Global Scientific JOURNALS

GSJ: Volume 8, Issue 7, July 2020, Online: ISSN 2320-9186
www.globalscientificjournal.com

Economic Evaluation of Laser Land leveling on Direct Seeded Rice in Rice-Wheat cropping system: A field survey

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ABSTRACT

A field survey was conducted in district Hafizabad during Kharif 2018 for economic evaluation of Laser Land leveling on Direct Seeded Rice (DSR) in Rice-Wheat cropping system particularly to estimate the effects on water saving and water productivity. The results indicated that with laser leveling, farmers could save irrigation water by 11.76%, energy by 10.71% and obtained 21.54% higher yields in DSR. The irrigation duration and total applied water depth was reduced to 9.52% and 14.10% in laser leveled DSR crop as compared to traditional leveled fields. The average water productivity in rice has improved by 30.43%. The average net return from the laser leveled field was 46.54% higher in DSR than that from the traditional leveled field mainly due to declined in costs of irrigation (21.35%) and weeding (10%). The BCR of 2.35 was computed for LLL DSR in comparison to 1.90 for conventional DSR crop. It was concluded that this technology has a great potential for optimizing the water-use efficiency in DSR cultivation without disturbing and harmful effect on the productivity of paddy crop; hence it could be adopted for uplifting of rice production and economic growth.

Keywords: Economic Evaluation, DSR, Laser Land Leveling, Rice-Wheat, Survey

INTRODUCTION

In Pakistan, Punjab Province due to its agro-climatic and soil conditions is producing more than 80% of fine rice in the country. The most important rice producing districts in Punjab are Hafizabad, Sialkot, Okara, Sheikhupura, Nankana, Gujranwala, Jhang and Mandi Bahaudin Din accounting for more than 70% of basmati rice production in the country (Ashfaq *et al.*, 2017).

Direct seeding of rice refers to the process of establishing the crop from seeds sown in the field rather than by transplanting seedlings from the nursery (Farooq *et al.*, 2011). DSR is becoming popular because of its potential to save water and labour (Kumari *et al*., 2019). Currently, DSR covers 23%, 26% and 28% of the total rice area in World, South Asia and India, respectively (Rao *et al.,* 2007). Direct seeding avoids three basic operations, namely, puddling, transplanting and standing water. Depending on water and labour scarcity, farmers are changing either their rice establishment methods only or both tillage and rice establishment methods. Direct seeding helped to reduce water consumption by about 30% as it saved from raising of seedlings in nursery, puddling and maintaining 4-5 inches of water continuously. There are three principal methods of establishing the DSR: dry seeding (sowing dry seeds into dry soil), wet seeding (sowing pre-germinated seeds on wet puddled soil) and water seeding (seeds sown into standing water) (Farooq *et al.,* 2011).

Effective land leveling is meant to optimize water use efficiency, improve crop establishment, reduce irrigation time and effort required to manage the crop (Rickman, 2002). With laser leveling, the field is leveled up to ±2 cm, resulting in better water application, distribution efficiency, improved water productivity, better fertilizer efficiency, and reduced weed pressure (Jat *et al.* 2004). However, only a few studies have been conducted to evaluate the impact of laser-land leveling. It was estimated that around 25-30 % of irrigation water could be saved through this technique without having any adverse affect on the crop yield (Bhatt and Sharma, 2009).

Laser-assisted precision land leveling system is also likely to enhance the cultivable area in the range of 3-6 % (due to reduction in bunds and channels in the field). Furthermore, on laser leveled fields, the performance of different crop establishment options such as of zero tillage, raised bed planting, and surface seeding are known to improve significantly (Jat *et al.*, 2006). Laser land leveling facilitates uniform and good crop establishment, permits precise and uniform water distribution, reduces weed infestation, increases cultivation area (2-3%), improves input-use efficiency (water, nutrients, and agrochemicals), and hence crop productivity (Jat *et al.*, 2006, Aryal *et al.* 2014). Whereas, Sattar *et al.* (2003) reported that on an average 747 mm water was required to irrigate cotton traditionally leveled field against 548 mm applied to precisely leveled field. Abdullaev *et al.* (2007) conducted a three years study on the impact of laser land leveling on cotton yield and water saving in Tajikistan. They found that laser leveled fields saved on average 81 mm water in comparison to non leveled fields. The average annual net income was 22% higher than that for the control fields.

On Farm Water Management (OFWM) Department in Pakistan are providing laser- guided PLL technologies to the farmers for attaining higher accuracy in leveling the fields. However, there have been some questions about the effectiveness of this technology, such as, whether leveling, really saves significant amount of irrigation water, improves crop yields and water-use efficiency. This study was conducted to find the effects of laser land leveling on water saving, water productivity and to conduct the economic evaluation of the laser-land leveling.

MATERIALS AND METHODS

The survey study was conducted in Adaptive Research Zone Gujranwala during kharif 2018. Among the six districts of the said zone district Hafizabad was randomly included in sampling frame. It is located with 32.06° N latitude, 73.5° E longitude and 207 m altitude. Weather is hot and humid with annual rainfall ranging between 396 and 992 mm. The soil and climate of region is favorable for the cultivation of wheat, rice, berseem, sugarcane, Maize, oil seeds and fodders but the general crop rotation is wheat- rice. In Pakistan, the cultivated area is about 20 M. ha, out of which about 16 M. ha is irrigated. Basmati rice is the principal crop in the Khraif (June-November) season and occupies about 25% of the total cropped area in the season. Wheat is a major staple crop of the Rabi (November-April) season and occupies 75% of the cultivated area in Rabi season (Khan *et al.*, 2006). To select the respondent farmers, convenience non-probability sampling method was adopted due to time and cost constraint. Thus 40 farmers from each of both tehsils namely Hafizabad and Pindi Bhatian making a total of 80 respondent farmers were interviewed. A well-structured and pretested questionnaire was employed for data collection which included the detailed information regarding production methods and constraints in adoptability of direct seeded rice.

The cost involved in laser land leveling was worked out on the basis of the actual time taken by the tractor to accomplish the task. This was based on the prevailing procedure and the rates charged by the OFWM and the private laser owners. The average monthly rainfall during the study period provided by National Weather Forecasting Center, Pakistan Meteorological Department, Islamabad is given in Table 1. The rainfall was assumed to be uniform over both the fields (i.e. conventional leveled and Laser leveled field) because of their smaller size.

Water productivity is generally defined as crop yield per cubic meter of water consumption, including 'green' water (effective rainfall) for rain-fed areas and both 'green' water and 'blue' water (diverted water from water systems) for irrigated areas (Cai X. and M.W. Rosegrant 2003). Water productivity analysis combine physical accounting of water with yield or economic output to assess how much value is being obtained from the use of water (Molden *et al.*, 2003; Abdullaev *et al.*, 2007; Bouman *et al.*, 2007). For this analysis, physical water productivity was calculated by:

WP = Output/Q

Where WP is the productivity of water in kg m^{-3}, output is the total biomass of crop in kilograms and Q is water resources applied and depleted (m^3). Sharma et al, (2015) explained that water use is estimated as mm of water applied or received as rainfall, converted to m^3 ha^{-1} (1 mm = 10 m^3 ha^{-1}).

In this study, only physical productivities of the applied and depleted water were analyzed.

The cost of production varies mainly due to land leveling in level field and the amount of water used for level and unlevel fields. The net return was calculated using following equation:

Net returns = Gross returns – Gross variable cost

The benefit cost ratio (BCR) was calculated by using the following formula (CIMMYT 1988);

BCR = Gross returns / Gross variable cost

The procedure adopted by Khan *et al.*, (2008) and Latif *et al,* (2018) was used for estimating the economic cost of production, gross revenue, net returns and BCR. The data was analyzed by using statistical software package for social sciences version 17.

RESULTS AND DISCUSSION

Socio-economic Profile

The average age (year) and education (schooling year) were estimated at 39.5 and 9.25, respectively. The average land holding size was recorded as 3.46 ha while prevailing land rent was found as 98.80 thousand Rs ha^{-1}. In studied area, the soil type was estimated as sandy (23%), clayey (19%) and loamy (58%) and source of irrigation was recorded as canal (04%), tube well (79%) and combined (17%). Regarding watercourse type only 12% were lined while others were non-lined. Pertaining to varietal adoption by farmers (%) it was recorded that PK aromatic 1121, Super basmati, PK 386, Chenab basmati, Kissan basmati and others were adopted as 60, 15, 10, 5, 5 and 5%, respectively. The years to adopt laser land leveling and area (ha) leveled in 2018 were recorded as 2.48 and 9.47 respectively.

Effects of adopting Laser Land Leveling (LLL)

Respondent farmers were using a varied seed rate (17-35 kg ha^{-1}) with a mean of 25-27.5 kg ha^{-1} claiming 9% less seed rate in laser leveled field of DSR.

Sanjay *et al.*, (2019) studied the impact of laser land leveling technology on rice wheat production in Haryana. He concluded that the use of human labour, seed and plant protection cost (PPC) was lower by about 6.90, 9.09 and 5.88 %, respectively under LLL farmers compared to CT farms. An increase in yield by 5.72 and 5.52 % respectively was recorded in the wheat and paddy crop.

Less attack of disease complex (7.31%) as well as less lodging (7.5%) was recorded due to the adoption of LLL technology (Table 2). Lodging had been observed more often in DSR than in TPR during recent years (Farooq *et al.*, 2011). In addition, mechanical harvesting of lodged crop was a challenge. Atkins (1979) explained that damage from brown spot can be lessened by maintaining good growing condition for rice like balanced fertilizer, crop rotation, and land leveling. Latif *et al.* (2017) estimated more disease incidence in DSR due to the reason of water deficit and shift from transplanting to direct seeding particularly due to uneven land.

Water saving and productivity

LLL provides the desired level of evenness of farm fields and thus, expected to reduce irrigation water requirements. Irrigation water requirements depend not only on crop type, but also on other factors such as the amount of rainfall and the temperature in the growing season (Thomas, 2008).

Data clearly revealed that laser leveling was effective in saving of irrigation water (11.76 %) and energy (10.71%). It was due to the fact that in precision leveling water spreads evenly over the entire land surface.; which may lead to positive impact on the overall deteriorating water situation of the field. Sapkal *et al.* (2019) explained that a uniform field improves irrigation efficiency through better control of water distribution and reduces the potential for nutrient loss through improved runoff control, leading to greater efficiency of fertilizer use and higher yields.

Laser land leveling proved to be an efficient technique for enhancing water productivity of paddy DSR crop. The per hectare water productivity (kg m^{-3}) on laser leveled DSR fields was 0.30 as compared to 0.23 on conventional DSR field. Bhardwaj (2014) estimated the water productivity in DSR in 2002 as 0.35 and in 2003 as 0.76 compared with that of transplanted rice (TPR) being 0.31 and 0.57, clearly indicating better water use efficiency under direct seeding. According to Aryal *et al.* (2014) rice-wheat system productivity is approximately 7% higher under LLL compared with TLL; LLL saves 10-12% irrigation water in rice and 10-13% in wheat.

However, there was a significant difference (14.10 %) for total water applied (mm) between LLL DSR (737 mm) and conventional DSR crop (858 mm). The remaining water requirement was therefore met from the rainfall as there was 569.85 mm of effective rainfall during Kharif 2018 season (Table 3). With leveled fields, it was possible to apply small depth of irrigation water, which was not possible on unlevel fields. Ashraf *et al.* (2017) reported that in the Lower Bari Doab Canal (LBDC) command area, on average, the farmers were applying 3680 mm of water to rice crop. Lack of precision land leveling was found to be one of the major factors for applying over irrigation. In levelled fields, on average, 33% (220 mm) less water was applied, 6% more yield and 27% higher WUE were obtained as compared to unleveled fields.

Cost and Return Structure

The data showed that the farmers who adopted the LLL technology received 20.70% more gross returns than non adopter of LLL in DSR. However, the net return was estimated at 119176 Rs ha^{-1} and 81324 Rs ha^{-1} for LLL DSR and conventional DSR fields respectively with 46.54% saving. This was mainly due to additional operational cost (2.55 %) in lieu of laser land leveling as compared to conventional field. A declined in costs of irrigation (21.35%) and weeding (10%) was estimated for LLL DSR sample farmers. The BCR of 2.35 was computed for LLL DSR in comparison to 1.90 for

Majority of the farmers (92%) practicing DSR reported the issue of *Panicum antidotale* (Bansi grass), *Paspalum distichum* (Naru grass) or *Dactyloctenium aegyptium* (Madhana grass), *Cynodon dactylon* (khabbal grass) or *Cyprus rotundus* (Deela) which were not properly controllable by any herbicide. According to Rao *et al.,* (2007) high weed infestation was the major bottleneck in DSR especially in dry field conditions whereas most of the weeds in TPR were controlled by flooding, unlike in DSR. More than 50 weed species infesting direct seeded rice caused major losses to rice production worldwide. When farmers shift from TPR to DSR the weed flora changed dramatically due to habitat change. Similar results were reported by Ramachandiran (2012) that weeds posed a serious threat to direct seeded rice crop by competing for nutrients, light, space and moisture thorough out the growing season.

The mean paddy yield on LLL DSR fields was 98.75 mound ha^{-1} as compared to 81.25 mound ha^{-1} on traditionally leveled fields. Thus, leveling of land with a laser leveler resulted in 21.54% increase in paddy yield over the conventional practice (Table 5). The increase in yield was due to improved weed control, improved water coverage due to better land leveled, less labor use and reduced expenditure on weedicides and irrigation cost.

Larson *et al.* (2013) conducted experiments at Punjab Agriculture University and found that laser leveling increases crop yield by around 11 % and results in water saving of around 25 %, holding constant other inputs like fertilizers and seed quality. These experiments have also demonstrated that leveling reduces weeds by up to 40 % and labor time spent weeding by up to 75 %

CONCLUSION

Precision land leveling with laser leveler is a resource conservation technology and has been proven to saving of irrigation water (11.76 %) and energy (10.71%) and increased in paddy yield by 21.54% over the conventional method. The water productivity on laser-leveled fields has been found to be higher by about 30.43% over the conventional field. The farmers who adopted LLL DSR received 46.54% more net return mainly due to declined in costs of irrigation (21.35%) and weeding (10%). The BCR of 2.35 was computed for LLL DSR in comparison to 1.90 for conventional DSR crop. Hence, this technology has a great potential for optimizing the water-use efficiency in DSR paddy cultivation without any disturbance and harmful effect on the productivity of paddy crop.

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Tables

Table 1: Weather data of district Hafizabad

Month	Temperature ^{0}C		Rainfall(mm)
	Max	Min	
May-18	38.3	23.6	24.9
Jun-18	39	24.8	0.03
Jul-18	35.5	25.5	381.4
Aug-18	34.6	26.2	93.7
Sep-18	33.8	22.7	40.22
Oct-18	30.9	17.4	13.6
Nov-18	24.6	10.3	16
Total	-	-	569.85

Source: Government of Pakistan. 2019

Table 2: Effects of adopting Laser Land Leveling (LLL)

Particular	Unit	Laser leveled field	Conventional field	% change
Rauni before sowing	Frequency	1.25	1.25	0.00
Seed rate	Kg ha^{-1}	25	27.5	-9.09
Pre-emergence weedicide	% farmer	84	47	78.72
Post emergence weedicide	Frequency	1.25	2.15	-41.86
Interval between post emergence weedicide (if)	Days	19	15	26.67
Urea	Bag ha^{-1}	3.13	3.13	0.00
DAP	Bag ha^{-1}	2.57	2.57	0.00
SOP	Bag ha^{-1}	0	0	-
Zinc	Kg ha^{-1}	15.1	15.1	0.00
Attack of disease complex	%	9.5	10.25	-7.31
Lodging	%	9.25	10	-7.5

Table 3: Water saving and productivity

Particular	**Laser leveled field**	**Conventional field**	**% change**
Diesel required (L Hr^{-1})	2.5	2.8	-10.71
Time consumed (Hr. $irrigation^{-1}$)	7.13	7.88	-9.52
Approx. depth of water applied (Inches)	2.25	2.55	-11.76
Rainfall applied (mm)	569.85*	569.85*	0.00
water depth/irrigation (mm)	57.15	64.77	-11.76
No. of irrigation/crop	12.9	13.25	-2.64
Total water applied (mm)	737	858	-14.10
Total water depth applied (mm)	1307	1428	-8.47
Total water depth applied (m^3 ha^{-1})	13071	14281	-8.47
Total output (kg ha^{-1})	3950	3250	21.54
Water productivity (kg m^{-3})	0.30	0.23	30.43

* Source: Government of Pakistan. 2019

Table 4: Cost and return structure of paddy crop (DSR) (Rs ha^{-1})

Particular	Laser leveled field	Conventional field	% change
Rauni irrigation	3125	3125	0
Land preparation	8000	8000	0
Laser land leveling	5690	0	0
Seed cost	2925	2925	0
Drill/broadcasting	963	963	0
Fertilizer & micronutrient	17252	17252	0
Irrigation	27575	35060	-21.35
Weedicide	4500	5000	-10
Plant protection	4375	4400	-0.57
Harvesting	11250	11250	0
Land Rent	49400	49400	0
Agriculture Income Tax (6 Months)	121	121	0
Marketing Expenses (Rs. 40kg^{-1})	99	81	22.22
Management charges (6 Months) @Rs 15,000/PM. for 40 ha	2250	2250	0
Gross operational cost	88124	90426	-2.55
Yield (40 kg)	98.75	81.25	21.54
Price (Rs. 40kg^{-1})	1960	1960	0
Rice straw (if)	13750	12500	10
Gross returns	207300	171750	20.70
Net returns	119176	81324	46.54
BCR	2.35	1.90	23.85