achieve a level field surface. It is also intended to enable the users to identify and understand the working of the various components of a laser-controlled land leveling system; undertake a topographic survey using a laser system; set up and use a laser-controlled leveling system. It is hoped that the users (farmers and service providers) could be beneficial by adopting this important resource conserving technology as a precursor to several other improved agronomic, soil and crop management practices. Laser technology can ensure very accurate and precision land leveling to extent of ±2 cm (London, 1995; Waker, 1989). The resource conservation technologies (RCTs) mainly include bed planting of wheat, sowing of wheat following zero tillage technology, bed and furrow sowing of cotton and management of crop residues.

Laser land leveling adopted in Pakistan has shown encouraging results under zero tillage technique wheat is sown using residual moisture with no or minimum tillage without irrigating the fields with the aim to sow wheat in time after rice, conservation of water, and reduced cultivation cost (Akhtar, 2006). In this Sindh laser land leveling was adopted last decade ago by the growers. However, necessary data to support its effectiveness on crop yield and water saving are scarce. It was therefore, felt imperative need to evaluate the effect of laser and traditional land leveling technologies on cotton and wheat productivity, land and water use efficiency in cotton-wheat system of Sindh. This study was conducted to evaluate the impact of laser leveling technology on crop production and water saving to compare these with conventional methods.

2. RESEARCH METHODOLOGY

The study was conducted through primary data collection from growers in two major districts of cotton-wheat cropping zone of Sindh i.e. Mirpurkhas and Tando Allahyar. The selection of growers was carried out based on the criteria that they had adopted laser leveler technology on their farm. The primary data was collected from the cotton and wheat growers through the well-structured pre-tested questionnaire. From each location about 4-5 growers were randomly selected and interviewed. A total of 120 growers including 60 wheat growers and 60 cotton growers were determined as a sample size on 95% confidence level with a interval of 9.7 for prediction of 5000 grower's. The interview with growers was carried out personally, which allowed very detailed insights in crop growing in the target areas. Data was collected during the crop year 2014-15. With the questionnaire of growers, information was collected about the impact of laser leveler on water use efficiency and crop production. After completion of data collection process, collected data were further entered, classified and analyzed on computer based spreadsheet software in order to reach on final results, discussion and conclusion.

3. RESULTS & DISCUSSION

3.1.SOCIO ECONOMIC CHARACTERISTICS OF RESPONDENTS

Socioeconomic conditions of the growers plays very important role in resource management decisions and consequent impacts on yield. Age is one of the important characteristics of the community. It reflects on the productivity of the population as it has it a bearing on the overall health situation within the community. In developing countries, aged members are more prone to diseases and thus are less productive. It has a bearing on the employment pattern, spatial mobility and quality of work done. Age plays a significant role in any kind of business, particularly in agriculture, because the use of child labour on the farms is quite high. Data presented in Table 1 shows that majority of the respondents (50 percent) were between 36 to 50 years, 25 percent of the respondents were between 20 to 35 years and 22 percent of the respondents were having age between 51 to 60 years. Education is always considered as an important factor of understanding and learning skills. It is education which changes the behavior

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of human beings in particular and living beings in general. Education changes moral character, thinking pattern and make learn how to talk and behave with other people. It helps in making the decisions on right direction. Information regarding the education level of selected growers was analyzed and presented in table 1. It was found that majority 38 percent of the respondents were illiterate, followed by 25 percent of respondent were educated at primary level, 5 percent had middle, 15.0 percent were matriculate, 8 percent were intermediate, 5 percent had bachelor level, and 3.3 percent were masters' level education.

Tenancy also has an important productivity impact. The length of the time horizon for owners and tenants is bound to differ, giving rise to differing attitude towards long term investment (especially natural resources management's investment) and crops with long gestation lags. Growers can be classified into various categories, especially with regards to land tenure. An important distinction is between landowners and tenants. The latter are either lease holder or share croppers who till the land of others in exchange to either a fixed rent or for a share in production as in the case for food crops and share of revenue generated in the case of cash crops. At one end of the scale do the large absentee landlords own thousands of acres of land, titled by tenant and managed by a 'Kamdar'. At the other are the owner-cum tenant who cultivate their own land and also rented in or shared in land. The share croppers are not involved in purchase of inputs and marketing of crop output. This is usually left to the landlord or his kamdar. The tenant's share of grain food crops is paid in kind, out of which some may be sold if they have surplus. Cash crops like cotton and sugarcane are always marketed by the landlord. The most common share cropping contract requires the tenant to bear the 50 percent costs of seeds, fertilizer and pesticides. In return the tenant receives 50 percent share in the crop output. Data presented in Table 1 indicate that, a majority (63.3 percent) of the respondents were land owners and remaining only 36.7 percent were tenants.

During the survey soil type were recorded according to the farmer's own classifications and terminology. For example, clay soil was described as "Pacci" whereas clay-loam was described as "Bhari" and sandy-loam as "Halki". Table.1 shows that 8.3 percent respondents have sandy soil, 50.0 percent have sandy loam soil, 16.7 percent growers have loam soil and 25.0 percent growers have clay soil. Growers used different sources such as canal and tube wells to provide irrigation. Tube well water is mostly used at the time of scarcity of canal water. The source of irrigation was examined and found that majority 75 percent respondents used canal water and 25 percent used canal plus tube well water as shown in table 1. During survey water course types were investigated and results presented in table 1. Results show that majority 50 percent of respondents reported their water courses were not lined followed 25 percent reported Lined water courses and 25 percent reported semi lined water courses.

Table 1: Socioeconomic Characteristics of the Selected Respondents

	No. of respondents	**Percentage of respondents**
Age		
20-35 years	15	25
36-50 years	30	50
51-60 years	13	22
Above 60 years	02	03
Education Level		

Illiterate Primary Middle Metric Intermediate Bachelor Masters	23 15 3 9 5 3 2	38.3 25.0 5.0 15.0 8.3 5.0 3.3
Tenancy Status		
Land owner Tenant	38 22	63.3 36.7
Soil Type		
Sandy Sandy loam Loam Clay	5 30 10 15	8.3 50.0 16.7 25.0
Source of Irrigation		
Canal Canal + Tube well	45 15	75 25
Type of water course		
Lined Semi Lined Not Lined	15 15 30	25.0 25.0 50.0

Source: Own Survey data, 2014-2015

3.2.IMPACT OF LASER LEVELING ON WATER USE

Information regarding irrigation application in wheat crop was collected, analyzed and presented in table 3. Most of the wheat growers' source of irrigation is canal in the study area. In case wheat data indicate that little bit less number of irrigation applied by laser leveling technology growers (5.17) as compared to conventional growers (5.67). Time to irrigate an acre of wheat area was analyzed and found that the mean time to irrigate an acre field was reduced from 2.26 hrs to 1.18 hrs by the use of laser levelling technology. In case cotton, almost same number of irrigation applied by laser leveling technology growers (7.36) as compared to conventional growers (7.48). Time to irrigate an acre of cotton area was analyzed and found that the mean time to irrigate an acre field was reduced from 2.58 hrs to 1.32 hrs by the use of laser levelling technology. It means almost 50 percent time was saved to irrigate laser levelled fields as compared to conventional. The information regarding average depth of water applied on per irrigation was analysed and presented in Table 2. In case of wheat results show that less average depth of water reported by laser levelling technology growers 2.79 inches and compared to conventional growers 3.85 inches. In case of cotton results also indicate that less average depth of water reported by laser levelling technology growers 3.12 inches and compared to conventional growers 4.22 inches as shown below in Table 2.

Table 2: Number of Irrigations, Time Consumed on Irrigation and Average Depth of Water Applied for Wheat and Cotton

	Wheat		***Cotton***	
	Conventional	**Laser leveling**	**Conventional**	**Laser leveling**
Number of Irrigation	5.67	5.17	7.48	7.36
Time consumed (Hrs/Irrigation/acre)	2.26	1.18	2.58	1.32
Average Depth of Water Applied (inches)	3.85	2.79	4.22	3.12

3.3.PROFITABILITY ANALYSIS

3.3.1. COST OF PRODUCTION OF WHEAT AND COTTON BY TECHNOLOGY

Farm costs represented the value of goods and services utilized in agricultural production. The results of the cost of production of wheat are presented in Table 3. Costs have been broken down in a cash costs and non-cash cost (depreciation and opportunity) costs for production factors that are owned by the wheat growers. The overall cash costs of wheat sowing on laser leveling technology was high Rs. 20,314/acre, as compared to on conventional sowing of wheat Rs. 18906/acre. The wheat sowing by laser leveling technology has highest cash cost due to highest land leveling cost Rs. 1721/acre as compared to Rs. 970/acre on convention wheat sowing.

In case of cotton cultivation, the overall cash costs of sowing on laser leveling technology was high Rs. 28,988/acre, as compared to on conventional sowing of cotton Rs. 26,456/acre. The cotton sowing by laser leveling technology has highest cash cost due to highest land leveling cost Rs. 1,861/acre as compared to Rs. 788/acre on convention wheat sowing.

Table 3: Cost of Production of Wheat and Cotton by Conventional and Laser Leveling Technology, 2014-2015 (Rs/acre)

Costs				***Wheat***		***Cotton***	
				Conventional	***Laser leveling***	***Conventional***	***Laser leveling***
Cash Costs	**Variable Costs**	**Labour Cost**	Land Leveling	970	1721	788	1861
			Plough	2445	2564	2250	2351
			Ridges making	-	-	712	737
			Sowing	-	-	622	631
			Weeding	-	-	2264	2341
			Harvesting	1790	1784	-	-

		Threshing	916	926	-	-
		Picking	-	-	6720	7440
		Loading /Unloading	214	247	280	310
		Total Labour Costs	**6335**	**7242**	**13636**	**15670**
	Factor Costs	Seed Cost	2548	2606	761	756
	Factor Costs	**Fertilizer**				
	Factor Costs	DAP	2260	2347	2830	2910
	Factor Costs	Urea	3282	3398	3882	3931
	Factor Costs	NP	787	691	312	294
	Factor Costs	Pesticide			3823	3798
	Factor Costs	Weedicide	392	415	312	381
	Factor Costs	Tube well irrigation	540	480	340	318
	Factor Costs	Threshing charges	2062	2375		
	Factor Costs	Transportation	396	456	560	620
	Factor Costs	**Total Factor Costs**	**12267**	**12768**	**12820**	**13007**
		Total Variable Costs	**18602**	**20010**	**26456**	**28678**
	Fixed Costs	water Charges	97	97	106	106
	Fixed Costs	Govt. Land Taxes	207	207	204	204
	Fixed Costs	**Total Fixed Costs**	304	304	310	310
	Total Cash Costs		**18906**	**20314**	**26766**	**28988**
Non-Cash Costs	Opportunity Costs	Rent of Own Land	7016	7016	7640	7863
Non-Cash Costs	Opportunity Costs	Irrigation labour	545	355	762	432
Non-Cash Costs	Opportunity Costs	Labour for Pesticide Application			845	832
Non-Cash Costs	Opportunity Costs	**Total Opportunity Costs**	**7561**	**7371**	**9247**	**9127**
Non-Cash Costs	**Total Non-Cash Costs**		**7561**	**7371**	**9247**	**9127**
Total Costs			**26467**	**27485**	**36013**	**38115**

3.3.2. TOTAL REVENUE OF WHEAT

The average yield, prices and total revenue of wheat by conventional and laser leveling were calculated and presented in Table 4. Overall high yield was obtained 38 mds/acre of wheat and 31 mds/acre of cotton with use of laser leveling technology as compared to 33 mds/acre of wheat and 28 mds/acre of cotton by conventional method of sowing. The uniform irrigation and fertilizer application with laser leveling technology were the reasons of obtaining more yield was reported by wheat growers. As for prices concerned, in case of wheat the conventional and laser leveling technology growers received Rs.931/mds and Rs.928/mds respectively. In case of cotton the conventional and laser leveling technology growers received Rs.3320/mds and Rs.3310/mds respectively. Total revenue was received by the growers who used laser leveling technology Rs.35,264/acre from wheat and Rs.102,610/acre from cotton followed by conventional wheat and cotton growers Rs. 30,723/acre and Rs.92,960/acre respectively.

Table 4: Average Yield, Price and Total Revenue of Wheat Production by Technology during, 2014-2015

	Wheat		***Cotton***	
	Conventional	**Laser leveling**	**Conventional**	**Laser leveling**
Average Yield (Mds/ Acre)	33	38	28	31
Average Price (Rs./mds)	931	928	3320	3310
Total Revenue (Rs./acre)	30723	35264	92960	102610

Source: Own Survey data, 2014-2015

3.3.3. PROFITABILITY OF WHEAT & COTTON BY TECHNOLOGY

The average accounting and economic profits of wheat were calculated and presented in table 6. Results of analysis show that laser leveling technology growers received highest accounting as well economic profit Rs.14850/acre and Rs.7484/acre respectively from wheat and Rs.73,622/acre and Rs.64,495/acre respectively from cotton. Whereas, conventional growers were received accounting and economic profits Rs.11817/acre and Rs.4156/acre respectively from wheat and Rs.66,194/acre and Rs.56,947/acre respectively from cotton as shown in Table 5 below.

Table 5: Profit of Wheat & Cotton Production by Technology, 2014-2015

	Wheat		***Cotton***	
	Conventional	**Laser leveling**	**Conventional**	**Laser leveling**
Total Revenue (Rs./acre)	30723	35264	92960	102610
Total Cost[1]	26567	27780	36013	38115
Opportunity Cost	7661	7366	9247	9127
Accounting Profit	11817	14850	66194	73622
Economic Profit	4156	7484	56947	64495

[1] . - Total Cost = Cash cost + Non cash cost
= Cash cost + (Depreciation + Opportunity costs)
Total cost is already included opportunity cost

3.3.4. BREAK-EVEN YIELD AND BREAK-EVEN PRICE

This analysis examined the break-even yield and break-even price of wheat production. The break-even yield is carried out by dividing total costs by the average wheat price. To calculate the break-even price, total costs are divided by the average wheat yield. The average break-even yield of wheat of laser leveling technology growers is 29.9 mds/acre, which is calculated from average total costs of Rs. 27,780/acre divided by the average price of Rs. 928/mds. The average break-even yield of conventional growers is 28.5 mds/acre, which is calculated from average total costs of Rs. 26,567/acre divided by the average price of Rs. 930/mds. In case of cotton the average break-even yield of cotton of laser leveling technology growers is 11.5 mds/acre, which is calculated from average total costs of Rs. 38,115/acre divided by the average price of Rs. 3,310/mds. The average break-even yield of conventional cotton growers is 10.9 mds/acre, which is calculated from average total costs of Rs. 36,013/acre divided by the average price of Rs. 3,320/mds as shown in Table 6. Break-even yield means that the conventional growers must receive this yield to cover the costs related wheat production. Considering the break-even price analysis, the break-even price is the price a producer must receive minimum for a product in order to cover the entire costs associated with the production of the product (Hofstrand, 2005). In case of wheat laser leveling technology growers has an average break-even price of wheat is Rs. 1230/mds, while conventional growers has an average breakeven price of Rs. 1286/mds. Therefore, the continuing production until the laser leveling technology growers is a good choice because they start making profit from price of minimum Rs. 1230/mds.

Table 6: Break-Even Yield & Break-Even Price Of Wheat & Cotton by Technology

	Wheat		***Cotton***	
	Conventional	**Laser leveling**	**Conventional**	**Laser leveling**
Total Cost	26567	27780	36013	38115
Average Price (Rs./mds)	931	928	3320	3310
Average Yield (Mds/ Acre)	33	38	28	31
Break-even yield (Mds/ Acre)	28.5	29.9	10.9	11.5
Break-even Price (Rs./mds)	805	731	1286	1230

3.3.5. GROSS MARGIN OF WHEAT

The analysis of gross margin is derived from the difference between total revenue and total variable costs. Total variable costs are calculated from the summation of total labor costs and total factor cost. The results are presented in (Table 7) indicate that laser leveling technology users obtained higher gross margin Rs. 15,154/acre from wheat and Rs.73,932/acre from cotton, as compared to conventional wheat and cotton growers Rs. 12,121/acre and Rs.66,194/acre respectively.

Table 7: Gross Margin of Wheat by Technology (Rs./acre)

	Wheat		***Cotton***	
	Conventional	**Laser leveling**	**Conventional**	**Laser leveling**
Total Revenue	30723	35264	92960	102610
Total Variable Cost	18602	20110	26456	28678
Average total labor cost	6335	7242	13636	15671
Average total factor cost	12267	12868	12820	13007
Average gross margin	12121	15154	66504	73932

3.4.FARMERS OPINION REGARDING WATER SAVED BY LASER LEVELING TECHNOLOGY

During this study farmers' opinion was regarding the quantity of irrigation water saved by laser leveling technology was recorded. Selected growers perceived that about 21 percent of irrigation was saved by the adoption of laser leveling technology. In the response of what is the utilization of saved water, majority of growers about 52 percent reported that they are able to survive in water shortage problem with adoption of laser leveling technology. As shown in Table 8 about 39 percent farmers reported that they utilize this saved water to increase their operational holding which was uncultivated due to water shortage problem and 9 percent reported able to cultivate sugarcane on some piece of their operational holding.

Table 8: Farmers Opinion regarding Percent of Irrigation Water Saved by Laser Leveling Technology and their Utilization

	Percentage
Percent of Irrigation Saved	21.15
Utilization of Saved Irrigation by Laser leveling Technology	
Possible to increase operational holding	39.3
Able to survive in water shortage problem	51.8
Grow some area under sugarcane	8.9

4. CONCLUSION

This study was carried out to assess the impact of laser level technology on irrigation water use and crop productivity based on the field survey in the cotton-wheat cropping zone of Sindh. Laser leveling has been adopting since last few years by some growers in Sindh, however, necessary data to support its effects on crop yield and water use efficiency are scarce. It was therefore, felt imperative need to evaluate the effect of laser and traditional land leveling technologies on cotton and wheat productivity, land and water use efficiency in cotton-wheat system of Sindh. Study findings revealed that average time to irrigate an acre field was reduced from 2.26 hrs to 1.18 hrs in wheat crop and from 2.58 hrs to 1.32 hrs in cotton crop means almost 50 percent time saved by using leaser levelling technology as compared to conventional methods. Leaser leveller technology users reported equivalence in the use of irrigation and average depth of water was 2.79 inches in wheat and 3.12 in cotton compared to conventional wheat and cotton growers 3.85 inches 4.22 inches respectively.Profitability analysis shows that overall cost of production on wheat and cotton crop by the use of laser leveling technology was higher as compared to conventional sowing of wheat. In case of wheat crop overall wheat growers obtained 38 mds/acre with the use of laser leveling technology as compared to 33 mds/acre by using conventional method of sowing. In case of cotton crop overall growers obtained 31 mds/acre with the use of laser leveling technology as compared to 28 mds/acre by using conventional method of sowing. The standardization use of irrigation and fertilizer application with laser leveling technology were the reasons of obtaining more yield was reported by wheat growers. Total revenue was received by the growers who used laser leveling

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technology Rs. 35,264/acre from wheat and Rs.102,610/acre from cotton followed by conventional wheat and cotton growers Rs. 30,723/acre and Rs.92,960/acre respectively. Also results further indicate that laser leveling technology users obtained higher gross margin Rs. 15,154/acre from wheat and Rs.73,932/acre from cotton, as compared to conventional wheat and cotton growers Rs. 12,121/acre and Rs.66,194/acre respectively. About 21 percent irrigation saved by the adoption of laser leveling technology and also utilize this save water for increasing operational holding and survive during water shortage problems. Study concluded that adoption of laser leveling technology helps in reducing the farm input costs, improve water use efficiency and enhance crop productivity.

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