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Impact of laser land levelling technology on rice-wheat production in Haryana

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Abstract
The paper has compared the economics of wheat as well as paddy production in North- Western Indo-Gangetic Plains of Haryana under laser land levelling and conventional methods and assessed the contribution of technology and inputs to the increased productivity due to laser land levelling (LLL). The net income has been found higher in LLL method, mainly due to incremental gain in productivity compared to that in conventional method. The study has observed that LLL technology has potential to provide additional income to farmers and help in conservation of scarce resources. The decomposition of productivity revealed 55 per cent and 12 per cent of the difference in productivity of wheat and paddy, respectively due to LLL and the rest due to changes in input use. In all, about Rs. 35244 of net incremental benefit was derived from per LLL operation. The LLL technology has thus proved to be a boon in rice-wheat system for water saving and better yield. Still apart from various advantages of technology there are number of constraints which restrict its widespread adoption. One major constraint identified as the lack of technical knowledge followed by high cost of levelling. Therefore, the study has suggested to raise the knowledge level of the farmers along with more exposure to the extension agencies to enhance the adoption of LLL.

Keywords: laser land levelling, conventional tillage, economics, decomposition analysis

Introduction
With increasing climate variability and rapid melting of glaciers, water scarcity is expected to be a major challenge to agricultural production and food security in South Asia. Increasing temperature, which has been observed in most of the region, increases the demand for irrigation water. The groundwater table is observed to be declining in India (Aggarwal *et al.* 2004; Joshi and Tyagi 1994; Kerr 2009; Kumar *et al.* 2007) [2, 17, 19, 20]. As agriculture is the largest beneficiary of groundwater, a declining groundwater table will impact the sustainability of agriculture and the overall food security of the country. Furthermore, the use of motorised pump to extract groundwater for irrigation raised the demand for energy by the agriculture sector in India. Given the existing consumption pattern, India will need to produce at least 37 per cent more rice and wheat by 2025 as compared to that of the year 2000, with nearly 10 per cent less water that will be available for irrigation (Jat *et al.* 2006) [14]. Therefore, there is a need of technologies that reduces water requirement, increasing the efficiency of energy use and enhances agricultural productivity. But, in the rice–wheat (RW) system of the Indo-Gangetic Plains (IGP), about 10–25 per cent of irrigation water is lost due to poor water management and uneven fields (Kahlown *et al.* 2000) [18]. To overcome such problem, the laser land levelling (LLL) is a technology that has the primary benefit of reduction in the loss of irrigation water occurring due to highly undulating land with achieving the desired level of accuracy through laser equipped drag buckets. It also facilitates uniformity in the placement of seeds or seedlings and promotes better crop stands, which eventually contributes to higher crop yields. 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. Despite this, there has been no comprehensive study which examines the impact of LLL on crop yield, irrigation duration, energy saving, and overall farm profitability. Hence, the major focus of the study is to assess the impact of LLL on cost of inputs, crop yield, irrigation duration, energy saving, and farm profitability.

Methodology

Laser land levelling (LLL) has been interpreted here as the process of levelling the land with the help of laser land leveller. The conventional tillage (CT) refers to the intensive tillage with multiple passes of a tractor to accomplish land preparation. Field level enquiry revealed that in Haryana farmers adapted LLL to a larger extent and the technology was found to be scale neutral i.e. adoption in all farm size groups. For this study, Karnal district was selected purposively due to implementation of climate smart village project by CGIAR through CIMMYT and other co-partners. From the Karnal district, four climate smart villages (CSV) and four non-climate smart villages (Non-CSV) were selected. A total of 74 farmers from CSV who adopted laser land levelling technology for wheat and paddy production were selected randomly. From the Non-CSV villages, 40 numbers of farmers practising conventional tillage method were selected. The characteristics and socio-economic conditions of both types of the households were almost similar. The primary data were collected during the agriculture year 2016-17 from 114 farmers.

The farm management cost concept was used to analyse the impact of LLL technology on farm income. The sample farmers were classified into two category based on their adoption of technology i.e. LLL technology adopter and non-adopter. The impact of the adapted technology was assessed in terms of enhancement in yield, income, and improvement in efficiency. In which the various cost components such as Costs A1, B1, B2, C2, and C3 was calculated to analyse the profitability of the wheat and paddy production.

Cost A1= Wages of hired labour, cost of inputs such as seed, manures, liquid and solid fertilizers, insecticides and pesticides, hired machinery charges, imputed value of owned machine power, implements like fertigation units and farm buildings, irrigation charges, land revenue and interest on working capital.

Cost B1 = Cost A1 + Interest on the value of owned fixed capital assets (excluding land).

Cost B2 = Cost B1 + Rental value of land.

Cost C1 = Cost B1 + Imputed value of family labour.

Cost C2 = Cost B2 + Imputed value of family labour.

Cost C3 = Cost C2 + 10 percent of Cost C2 accounting for managerial input.

The cost C_1 was taken into account in this study to calculate net income and benefit-cost ratio. The cost of irrigation was calculated by multiplying the time required to irrigate the farm with cost of electricity or diesel consumption per hour. The cost of electricity was taken based on per unit rate fixed by the Haryana Electricity Distribution Corporation. The cost on human labour, machine labour and diesel were taken on actual expenditure basis. Gross income included the total value of main crop and by-products. Net income was calculated as the difference between gross income and cost of production (cost C_1).

The output decomposition model developed by Bisaliah (1977) [8] was used to quantify the contribution of various sources to the productivity differences between LLL and CT methods. It is expected that the practice of LLL technology will result in changes in input-use pattern, which in turn will affect the land productivity. Hence, increase in land productivity is not only due to adoption of LLL method but also due to the changes in use of factors in production. The following output decomposition model was used in this study.

The Cobb-Douglas production function in logarithmic form for LLL method of wheat production on per hectare basis is as follows:

$$\text{Ln } Y_{LLL} = \ln b_0 + b_1 \ln X_{1LLL} + b_2 \ln X_{2LLL} + b_3 \ln X_{3LLL} + b_4 \ln X_{4LLL} + b_5 \ln X_{5LLL} + b_6 \ln X_{6LLL} + U_{zt} \quad \ldots(1)$$

Where,

Y= Output of wheat / paddy (qtl);
X_1= Human Labour (man days);
X_2= Machine labour (hrs);
X_3= Seed (kg);
X_4= Fertilizer (kg);
X_6= Plant Protection Chemicals (gm);
X_6= Irrigation (hrs);
U= Random disturbance term, in conformity with the OLS assumptions;
b_0= Scale parameter, and
b_i= Slope parameters of the regression function (Production elasticities, i=1to 6)

The per hectare production function for conventional tillage method is given in Equation as below:

$$\ln Y_{CT} = \ln a_0 + a_1 \ln X_{1CT} + a_2 \ln X_{2CT} + a_3 \ln X_{3CT} + a_4 \ln X_{4CT} + a_5 \ln X_{5CT} + a_6 \ln X_{6CT} + U_{CT} \quad \text{---} (2)$$

Taking difference between the equation (1) and (2), the following decomposition model was arrived as follows:

$$\ln [Y_{LLL} / Y_{CT}] = \{ \ln (b_0/a_0)\} + \{(b_1-a_1)\ln X_{1CT} + (b_2-a_2) \ln X_{2CT} + (b_3-a_3) \ln X_{3CT} + (b_4-a_4) \ln X_{4CT} + (b_5-a_5) \ln X_{5CT} + (b_6-a_6) \ln X_{6CT}\} + \{b_1 \ln (X_{1LLL}/ X_{1CT}) + b_2 \ln (X_{2LLL}/ X_{2CT}) + b_3 \ln (X_{3LLL}/ X_{3CT}) + b_4 \ln (X_{4LLL}/ X_{4CT}) + b_5 \ln (X_{5LLL}/ X_{5CT}) + b_6 \ln (X_{6LLL}/ X_{6CT})\} + \{U_{LLL} - U_{CT})\quad \text{----}(3)$$

The left hand side of the equation (3) gives the total difference in productivity expressed as an approximate percentage over conventional tilled farm. The natural logarithm of the ratio of per hectare net returns of LLL adopter farms and conventional tilled farms is approximately a measure of percentage difference in net outputs of the two categories of farmers. The first bracketed term on the right hand side, the natural logarithm of constant terms, is the gap attributable to the neutral component of technology. It is a measure of neutral technological gap. The second bracketed term is the gap attributable to the non-neutral component of technology weighted by input use expenditure for conventional tilled farms. That is, it is a measure of non-neutral technological gap, after adjustment in the level of input use expenditure weighted by the slope coefficients of the production function fitted for the LLL technology adopter farms. Hence, it is the gap due to difference in the levels of input use between two category of farmers after making due adjustment for production elasticities of different inputs. The last component is a random term which the model could not take into account.

The incremental benefit generated over conventional tillage farm under LLL is computed on per hectare and per LLL operation by equation (Aryal *et al*., 2014) [5] as follows:

$$\text{Incremental Benefit (Rs/LLL)} = \sum_{i=1}^{n} [P_{Wi}\Delta Y_{Wi} + P_{Ri}\Delta Y_{Ri}] - C_L H_L$$

Where,

P_{Wi} = Price of wheat per unit; ΔY_{Wi}= Additional yield of wheat in LLL field over CT farm

P_{Ri} = Price of rice per unit; ΔY_{Ri}= Additional yield of rice in LLL field over CT farm

C_L= Cost of hiring laser leveling service per hour; H_L= Time required to laser level the land

i= 1,…, n i.e. frequency of LLL operation (years)

Results and Discussion

In the study area, crop production was the major activity reported by about 90 per cent of the sample farms (Table 1). The paddy (*Oryza sativa*) crop was sown during the *kharif* season (June to November), whereas wheat (*Triticum aestivum*) was the major crop grown extensively by the farmers in the *rabi* season (November to May).

Age of CSV farmers was lower than Non-CSV farmers. It is observed that younger people are more receptive to new technology. The family size of CSV farmers is smaller, are better educated and higher proportion had farming as a main occupation than those of Non-CSV farmers in study area. More number of CSV farmers were members of various organisations likes Farmers Club, Self-Help Groups, Grampanchayat, Co-operative societies etc. as compared to Non-CSV farmers, which could play a role in to get more exposure to the availability of various adaptation strategies to climate change. The CSV farmers have on an average two times more access to credit and four times more access to training as compared to Non-CSV farmers. The average farm size was also observed to be more in case of CSV farms (4.53 ha) as compared to Non-CSV farms (4.28 ha). At overall level, the cropping intensity on CSV sample farms is 8 per cent more than Non-CSV sampled farms.

Table 1: Table 4.1 Socio-economic characteristics of sample farm households

Sr. No.	Particulars	Karnal farmers		Overall
		CSV	NCSV	
1	Sample size (No.)	80	40	120
2	Average age (years)	45.84	47.3	46.57
3	Average family size (No.)	6.3	6.9	6.6
4	Literacy (%)	77.5	72.5	75
5	Farming main occupation (%)	92.5	87.5	90
6	Farm size (ha)	4.53	4.28	4.41
7	Training access (Yes=1; otherwise=0)	67	17	42
8	Membership of organization (Yes=1; otherwise=0)	36	11	24
9	Credit access (Yes=1; otherwise=0)	66	28	47
10	Cropping intensity	198	183	191

Resource-use, Cost and Return Structure in Wheat and Paddy Production

The major farm inputs used for the production of wheat and paddy in LLL and CT methods are mentioned in Table 2.

Table 2: Major farm inputs used in wheat and paddy production in Haryana (Per hectare)

Particulars	Laser Land Leveling	Conventional Tillage	Change (%)
Wheat			
Human labour (man days)	53.2	56.3	-5.83
Machine labour (hours)	9.5	8.72	8.21
Seeds (kg)	105.72	110	-4.05
Fertilizer (kg)	480.29	492	-2.44
PPC (gm)	445.3	530	-19.02
Duration of Irrigation (hr)	35.6	45.1	-26.69
Yield (Qtl)	54.2	51.1	5.72
Paddy			
Human Labour (man days)	58	62	-6.90
Machine Labour (hr)	11.5	10.5	8.70
Seed (Kg)	22	24	-9.09
Fertilizers (Kg)	440	440	0.00
PPC (gm)	510	540	-5.88
Duration of Irrigation(hr)	96.98	149.5	-54.16
Yield (Qtl)	56.5	53.38	5.52

From the table it is revealed that for the wheat crop on an average about 6 per cent less human labour is required under LLL farms. But the machine labour requirement was observed to be 8.12 per cent higher in case of LLL farms. A reduction in use of seed, fertilizers and PPC was observed to the extent of 4.05, 2.44 and 19.02 per cent, respectively under the LLL farms as compared to CT. The maximum reduction of seed was found on large farms, while that of fertilizers and PPC was observed on small farms. At overall farm size level, about 27 per cent reduction in duration of irrigation was observed in wheat crop under LLL. But as per farm wise reduction was more on large farms.

While in case of paddy, LLL technology led to higher reduction in duration of irrigation as compared to that observed under wheat crop and it was 52.52 hours per hectare per season. The reduction was high on large farms. The use of human labour, seed and PPC was lower by about 6.90, 9.09 and 5.88 per cent, respectively under LLL farmers compared to CT farms. The machine labour requirement was reported to have increased on LLL fields. Therefore, due to adoption of LLL technology about 62.02 hours of irrigation was saved in wheat and paddy cultivation. LLL also saved the input use especially human labour, seed, fertilizers and PPC as compared to that in CT and also increase in yield by 5.72 and 5.52 per cent, respectively was observed in the wheat and paddy crop.

The production costs and returns of wheat and paddy production using LLL and CT methods are presented in Table 3.

Table 3: Cost and return in wheat and paddy production using LLL method in NE IGP **(Rupees per hectare)**

Particulars	Laser Land Levelling	Conventional Tillage	Change (%)
Wheat			
Cost on human Labour	14630	15483	-5.83
Cost on machine Labour	5700	5232	8.21
Cost on seeds	2114	2200	-4.07
Cost on fertilizer	4203	4307	-2.47
Cost on PPC	2083	2160	-3.70
Irrigation charges	1709	2194	-28.38
Overhead Cost	3045	3158	-3.71
Total Operational cost	33483	34734	-3.74
Gross income	89430	84315	5.72
Return over operational cost	55947	49581	11.38
Benefit-cost ratio over cost C_1	1.86	1.66	10.75
Cost of grain production (Rs/kg)	6.18	6.8	-10.03
Paddy			
Cost on human Labour	16530	17670	-6.90
Cost on machine Labour	6900	6300	8.70
Cost on seeds	880	960	-9.09
Cost on fertilizer	3850	3850	0.00
Cost on PPC	2168	2295	-5.86
Irrigation charges	4655	7176	-54.16
Overhead Cost	3650	3827	-4.85
Total Operational cost	38633	42078	-8.92
Gross income	89835	84874	5.52
Return over operational cost	51202	42796	16.42
Benefit-cost ratio over cost C_1	1.65	1.47	10.91
Cost of grain production (Rs/kg)	6.84	7.88	-15.20

From the table it is revealed that the gross returns of wheat production were Rs. 89430 per hectare in LLL and 84315 per ha in CT which was found to be 6 per cent more under LLL. The return over operational cost amounted to Rs. 55947 per ha in LLL and Rs. 49581 per ha in CT method of wheat production. The net income was higher in LLL method due to higher yield and reduction in cost of cultivation as compared to CT method of wheat cultivation. The cost of cultivation amounted to Rs. 33483 per ha in LLL method and Rs. 34734 per ha in CT method. The lower cost of cultivation was due to lower expenses on human labour (6 per cent), irrigation (28 per cent) and other inputs like seed, fertilizers and PPC in LLL than in CT method. The benefit-cost ratio of 1.86 was observed in LLL as against 1.66 in CT method of wheat production. The cost incurred to produce a kilogram of wheat was Rs. 6.18 in CT and Rs. 6.80 in LLL methods. Thus, the cost of wheat grain production was lower by 10 per cent in LLL as compared to in CT method.

However, in case of paddy production the total operational cost under LLL technology adopters' field was found to be reduced by 9 per cent over conventional tilled farm. In which the more reduction was observed in case of irrigation charges mainly due to reduction in duration of irrigation under LLL field. In all the paddy production under LLL helped to raise the return over operational cost by 16 per cent mainly due to reduction in cost incurred on inputs as well as due to incremental gain in productivity as compared to conventional tilled farm. The benefit-cost ratio was observed 11 per cent more in LLL as against CT method of paddy production. In all, significant difference was observed in wheat and paddy yield with and without LLL method. The cost incurred to produce a kilogram of paddy was Rs. 6.84 in LLL and Rs. 7.88 in CT methods. It indicates 15 per cent less under LLL paddy cultivation. This analysis suggests that LLL technology offers ample scope to generate additional income and help to conserve scarce resources. In this context, it is essential to assess the extent of change in productivity of wheat and paddy crop due to adoption of LLL technology and change in input use. Therefore, the productivity difference among adopters and non-adopters of laser land leveling for wheat and paddy production was segregated into its constituent sources i.e. technological change and input use differential with the help of decomposition model as suggested by Bisaliah (1977) [8].

Decomposition Analysis

Using Equation (3), the values of production parameters and the geometric mean of input levels the total change in wheat and paddy output with the adoption of LLL technology was decomposed. Per hectare production of wheat and paddy was about 6 per cent higher with LLL technology than with CT method. How much of this increased output was due to technological change and how much of it was due to change in input levels were also computed and are given in Table 4.

Wheat: The estimated improvement in productivity (per cent) with adoption of LLL technology was partly attributed to technological change and partly to input use, however, the two together contributed to 6.07 per cent of change in yield of wheat crop. However, the contribution of technology in yield increase was around 55 per cent. It indicates that the farmer could increase returns from wheat by 55 per cent just by shifting from conventional tillage to laser land levelling in Haryana. As the laser land levelling technology has resource conserving potential, the impact of majority of inputs was observed to be negative in study area. The change in PPC was contributed to around 1.55 per cent of the increased output. Since, LLL is a resource conserving technology and gives more yield than CT it is recommended to increase the existing productivity of wheat by increasing the level of adoption of LLL technology.

Table 4: Decomposition of Total Productivity Differences between LLL and CT Technology of Wheat and paddy in Haryana. (Percent Contribution)

Sources of productivity Difference	Wheat	Paddy
Total observed difference in productivity	6.21	5.18
A. Due to difference in technology	54.82	12.06
B. Due to difference in input use level		
I. Human Labour	-10.30	-4.77
II. Machine Labour	-2.22	0.03
III. Seed	-13.43	0.13
IV. Fertilizer	-6.93	0.03
V. Plant Protection Chemicals	1.55	1.14
VI. Irrigation	-17.41	-3.55
C. Total Estimated difference in productivity due to all resources (A+B)	6.07	5.08

Paddy

In case of paddy cultivation, the estimated improvement in productivity with LLL technology are due to technological change and due to input use and the two together technologies together contributed 5.08 per cent of total increase in yield. The estimated contribution of technology in increase in yield of paddy was 12 per cent. It indicates that the farmer could increase the yield of paddy crop by 12 per cent just by shifting from conventional tillage to laser land levelling. The impact of input use levels was observed to be negative mainly because of resource conserving potential of technology. Some inputs namely; machine labour, seed, fertilizers and PPC contributed around 0.03, 0.13, 0.03 and 1.14 per cent of the increased output. Hence in order to increase the existing productivity of paddy, there is need to increase in level of LLL adoption. Technology influences the sources of output growth by shifting the values of scale and slope parameters of the production function (Bisaliah, 1977) [8].

Farmers' perception on impact of laser land levelling technology

In case of study area the adoption pattern of LLL technology was found scale neutral. Hence there is greater scope to extend the technology to all farms. Majority of the farmers felt that there was decrease in time required for field preparation when they adopt laser land leveler but some felt that there was an increase in time. The average time for leveling of one acre of land was 1.5 to 2 hours but it ranged from 1.5 hour to 3 hours depending on topography of land. Most of the farmers observed that there was an increase in area by 1-2 per cent under cultivation when they adopted laser land leveler, mainly because of reduction in number of bunds per plot. The bunds are used to sub-divide the plots to bring them to manageable limit for the purpose of ease of irrigation. All the farmers observed that there was reduction in time taken to irrigate the crop to a tune of one third to one half in laser leveled fields due to even distribution of irrigation water. All the farmers recorded water saving upto 25-30 per cent after adoption of laser land leveler in wheat and rice crop. Majority of farmers felt that cost of cultivation was same for adoption of laser land leveler but a few felt that during first time it increases. However, such farm farmers also perceive no or little increase in cost in later years. Most of the farmers recorded more (5-6.5%) yield after leveling the field. Number of farmers reported that there is increase in germination of seed on laser land leveled fields. The LLL technology has thus proved to be a boon in rice-wheat system for water saving and better yield. Still apart from various advantages of technology there are number of constraints which restrict its widespread adoption. The main reasons for non-adoption of LLL in Haryana were observed as lack of technical knowledge followed by high cost of levelling which restrict the adoption of technology. The Non-CSV farmers in study area are also facing the problem of poor institutional support which limits their exposure to LLL advantages. So there is need to increase the institutional support and provide technical knowledge to the farmers to enhance the adoption of LLL.

Benefits of using laser land levelling

When a farmer levels 1 ha of land using laser land leveller, the effect typically lasts for at least 4 years in NW IGP i.e. Haryana. Thus, it is assumed that the life of one levelling to be 4 years. Secondly it is also assuming that the farmer practices the dominant cropping pattern of rice-wheat during the entire period; planting rice in *kharif* and wheat in *rabi* season. Finally it is assumed that the increase in price of wheat and rice and the discount rate over time will balance each other so that prices stay constant at the current minimum support prices (MSPs) as fixed by the government of India. Based on above mentioned assumptions the benefit derived from LLL operation is compiled and presented in Table 5. The incremental benefit to the farm due to use of LLL technology is calculated by using the equation as given below:

$$\text{Incremental Benefit (Rs. / LLL)} = \sum_{i=1}^{4} [P_{Wi}\Delta Y_{Wi} + P_{Ri}\Delta Y_{Ri}] - C_L H_L$$

The benefit stream is calculated by using minimum support price (2017-18) for respective crop which is Rs.16.25 per kg for wheat and Rs.15.50 per kg for rice. The study consider the yield differential in laser leveled land and conventional tilled land to be 310 kg/ha for wheat and 312 kg/ha for in paddy.

Table 5: Incremental benefit of using LLL

Sr. No.	Particulars	Incremental Benefit
1	Price of wheat (Rs/kg)	16.25
2	Price of paddy (Rs/kg)	15.5
3	Incremental yield of wheat(kg/ha)	310
4	Incremental yield of paddy(kg/ha)	312
5	Benefit per year from wheat(Rs/ha)	5037.5
6	Benefit per year from paddy (Rs/ha)	4836
7	Number of years LLL applicable	4
8	Benefit per LLL operation	39494
9	Cost of LLL (Rs/ha)	4250
10	Net Benefit per year (Rs)	8811
11	Net Benefit per LLL operation	35244

Based on farmers' response, in study area the cost of hiring laser land leveling service was Rs. 850 per hour and on an average around 5 hours time was required to level a hectare of land by LLL technology. Therefore, the total cost of levelling one hectare is Rs. 4250. In all, about Rs.35244 of net incremental benefit was derived from the adoption of LLL in study area.

Conclusions

The study has revealed that it is possible to save scare resources and irrigation water under LLL than under conventional method. Due to resource saving, net return has been significantly higher in LLL technology. Hence, this technology is an important alternative to save scarce resources and enhance the net farm income. The decomposition analysis has shown that per hectare production of wheat and paddy was 6.07 per cent and 5.08 per cent, respectively higher in LLL than in conventional tillage method. In this improved production method, LLL technology contributed around 55 per cent and 12 per cent change in productivity of wheat and paddy crops, respectively. By adopting this technology, farmers could save scarce resources and reduce the cultivation cost. The availability of institutional support and provision of technical knowledge to the farmers needs to be accorded more attention to foster the adoption of LLL technology.

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