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Evaluation of the laser leveled land leveling technology on crop yield and water use productivity in Western Uttar Pradesh

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A study has been conducted for 3 year on impacts of the laser land leveling versus traditional land leveling on water use productivity and crop yields. The major concerns were effectiveness of laser land leveling as a water saving tool in the new context of land use and ownership, affordability of laser land leveling for farmers and the economic viability of this technology. These research questions were studied in a sizable area of laser leveled and neighboring non-leveled (control) fields for 2009 to 2011. The result indicated that with laser leveling, farmers could save irrigation water 21%, energy by 31% and obtained 6.6, 5.4 and 10.9% in rice, wheat and sugarcane higher yields. The total irrigation duration and applied water depth was reduced to 10.9, 14.7% in rice; 13.7, 13.3% in wheat and 13.5, 20.3% in sugar-cane as compared to traditional leveled fields. The laser leveled fields exhibited the highest water use efficiency (WUE), which was 48, 47 and 49% higher in precisely leveled field than control (unleveled), 22, 19 and 20% higher than traditionally leveling fields, respectively. The average water productivity in rice, wheat and sugarcane has improved by 33%. The average annual net income from the laser field was 14, 13.5 and 23.8% in rice, wheat, sugarcane higher than that from the traditional leveled field. It was concluded that the use of laser land leveling increases yield and saves irrigation water as compared to traditional method of leveling in different cropping system prevailing in western U.P.

Key words: Crop productivity, laser leveled land leveling, water use efficiency, water productivity.

INTRODUCTION

Declining water table and degrading soil health are the major concerns for the current growth rate and sustainability of Indian Agriculture. Thus, proper emphasis is being given on the management of irrigation water usage for adequate growth of agriculture. Keeping in view, the need for judicious use of our natural resources, concerted efforts are being made to enlighten the farmers for efficient use of irrigation water at farm level (Kaur et al., 2012). Generally, in sugarcane-wheat and rice-wheat, rotation farmers believed that their fields are leveled and needed no further leveling. But the digital elevation survey sheet of a field shows that most of the

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fields are not adequately leveled and requires further precision land leveling. The enhancement of water use efficiency and farm productivity at field level is one of the best options to readdress the problem of declining water level in the state. The planner and policy makers are properly informed and motivated to develop strategies and programs for efficient utilization of available water resources. Laser Land leveling is one such important technology for using water efficiently as it reduces irrigation time and enhances productivity not only of water but also of other non-water farm inputs.

The use of laser technology in the precision land leveling is of recent origin in India. It does not only minimize the cost of leveling but also ensures the desired degree of precision. However, the laser land leveling was introduced in the state in 2001 by Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut (U. P.) in collaboration with Rice-Wheat Consortium, New Delhi under the leadership of Dr. R. K. Naresh. Land leveling of farmer’s field is an important process in the preparation of land. It enables efficient utilization of scarce water resources through elimination of unnecessary depression and elevated contours (Naresh et al., 2011). It has been noted that poor farm design and uneven fields are responsible for 30% water losses (Asif et al., 2003). Precision land leveling (PLL) facilitated application efficiency through even distribution of water and increased water-use efficiency that resulted in uniform seed germination, better crop growth and higher crop yield (Jat et al., 2006). The scarcity of canal water supplies coupled with unfit ground water has compelled the farmers to utilize available water resources more wisely and efficiently. Under these circumstances, PLL can help the farmers to utilize the scarce land and water resource more effectively and efficiently towards increased crop production (Abdullaev et al., 2007). It was estimated that around 25 to 30% of irrigation water could be saved through this technique without having any adverse affect on the crop yield (Bhatt and Sharma, 2009).

The land leveling have resulted smoother soil surface, reduction in time and water required to irrigate the field, more uniform distribution of water in the field, more uniform moisture environment for crops, more uniform germination and growth of crops, reduction in seed weight, fertilizer, chemicals and fuel used in cultivation, and improved field traffic ability (for subsequent operations). Limitations of laser leveling include high cost of the equipment/laser instrument, the need for a skilled operator to set/adjust laser settings and operate the tractor, and restriction to regularly shaped fields. Farmers, as entrepreneurs are unwilling to adopt new technologies unless they clearly see quick and tangible results in terms of farm profitability. Theoretically, a farmer would opt for a new technology if assurance of earning a net profit were shown. Some economists believe that the net returns must be at least 30% higher than for the traditional technology before farmers would consider adoption. According to an estimate, the number of laser levelers in western Uttar Pradesh has increased sharply from mere 01 in the year 2001 to 350 in the year 2011 of this, on farm resource conservation technologies in States like Uttar Pradesh have an edge over other technologies. Land leveling through laser leveler is one such proven technology that is highly useful in conservation of irrigation water and enhancing productivity. Keeping this in view, this study was undertaken with the objective to access the impact of laser land leveling on the productivity of rice, wheat and sugarcane 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 leveling.

MATERIALS AND METHODS

Biophysical, demographic, and socioeconomic profile

Initially, a baseline survey of randomly selected farmers from different villages was conducted to understand their social, economic, and educational status in addition to input use (seed, irrigation, tractor, labor, fertilizer, and pesticide use) and outputs (grain and straw yield) in conventional farmers’ practices. The study was conducted for three years from June 2009 to May 2011 in 50 farmers’ fields at Sardar Vallabhbhai Patel University of Agriculture and Technology Meerut and Ghaziabad sites. Out of 50 farmers, 57% had land holdings of <2 ha, 31% had 2 to 4 ha, and 12% had more than 4 ha (Figure 1A). About 5% of the farmers were literate, out of which 27% were middle-school pass, 47% were high-school pass, and 21% were college pass (Figure 1B).

The literacy rate was higher for large farmers than for small farmers. The average family size was 6.4 family members. The large farmers usually lived in joint families; whereas medium and small farmers had a separate nuclear family. Out of 320 family members of the 50 households surveyed, 29% were fully engaged in agriculture and 41% were partly engaged, whereas 30% were students who also helped with agricultural activities during vacation and/or leisure periods (Figure 1C). 38% of the farmers were members of different cooperatives existing in the area. Sugarcane and wheat were the major source of income for 52% of the farmers, followed by rice (34%), vegetables (12%), and oilseeds (9%).

Socio economics and demographics of project sites of Uttar Pradesh, India

An experiment was conducted on sugarcane-wheat and rice-wheat rotation in two districts (Meerut and Ghaziabad) in farmers participatory mode in the juridiction of Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut (Uttar Pradesh), India, (28°40′07″N to 29°28′11″N, 77°28′14″E to 77°4418″E) during 2009 to 2011. The experiment was farmer-managed, with a single replicate, repeated over many farmers. Therefore, the experimental design was Randomized Block Design in which the number of treatments varied from farmer to farmer, with the farmer as a replicate/block. The treatments consisted of Laser land leveling (T_1), Traditional land leveling (T_2) and Control (Unleveled) (T_3).

In treatments T_1 and T_2 leveling of experimental field was done as per treatment and information on the topography of each experimental unit was compiled. The climate of the area is semiarid, with an average annual rainfall of 805 mm (75 to 80% of which is received during July to September), minimum temperature of 4°C in January, maximum temperature of 41 to 45°C in June, and relative

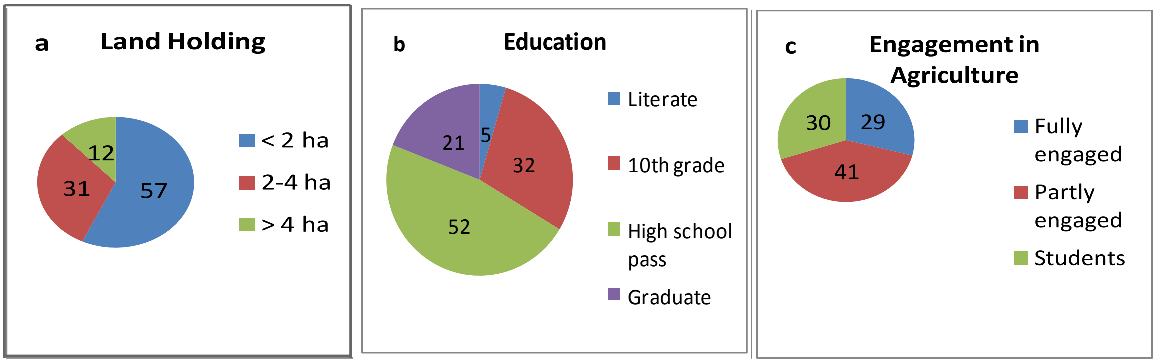

Figure 1. Socioeconomics and demographics of project sites of western Uttar Pradesh, India.

humidity of 67 to 83% during the year. The soils are generally sandy loam to loam in texture and low to medium in organic matter content, soil with a bulk density of 1.48 Mg m^{-3}, weighted mean diameter of soil aggregates 0.74 mm, pH = 7.9, total C = 8.3 g kg^{-1}, total N = 0.83 g kg^{-1}, Olsen P = 28 mg kg^{-1}, and K = 128 mg kg^{-1}. Groundwater pumping is the predominant method of irrigation. Western UP has a diversified cropping system, with sugarcane-wheat and rice-wheat as the dominant cropping system. The crop was kept free of weeds by chemical spray. Observations on the desired parameters were recorded using the standard procedures. The main source of irrigation was canal water which was supplemented with tube well water as and when needed to meet the crop water requirements. The discharge available at outlet was measured every time. The time of irrigation application for each treatment was noted during each irrigation. The applied irrigation depth was calculated from measured discharge applied to known area for recorded time by the following equation:

$$QT = AD$$

Where Q = Discharge (Cusec,ft^3 s^{-1}); T = Time (h); A = Area (acres), and D = Depth (inches).

The amount of water (ft^3) applied to each treatment was determined by multiplying the discharge at field outlet with the time of application. The total amount of water so applied was computed for the entire crop season. The amount of water saved was determined by the difference of water applied to precisely leveled, unleveled and traditionally leveled experimental units. Water use efficiency was computed as follow:

$$WUE = Yield/Water\ applied\ (kgm^{-3})$$

Water productivity and economic analysis

Water productivity analysis combines 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., 2008). For this analysis, physical water productivity was calculated by:

$$WP = Output/Q$$

Where WP is the productivity of water in kgm^{-3}, output is the mass of crop in kilograms and Q is water resources applied and depleted (m^3). In this study, only physical productivities of the applied and depleted water are analyzed. To compare the laser-leveled field to the control field, both gross margin analysis and partial enterprise budgeting techniques were applied for three cropping seasons of 2009, 2010 and 2011.

The use of partial enterprise budgets required to evaluate technological innovations compared to old techniques, as the capital costs associated must be discounted over the life of the new investment.

RESULTS AND DISCUSSION

Yield and yield components

The laser leveling significantly affected the yield and yield components of rice, wheat and sugarcane crop (Tables 1 and 3). The maximum productive tillers were recorded in laser leveled field against the minimum in the unleveled field. No significant difference was recorded for 1000 grain weight. Laser land leveling produced maximum grain/cane yield (5.73, 4.60 and 82.8 t ha^{-1}) against the minimum (4.25, 3.85 and 54.9 t ha^{-1}) in unleveled field. Significantly higher grain/cane yield over traditionally leveled field and unleveled field might be attributable to better development of yield components like higher productive tillers m^{-1} row length and more 1000 grain weight due to more efficient use of inputs, uniform internode length, thicker canes and uniform availability of soil moisture in the effective root zone of the crop. Naresh et al. (2012) attributed higher grain yield in precision land leveling to more uniform "wattar" conditions that facilitated timely preparation of field and timely sowing of the crop as compared to unleveled fields. The reason for lower grain/cane yield in unleveled field might be uneven distribution of water over the field which drastically reduced the yield and yield components in lower and elevated spots.

Water saving

There was a significant improvement in irrigation performance when the precision laser land leveling was under taken prior to sowing (Tables 2 and 3). The maximum water depth for rice (122.4 mm), for wheat

Table 1. Rice - Wheat yield and its components as affected by laser land leveling and traditional leveling techniques.

Treatment	Plant height (cm)		Productive tillers (m^{-1} row length)		Grains $spike^{-1}$		1000 grain weight (g)		Grain yield (t ha^{-1})	
	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat
Laser land leveling	131.6	95.5	105	84	82	45	24.1	42	5.73	4.47
Traditional land leveling	127.7	87.4	97	68	77	43	23.4	39	5.35	4.23
Control (Unleveled)	111.8	76.1	84	59	68	39	21.3	39	4.25	3.75
CD at 5%	16.9	12.3	13.7	14.3	9.5	5.3	NS	NS	0.47	0.32

Table 2. Total duration, applied water depth and water use efficiency as affected by laser land leveling and traditional leveling techniques.

Treatment	Total duration min ha^{-1}		Water depth applied (mm)		Water depth/ irrigation (mm)		Volume of water applied (m^{-3})		WUE kg m^{-3}	
	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat
Laser land leveling	3049	1263	810	340	90	63	4316	3310	1.33	1.35
Traditional land leveling	3414	1456	950	392	101	73	4982	3842	1.07	1.10
Control (Unleveled)	4134	1857	1260	501	122	93	6118	4915	0.69	0.76
CD at 5%	385	298	183	97	17	15	873	786	0.21	0.23

Table 3. Sugarcane yield and total duration, applied water depth and water use efficiencies as affected by laser land leveling and traditional leveling techniques.

Treatment	Total duration min ha^{-1}	Water depth applied (mm)	Water depth/ irrigation (mm)	Volume of water applied (m^{-3})	yield (t ha^{-1})	WUE (yield /mm water/ha)
Laser land leveling	6386	1630	160	7500	77.3	1.03
Traditional land leveling	7353	2046	185	8362	68.9	0.82
Control (Unleveled)	8382	2350	219	10363	55.7	0.53
CD at 5%	529	314	39	962	9.6	0.23

(100.3 mm) and (218.9 mm) for sugarcane were required to irrigate unleveled field during each irrigation as against the minimum in the field precisely leveled by laser and followed by traditionally leveled field. On an average, 36 to 12% in rice, 47 to 15% in wheat and 36 to 15% in sugarcane crop as compared to control and traditionally leveled fields reduced the total irrigation duration and water depth in each irrigation event, respectively. Thus, laser leveled field utilized less water per irrigation. The precisely leveled and smooth field showed a positive impact on the total water use resulting in a tangible reduction. At uniform discharge, before and after laser land leveling there was about 32% saving in water over control and 13% over traditional leveled field. Significantly, higher amount of water (6118.4; 4915.1 and 10362.8 m^3) were required for unleveled field than laser leveled field (4316.2, 3310.3 and 7500.4 m^3), which did not differ significantly from the traditionally leveled field. The results further revealed that 1802.2 m^3 in rice crop, 1604.8 m^3 in wheat crop and 2862.4 m^3 in sugarcane crop, that is, about 42, 47 and 38% excess volume of water was required to irrigate unleveled fields as against 15% (666.2; 531.7 and 861.9 m^3) in traditional leveled field. The only reason for excessive water application in control treatments was uneven surface to the unleveled treatment. The greater variation in surface level on unleveled and traditional leveled field resulted not only in wastage of water but also reduced crop yield by about 26 to19% in rice crop, 28 to 11% in wheat crop and 28 to 15% in sugarcane crop, respectively.

For rice:

Total duration	LL vs TL	3049.6 – 3414.7	= - 365.1 (12%)
	LL vs UL	3049.6 – 4134.3	= - 1084.7 (36%)
Water depth per irrigation	LL vs TL	90.3 – 101.5	= - 11.2 (12%)
	LL vs UL	90.3 – 122.4	= - 32.1 (36%)
Water use efficiency	LL vs TL	1.33 – 1.07	= 0.26 (21.8%)
	LL vs UL	1.33 – 0.69	= 0.64 (48.1%)

Table 4. Comparative energy and economics of laser land leveling and traditional leveling techniques.

Parameter	Laser land leveling		Traditional land leveling		Control (Unleveled)	
	Rice	Wheat	Rice	Wheat	Rice	Wheat
Energy requirement, MJ ha^{-1}	4768	2498	5658	2885	6960	3647
Tillage cost, Rs ha^{-1}	11675	8470	12450	10350	14370	12675
Grain yield, t ha^{-1}	5.73	4.47	5.17	4.23	4.25	3.75
Straw yield, t ha^{-1}	-	6.05	-	5.12	-	4.25
Gross income, Rs ha^{-1}	65,895	49,301	61,525	46,045	48,875	40,031
Cost of production, Rs ha^{-1}	24,175	18,720	25,700	19,578	27,425	21,460
Net income, Rs ha^{-1}	41,720	30,581	35,825	26,467	21,450	18,571
Benefit : cost ratio	2.73	2.63	2.08	2.35	1.78	1.87

For wheat:

Total duration	LL vs TL	1263.05 -1456.3	= - 192.95 (15%)
	LL vs UL	1334.05 – 1857.9	= - 594.85 (47%)
Water depth per irrigation	LL vs TL	63.2 – 72.9	= - 9.7 (15%)
	LL vs UL	63.2 – 93.1	= - 29.9 (47%)
Water use efficiency	LL vs TL	1.35 – 1.10	= 0.25 (18.52%)
	LL vs UL	1.35 – 0.76	= 0.59 (43.7%)

LL = Laser land leveling TL = Traditional land leveling and UL = Unleveled.

Water use efficiency

Water use efficiency (WUE) was significantly affected by different land leveling techniques (Tables 2 and 3). The highest WUE for rice, wheat and sugarcane crops (1.33, 1.35 and 1.03 kg m^{-3}) were recorded in laser-leveled field against the lowest (0.69 and 0.76 kgm^{-3}) in unleveled field while in traditionally leveled field were (1.07, 1.10 and 0.82 kg m^{-3}). Overall, the water-use efficiency was 48, 47 and 49% higher precisely in leveled field than control and 22, 19 and 20% higher than traditional leveling. This huge difference in water use efficiency was because of reduced grain/cane yield and higher amount of water applied to unlevel and traditional leveled fields. The decrease in water use efficiency in unleveled fields also reflected the sensitivity of the crop to water excess/deficit, a characteristic of undulating fields' surface of unleveled fields.

The reason for lower WUE in traditionally leveled and unleveled fields was the inefficient use of the water applied. The result suggests that laser land leveling is more water use efficient, more cost effective and give higher crop yield through efficient utilization of scarce land and water resources. Thus in the light of this study, it is imperative to recommend that laser land leveling should be popularized among the farmers at it not only increase water use efficiency and yield but also ensure better germination, better utilization of water and non water inputs towards increased yield.

For sugarcane:

Total duration	LL vs TL	6385.6 – 7352.7	= - 987.1 (15%)
	LL vs UL	6385.6 – 8682.1	= - 2296.5 (36%)
Water depth per irrigation	LL vs TL	160 – 184.5	= - 24.5 (15%)
	LL vs UL	160 – 218.9	= - 58.9 (36%)
Water use efficiency	LL vs TL	1.03 – 0.82	= 0.21 (20.4%)
	LL vs UL	1.03 – 0.53	= 0.50 (48.5%)

LL = Laser land leveling TL = Traditional land leveling and UL = Unleveled.

Profitability

Using scarce water resources in rice, wheat and sugarcane cultivation in a sustainable manner, brought a larger area under rice-wheat and sugarcane cultivation; the laser land leveling fields irrigation of these crops appeared to be an eco-friendly and economically viable technology. It led to higher productivity in rice, wheat and sugarcane and increased sucrose content in sugarcane and ultimately increased income for the farmers (Tables 4 and 5). Higher net returns were observed by laser land leveling technology Rs. 41,720; 30,581 and 66,280 ha^{-1} in rice, wheat and sugarcane crops in comparison to control (unleveled) fields. Other benefits include saving on fuel expenses, improvement in fertilizer use efficiency, uniform internode length, thicker canes, less weed growth and uniform irrigation of rice/wheat/sugarcane grown on undulated terrains.

Although, laser land leveling is beneficial, there are certain limitations associated with it such as high cost of the equipment/laser instrument and need for a skilled operator. It may be less efficient in irregular and small sized fields. Utilizing these eco-friendly and economically viable options will go a long way in sustaining rice, wheat and sugarcane productivity and economizing water under conditions of ever-depleting water resources.

Table 5. Economics of some agronomic measures on sugarcane production (plant cane).

Parameter	Demonstrated agronomic measure		
	Laser land leveling	Traditional land leveling	Control (Unleveled)
Energy requirement, MJ ha^{-1}	8339	9670	12100
Cane yield (t ha^{-1})	77.3	65.9	55.7
Cost of production (Rs ha^{-1})	49,640.0	52,830.0	56,790.0
Gross return (Rs ha^{-1})	115,920.0	103,350.0	83,550.0
Net return (Rs ha^{-1})	66,280.0	50,520.0	23,760
Benefit : cost ratio	2.34	1.87	1.47

Over the past decade, researchers in association with farmers and entrepreneurs have been trying to overcome the problems of depleting water resources, diminishing input use efficiency, declining farm profitability, and deteriorating soil health by developing, evaluating and refining conservation and precision agriculture-based resource-conserving technologies for the sugarcane-wheat and rice-wheat system in western Uttar Pradesh. Recently, laser-assisted precision land leveling has shown promise for better crop establishment, water savings and enhanced input use efficiency. This study have shown the effect of rice, wheat and sugarcane planting on laser leveled fields increased yields (av. of 3 yrs) by 6.6, 5.4 and 10.9% on traditionally leveled fields.

The saving in irrigation water with precision-conservation were 13.4, 13.8 and 10.3% compared to traditional leveling field and 29.5, 32.7, 27.6% to unleveled fields in rice, wheat and sugarcane crop, respectively. Therefore, this study confirms that Precision-Conservation Agriculture (PCA) based crop management solutions seem to be promising options to sustain the irrigated sugarcane-wheat and rice-wheat systems of western U. P. on a long-term basis.

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