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Enhancing Water Productivity through On-farm Resource Conservation Technology in Punjab Agriculture

Baljinder Kaur*, Satwinder Singh, B.R. Garg, J.M. Singh and Jasdev Singh

Department of Economics & Sociology, Punjab Agricultural University, Ludhiana -141 004, Punjab

Abstract

Rice is a major *kharif* crop in Punjab and accounts for more than 80 per cent of the water use in this season. In the past one decade, groundwater table has declined from 18 metres to 27 metres. This trend can be checked to a large extent by using appropriate natural resource management technologies including laser land levelling technology. In this paper, economic and environmental benefits have been estimated from the adoption of laser level technology using farm-level information from the Moga district of Punjab. The results have shown that with laser levelling farmers could save irrigation water and energy by 24 per cent and obtained 4.25 per cent higher yields. The irrigation cost reduced by 44 per cent over the conventional practice, and water productivity improved by 39 per cent. The returns over variable cost were higher by ₹1000 per hectare with application of this technology. In sum, laser land levelling has a great potential for optimizing the water-use efficiency in paddy cultivation without any disturbing and harmful effect on its productivity. Popularization of this technology among farmers in a participatory mode on a comprehensive scale, therefore, needs a focused attention.

Key words: Water productivity, laser land levelling, resource conservation technology, paddy, Punjab

JEL Classification: Q25, Q16

Introduction

The state of Punjab contributes 43.8 per cent of wheat and 25.4 per cent of rice to the central pool of the country (GoP, 2009), and is known as food bowl of the country. However, excessive emphasis on rice and wheat production has led to increase in the total water requirement from 4.377 M ha-m (million hectare metre) in 1994-95 to 6.15 M ha-m in 2005 of which more than 80 per cent is used in the rice growing season (WRD, 2005). This has necessitated the development of efficient techniques to conserve underground water by increasing irrigation efficiency in rice (Singh *et al.*, 2009). Future food production in the state will be severely threatened by unsustainable groundwater-use and inappropriate water management practices. In lieu of this, on farm resource conservation technologies in states like Punjab have an edge over other technologies. Land levelling through laser leveller is one such proven technology that is highly useful in conservation of irrigation water and enhancing productivity.

Laser levelling of agricultural land is a recent resource conservation technology in India. Its results are quite encouraging. Precision land levelling may increase the water application efficiency and consequently increase the yield of crops (Ahmed *et al.*, 2001). It has the potential to change the way food is produced by enhancing resource-use efficiency of critical inputs without any disturbing and harmful effects on the productive resilience of the ecosystem. Rice-Wheat Consortium has estimated that extension of laser-assisted precision land levelling system to just two million hectares of area under rice-wheat system

* Author for correspondence,
Email: baljindersidana@gmail.com

could save 1.5 M ha-m of irrigation water and save diesel up to 200 million litres (valued at US $1400 million), and improve crop yields amounting to US$ 500 million in three years and reduce green houses gases (GHG) emissions equivalent to 500 million kg. Laser-assisted precision land levelling system is also likely to enhance the cultivable area in the range of 3-6 per cent (due to reduction in bunds and channels in the field). Furthermore, on laser-levelled 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 levelling in rice field brings down the water-use by 36.19 cm along with the yield improvement of 0.78 t/ha. Further, by adoption of this technology the Punjab state could achieve 0.99 M ha-m water saving and can save 583.51 million kilowatt hour of electricity (Sidhu *et al.*, 2010).

Effective land levelling is meant to optimize water-use efficiency, improve crop establishment, reduce irrigation time and effort required to manage the crop. Research conducted at PAU, Ludhiana has shown that proper field levelling increased crop yield by 24 per cent and reduced weed problems up to 40 per cent (Rickman, 2002).

In Punjab, laser leveller was introduced on an experimental basis in the Sukhanand village of Moga district on an area of 150 acres and around 300 farmers took part in these demonstrations. It was estimated that around 25-30 per cent of irrigation water could be saved through this technique without having any adverse affect on the crop yield (Bhatt and Sharma, 2009). According to an estimate, the number of laser levellers in Punjab has increased sharply from mere 8 in the year 2005 to 2000 in the year 2009 (Figure 1).

Keeping this in view, this study was undertaken with the objective to asess the impact of laser land levelling on the productivity of paddy crop by comparing it with the conventional practice and to find out the extent of water and energy saving as a result of laser or precision land levelling.

Material and Methods

The study is based on the primary data collected from the village Kokri Kalan in the Moga district. A list of farmers, who have got their fields levelled with traditional method and with laser technology was taken from the co-operative society of Kokri Kalan. A sample of 25 farmers, taken at random, was chosen in such a way that all the farmers fall under the category of partial adopters. They had applied laser technology to a part of the cropped area and rest was put under traditional method of cultivation. A well-designed, comprehensive and pre-tested questionnaire was used to collect the required data from farmers. It was found that paddy-wheat was the main crop rotation being followed by the sample farmers. Data pertaining to the practices, i.e. conventional method of land levelling and laser land levelling were collected for *kharif* season of 2010 to study input-output coefficients of paddy crop.

Water Productivity and Economic Analysis

Water productivity and economic analysis combines physical accounting of water with yield or economic output to assess how much value is being obtained from the use of water (Abdullaev *et al.,* 2007). For this analysis, physical water productivity was calculated by Equation (1):

$$WP = Output/Q \quad \ldots(1)$$

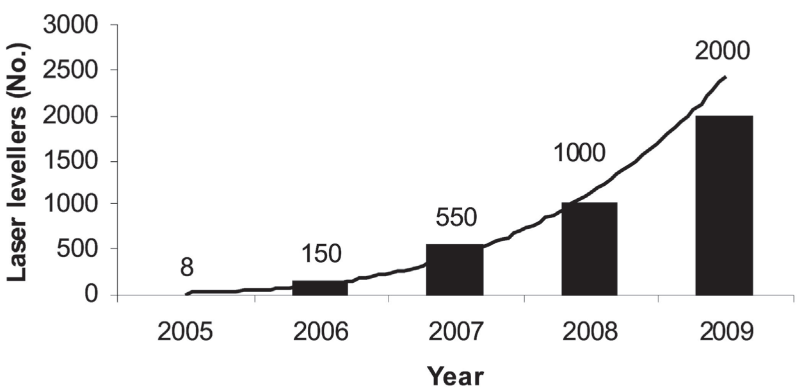

Figure 1: Growth of laser levellers in Punjab

where, WP is the productivity of water in kg/m^3, output is the production of crop in kilograms and Q is water used by the crop (m^3).

Total amount of water used in paddy crop was calculated by multiplying the discharge from the tube-well bore with total time taken for irrigating the crop throughout the season (total irrigation hours multiplied by volume of water drawn out per hour by submersible pump). The volume of water drawn out by a submersible pump differed with the horse power of the pump. The submersible motors having different horse powers were brought to the same denominator by allocating the weight (i.e. discharge rate in litres/second) to different horse power motors. The average water table depth of the area was 25 metres. Based on the water table depth, the average discharge of pump sets with prime mover of 10 HP, 12.5 HP, 15 HP and 20 HP was considered as 12 litres/sec, 15 litres/sec, 17 litres/sec and 22 litres/second, respectively.

To compare the laser technology with the control group, gross margin analysis was carried out. Student's t-test was applied to show whether there was any significant difference between the results of laser technology and traditional methods of levelling the fields.

In a sample of 25 farmers, 64 per cent were large farmers having operational area of 6 hectares and more. The paddy area in the sample comprised 105.2 ha as laser levelled and 110.4 ha under traditional method of paddy cultivation. The variable costs on the sample farms were calculated as per the actual payments made by the farmer for the purchase of inputs. As the supply of electricity is free to the agricultural sector, the irrigation cost for paddy crop raised on the sample farms was calculated by taking into account expenditure incurred on diesel oil consumed for the given crop.

Table 1. Socio-economic characteristics of sample farmers, Punjab: 2010

Indicators	Number	Percentage
Age group (years)		
Up to 30	5	20
31-40	13	52
> 40	7	28
Education		
Illiterate	2	8
Up to matric	14	56
Secondary	5	20
Post secondary	4	16
Farming experience (years)		
Up to 10	4	16
> 10 – 15	4	16
> 15 – 20	9	36
> 20	8	32

Table 2. Land ownership and cropping pattern of sample farmers, Punjab: 2010

Particulars	Area (ha)	Percentage
Landholdings		
Area owned	6.14	56.96
Leased-in	4.8	44.53
Leased-out	0.16	1.48
Total operational area	10.78	100.00
Cropping pattern		
***Kharif* crops**		
Paddy	9.92	92.02
Basmati	0.29	2.69
Fodder	0.55	5.10
Others (banana)	0.02	0.19
Total *kharif* cropped area	10.78	100.00
***Rabi* crops**		
Wheat	9.25	85.81
Fodder	0.58	5.38
Potato	0.86	7.98
Others (gram and banana)	0.09	0.83
Total *rabi* cropped area	10.78	100.00

Results and Discussion

Socio-economic Profile

The socio-economic profile of the farmers showed that 52 per cent of them were in the age-group of 31-40 years, with 84 per cent having farming experience of more than 10 years. Fifty-six per cent of farmers were educated up to matric level and 16 per cent were post-graduates. It clearly indicated that the adoption of this technique was made by large, progressive, educated and young farmers (Table 1).

Landholding and Cropping Pattern

The data in Table 2 revealed that of the average operational landholding size of 10.78 ha, 56.96 per

Table 3. Status of groundwater level of sample farmers, Punjab: 2010

Water level (m)	At present		5 years back		10 years back	
	Number	Average depth of water level (m)	Number	Average depth of water level (m)	Number	Average depth of water level (m)
≤ 15	0 (0.0)	-	3 (12.0)	14	16 (64.0)	13.8
> 15 - 18	0 (0.0)	-	9 (36.0)	18	8 (32.0)	18.5
> 18 - 21	3 (12.0)	21	12 (48.0)	20.8	1 (4.0)	21
> 21 - 24	9 (36.0)	23.8	1 (4.0)	24	0 (0.0)	-
> 24 - 27	12 (48.0)	27	0 (0.0)	-	0 (0.0)	-
> 27	1 (4.0)	30	0 (0.0)	-	0 (0.0)	-
Average depth		**25.36**		**19.21**		**15.52**

Note: Figures within the parentheses represent percentage to total farmers in the sample

cent was owned and 44.53 per cent was leased-in. Paddy dominated the cropping pattern in *kharif* season with 92.02 per cent of *kharif* cropped area and wheat in *rabi* season with 85.81 per cent area. Fodder accounted for a mere 5 per cent area in both the seasons, whereas, potato accounted for 8 per cent in *rabi* season. So, paddy-wheat emerged as the major cropping pattern on the sample farms.

Groundwater Status

The average underground water depth in the village Kokri Kalan was 15.52 m in the year 2000, 19.21 m in 2005 and presently it was estimated to be 25.36 m (Table 3). In 2000, about 96 per cent of the sample farmers had groundwater depth of less than 18 m, whereas in 2010, about 48 per cent of the sample farmers reported that their average water table had fallen to 27 m, almost one and half times decline within a decade. Such a drastic change in groundwater level from 15.52 m in 2000 to 25.36 m in 2010 was due to 92 per cent of cropped area under paddy. The groundwater abstraction structures like electric motors have been replaced by submersible pumps in the area and presently the irrigation structure inventory of the sample farms comprised 71 submersible pumps, 5 diesel engines and 12 generators.

Table 4. Labour-use pattern of paddy crop of sample farmers, Punjab: 2010

(hours/hectare)

Particulars	Family labour		Hired labour		Total labour	
	Laser-levelled field	Conventional field	Laser-levelled field	Conventional field	Laser-levelled field	Conventional field
Laser leveller	4.35	0	3.62	0	7.97	0
Preparatory tillage	8.92	9.5	0.2	0	9.12	9.5
Sowing/Transplanting	6.27	4.65	133.02	112.5	139.3	117.15
Manures & fertilizers	8.56	8.77	2.02	0.77	10.58	9.54
Irrigation	30.05	45.85	0	0	30.05	45.85
Interculture/Weeding	2.07	4.37	4.6	7.85	6.67	12.22
Plant protection	3.72	4.22	10.6	10.42	14.32	14.64
Harvesting	3.12	2.5	1.25	1.12	4.37	3.62
Transportation & marketing	4.37	3.75	0.62	0.5	4.99	4.25
Total	71.43	83.61	155.93	133.16	227.37	216.77

Table 5. Machine-use pattern of paddy crop of sample farmers, Punjab: 2010

(hours/hectare)

Particulars	Owned		Hired	Total	
	Laser-levelled field	Conventional field	Laser-levelled field	Laser-levelled field	Conventional field
Laser leveller	1.77	0	3.62	5.39	0
Preparatory tillage	7.72	8.2	0.2	7.92	8.2
Manures & fertilisers	0.37	0.3	0	0.37	0.3
Irrigation	130.95	179.55	0	130.95	179.55
Plant protection	0.65	0.97	0	0.65	0.97
Harvesting	1.87	1.25	0	1.87	1.25
Transportation & marketing	4.37	3.75	0	4.37	3.75
Total	147.7	194.02	3.82	151.52	194.02

Note: The hired labour in conventional field for machine-use was zero

Labour-use Pattern

The human labour is the major cost component in agriculture. The per hectare human labour hours used for irrigation on laser-levelled fields worked out to be 30.05 hours as compared to 45.85 hours on conventional fields, resulting in a decline of human labour use by 16 hours (Table 4).

For weeding too, half of the time was saved on using laser level technology as compared to the conventional practice. The farmers adopting this technology being progressive ensured the desired number of plants per hectare, so they put more efforts while transplanting paddy crop and thus per hectare labour use for transplanting paddy in case of laser levelling was 139.3 hours compared to 117.15 hours on non-laser levelled field. Therefore, a total of 227.36 labour hours per hectare were spent on various crop operations on laser-levelled fields as compared to 216.77 hours on conventional fields on the sample farms.

Machine-use Pattern

A perusal of Table 5 revealed that the machine hours used on laser-levelled field accounted for 151.55 hours per hectare compared to 194.03 hours on conventional field. There was a significant decline in the machine hours used in irrigation on sample farms. The machine hours used for irrigating paddy were 130.95 hours/ha on laser-levelled field and 179.55 hours/ha on conventional fields, resulting in a saving of 37 per cent. In spite of spending 5.4 hours per hectare on laser levelling, there was a saving of 28 per cent on machine hours with use of laser technology.

Table 6. Cost and return structure of paddy crop of sample farmers, Punjab: 2010

(₹ /ha)

Particulars	Laser-levelled field	Conventional field
Cost of laser leveller	2122	0
Preparatory tillage	1575	1466
Seedling	1040	1067
Manures & fertilizers	2849	2757
Irrigation	60	488
Interculture/weeding	563	600
Plant protection	2093	2525
Harvesting	1875	1750
Transportation & marketing	753	662
Family labour	858	1003
Hired labour	4446	3670
Total variable costs	18233	15989
Gross returns	79568	76323
Returns over variable cost	61335	60334

Cost and Return Structure

The gross margins of paddy cultivation showed that the farmers who adopted the technology received ₹ 3244/ha incremental gross margins over the traditional practice (Table 6).

Table 7. Benefits of laser levelling in paddy cultivation of sample farmers, Punjab: 2010

(per hectare)

Particulars	Laser-levelled field	Conventional field	Gain/loss	t-statistics
Gain in productivity (quintals)	77.25	74.1	3.15 (4.25)	3.97*
Reduction in weeding/interculture cost	821	945	-124 (13.1)	2.09*
Irrigation cost	911	1631	-720 (44.13)	4.48*

Notes: Figures within the parentheses represent the percentage change over farmers' practice
* indicates significance at 1 percent level of significance

However, the per hectare returns over variable cost was estimated ₹ 61334 and ₹ 60334 on laser-levelled and conventional field, respectively, which were about ₹ 1000/ha higher than non-laser levelled fields. The total cost incurred on the cultivation of paddy on laser-levelled field (₹ 18233/ha) was higher than on the conventional field (₹ 15988/ha); this was mainly due to the 12 per cent higher expenditure incurred for levelling the field with laser leveller as compared to non-laser levelled field. A decline in irrigation costs was also observed on the sample farms. The results indicated that as a percentage to total variable cost, expenditure incurred on irrigation was only 0.33 percent on laser-levelled fields, whereas it was 3 per cent on conventional fields. In a nutshell, laser levelling technology increased productivity, reduced irrigation and weeding costs and hence increased the returns to the farmers from paddy.

Benefits of Laser Levelling

The mean paddy yield on levelled fields was 77.25 q/ha as compared to 74.1 q/ha on traditionally-levelled fields. Thus, levelling of land with a laser leveller resulted in 4.25 per cent increase in paddy yield over the conventional practice. The increase in yield was due to improved weed control, improved water coverage due to better land levelling which reduced labour use in weeding by 5 per cent (Table 7). A reduction in weeding cost of ₹ 124/ha was observed, primarily due to less labour-use and reduced expenditure on weedicides. Further, due to labour saving in irrigation and reduction in expenditure on diesel oil, 44 per cent gain in irrigation cost was found. The't'-test highlighted a significant difference in yield of paddy at 1 per cent level of significance. The reduction in cost of weeding and irrigation was also highly significant.

Extent of Water and Energy Saving

Data given in Table 8 clearly revealed that laser levelling was effective in saving of irrigation water and energy to the tune of 24 per cent. It is due to the fact that in precision levelling water spreads evenly over the entire land surface. Thus, almost one-fourth of the water and energy is saved due to laser levelling which may lead to positive impact on the overall deteriorating water situation of the country.

Water Productivity

Laser land levelling proved to be an efficient technique for enhancing water productivity of paddy crop (Table 9). The per hectare water productivity on laser-levelled fields was 102.89 kg/m^3. However, on conventional field it was 74.06 kg/m^3. It clearly indicates that under the present agricultural situation

Table 8. Water and energy used for irrigation of paddy crop by sample farmers, Punjab: 2010

(per hectare)

Particulars	Laser-levelled field	Conventional field	Saving	t-statistics
Water use (cubic metres)	7508	10005	2497 (25)	2.92*
Energy use (kW)	1332	1756	424 (24)	2.95*

Notes: Figures within the parentheses represent the percentage change over farmers' practice
* indicates significance at 1 per cent level

Table 9. Water productivity of paddy crop of sample farmers in Punjab: 2010

Particulars	Water productivity (kg/m^3)
Laser-levelled field	102.89
Conventional field	74.06
Difference	28.83 (38.93)

Note: Figures within the parentheses represent the percentage change over farmers' practice

of Punjab, where farmers are not willing to shift from prevailing rice-wheat system, laser land levelling can effectively help in sustaining the falling groundwater table by getting more economic yield with less amount of irrigation water.

Conclusions and Recommendations

Precision land levelling with laser leveller is a recent resource conservation technology and has been proven to save water and energy to the extent of 25 per cent, and increase in paddy yield by 4 per cent over the conventional method. The incremental per hectare increase in gross margins of the technology adopters has been to the tune of ₹ 3244. The adoption of this technology has reduced irrigation cost by ₹ 720/ha which is about 44 per cent over the conventional practice. The water productivity on laser-levelled fields has been found to be higher by about 39 per cent over the conventional field. Evenly distributed irrigation water on laser-levelled field could reduce the emergence of weeds in the paddy field which has further reduced the cost of weedicides by about 13 per cent over the farmers' practice. Hence, this technology has a great potential for optimizing the water-use efficiency in paddy cultivation without any disturbing and harmful effect on the productivity of paddy crop.

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