Indian Journal of Ecology (2022) 49(6): 2254-2259
DOI: https://doi.org/10.55362/IJE/2022/3817

Manuscript Number: 3817
NAAS Rating: 5.79

Potential of Laser Levelling Technology for Enhancing Land and Water Productivity in North Western Gangetic Plains

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***Abstract*:** Rice-wheat cropping system is dominating cropping pattern in North Western Gangetic Plains. The effect of Laser Land Levelling on-farm input water use efficiency and crop production was studied. The major constraint in the adoption of this technology is a huge capital investment in laser leveller, so collective effort or custom hiring can help. Also, it has been suggested to raise the knowledge level of the farmers along with more exposure to the extension agencies to enhance the adoption of this technology. Further evaluation of this technology is strongly recommended under different Agro-climatic zone for their large-scale adoption in the whole Indo Gangetic plans in India.

***Keywords*:** Irrigation, Laser land levelling, Precision technology, Rice, Wheat

The Indo Gangetic Plains (IGP) covers an arc from the Swat valley in Pakistan, through the Indian states of Punjab, Haryana, Delhi, Uttar Pradesh, Bihar, West Bengal, parts of Rajasthan, across the Nepal Terai and into Bangladesh, where it characterizes most of the country. IGP is a fertile alluvial plain in South Asia, which is home to an estimated one billion people around seventh portion of the world's population (Bhatt et al 2021). The Plain is bounded by the floodplains of the rivers Indus to the west and Ganges to the east, the Himalayan foothills to the north, and the Deccan plateau to the south (Jain et al 2020). It is approximately 3,000 km from east to west and 250-300 km from north to south. It contains some of the Subcontinent's richest agricultural land (Abrol 1999, Prakash et al 2014). Rice and wheat are the two principal food grains in the region, crops which are grown in sequence on 13.5 million hectares of the Plain and contribute 80 percent of its food production (Jat et al 2006: Parihar et al 2022). It also constitutes 85% of South Asia's Rice-Wheat system and other important crops are maize, sugarcane, and cotton are also cultivated in this region (Gupta et al 2003).

Declining water tables have serious implications by increased pumping costs as farmers have to shift to costly deep tube wells (Tripathi et al 2016, Pandey 2016), where in some areas there are indications of water quality decline due to possible intrusion of brackish water from adjoining saline groundwater regions. In Punjab and Haryana, with the water table falling in 90 percent of the area of the State (Chaudhry and Sachdeva 2020). It is estimated that to meet growing food needs, India will have to produce almost 40 percent more food with almost 10 percent less water by 2025 (FAO 2017). Groundwater depletion is already a huge area of concern, particularly in the NWGP. The total water requirement for the rice-wheat system in the NWGP is estimated at between 1,382 mm and 1,838 mm, 80 percent of which is for irrigation in the rice component (Jat et al 2006). Water withdrawals from aquifers are estimated at 13-17 cubic kilometres per annum, in NWGP which greatly exceeds the recharge level, so that water tables have been falling (Aryal et al 2013).

Indian farmers commonly use flood irrigation in the Indo Gangetic plain (IGP) moreover, the highly irrigated areas like Punjab, where 99% of the water is obtained through tube wells and canals (Brar 2014). Flood irrigation method is commonly adopted in the Indo Gangetic plain (IGP) of India as well as in other countries (Kumar et al 2013, Jat et al 2021). In Northwest India, conventional irrigation is inefficient when flow rates are not enough to achieve rapid irrigation. The inefficiency is due to deep drainage below the root zone. Flood irrigation also causes temporary waterlogging, with adverse effects on crops like wheat, maize, and legumes (Kaur et al 2020). Waterlogging is more prolonged and more severe on heavy textured soils, and on soils used for rice culture because of the well-developed, shallow, hardpan as a result of puddling (Singh et al 2009). This leads to aeration stress in upland crops, especially in wheat (Kukal and Aggarwal 2003). When land is flood irrigated, any degree of undulation in the soil surface can seriously reduce both water and land productivity (Sheikh et al 2022). Hence farmers in the NWGP have traditionally spent considerable time and resources leveling the land, usually by passing a weighted tractor or animal-drawn leveling plank or harrow repeatedly over the dry field (Aryal et al 2015). The field is then irrigated so that high spots can be identified and further levelled. There are clear limits to the degree of inaccuracy that can be achieved by such conventional techniques.

Low efficiency of irrigation and poor recovery of water charges are the major problems associated with agricultural water management in India. In the rice-wheat (RW) system of the Indo-Gangetic Plains (IGP), about 10-25 % of irrigation water is lost due to poor water management and uneven fields. LLL is an alternative land leveling technology that has the primary benefit of a reduction in the loss of irrigation water occurring due to highly undulating land. Therefore, applying LLL rather than traditional land leveling (TLL) can help reduce the use of irrigation water and save energy through reduced duration of irrigation (Jat et al 2011).

To arrest this dangerous trend of groundwater exploitation, there is an urgent need to conserve irrigation water through various on-farm water conservation practices. Land Leveling through Laser Leveller is one such proven technology that is highly useful in the conservation of irrigation water (Pradeep et al 2014). Laser levelling uses high-precision laser technology to level out the undulations in agricultural fields. Laser levelling is an assistive technology, in the sense that it supplements rather than replaces the traditional method of leveling a field. In traditional levelling, a grading implement with a blade is towed behind a tractor over the field. The height of the blade is adjusted manually by the operator so as to achieve a surface that appears undulated to the human eye. The innovation in laser leveling is to use a laser guidance system to position the blade of the grading to implement automatically. Technology can ensure very accurate and precision land leveling to extent of ± 2 cm. Remains other input constant like fertilizer and seed, laser land leveling can increases crop yields by around 11 percent and water saving of around 25 percent (Hung et al. 2022). Studies have also demonstrated that leveling reduces weeds by up to 40 percent and labor time spent weeding by up to 75 percent (Bhatt and Sharma 2009). In the rice field, this technology brings down the water use by 36.19 cm along with the yield improvement of 0.78 t/ha. Further, by the adoption of this technology the Punjab state could achieve 0.99 Mha-m (million-hectare metre) water-saving and can save 583.51 million kilowatt-hour of electricity (Sidhu et al 2010).

Laser levelling technology is widely used in developed countries such as Australia, Japan and the USA, where large-scale irrigated agriculture is practiced (Bhatt and Sharma 2010). This technology spread rapidly to the extent that a survey estimated that by 2012 there were more than 9030 units of laser leveller in operation in the rice-wheat area of the NWGP (Jat 2012).The main objective of this paper to study the benefits, need and challenges in adoption of laser land levelling technology in the NWGP India. Also this study may provide scientific insights for researchers working on laser land levelling technology and its importance for NW India.

MATERIAL AND METHODS

Description of laser leveller: Description of various components of laser land leveller is explained in Table 1 and shown in Figure 1.

Working principle: The fields may be required ploughing

Table 1. Description of various components of laser land leveller

Part name	Description
Laser transmitter	Laser transmitter transmits a laser beam which is intercepted by the laser receiver mounted on the levelling bucket The control panel mounted on the tractor interprets the signal from the receiver and opens or closes the hydraulic control valve which will raise or lower the bucket. It needs to place on higher ground, so laser beam does not get blocked by tractor.
Laser emitter	The laser emitters mounted on a tripod stand placed outside the field and high enough to have unobstructed laser beam travel. The laser emitter unit sends continuous self-levelled laser beam signal with 360° laser reference up to a command radius of 300-400 m (Irsel and Altinbalik2018)
Laser beam receiver	The laser receiver mounted on the scraper (bucket), is an omni-directional (360°) receiver that detects the position of the laser reference plane and transmits it to the control box.
Control box	The control box is to be mounted on the tractor so that the operator can easily access the switches and view the indicator lamps. The control box receives and processes signals from the laser receiver mounted on the bucket to actuate the double acting hydraulic valves.
Hydraulic valve unit	The valve assembly regulates the flow of tractor hydraulic oil to the hydraulic cylinder to raise and lower the scraper blade. The solenoid control valve controls the flow of oil to the hydraulic ram which raises and lowers the bucket.
Drag Bucket	The levelling bucket can be either three-point linkage mounted or pulled by the tractor's drawbar. A 60 hp tractor will pull a 2 m wide x 1 m deep bucket in most soil types. The design specifications forthe bucket should match the available power from the tractor (Maqsood and Khalil2013).
Power unit	It is preferable to have a four-wheel drive tractor than two-wheel drive and the higher the horsepower the faster will be the operation. Power shift transmissions in the tractor are preferred to manual shift transmissions.

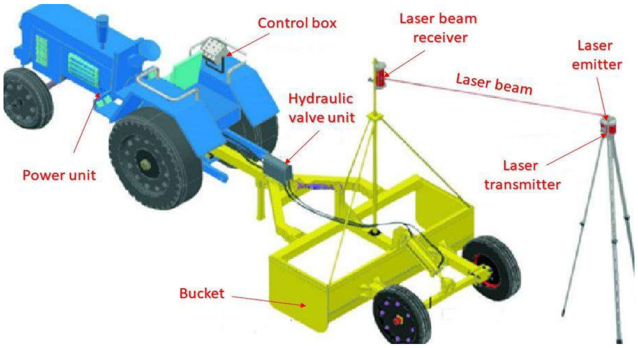

Fig. 1. Components of laser leveler with tractor

before and after land levelling. Depending on the amount of soil that must be cut it may also be necessary to plough during the levelling operation. Laser land levelling technology achieves a flat even surface by using a rotating laser transmitter placed at the side of the field. This controls the degree of cut and fill to be made by the tractor towed laser land leveller. A levelling blade is used on wet fields and a drag bucket on dry fields. As the tractor moves the leveller across the field, the signal from the transmitter is picked up by a receiver mounted on top of the laser land leveller. This is then routed via a control box in the tractor cab which operates hydraulic valves, which raise and lower the bucket or blade so as to level out undulations in the field. The tripod-mounted transmitter in the foreground, at the side of the field and the corresponding receiver is visible above the laser land leveller. The soil can also be seen, piling up within the drag bucket as high spots are eliminated including even the tyre tracks behind the machine.

RESULTS AND DISCUSSION

Adoption of laser leveller in Punjab and Haryana: The work on laser land levelling was started in rice crop initially from 2005-06 from 8 units of machine at PAU, Ludhiana and various farmer's field in farmer's participatory research mode. Few machinery modifications has also been done like hitch system of scraper bucket was modified from its V shape to Y shape which improved it's turning radius by 27 percent for its easy manure-ability in the small fields and hydraulic control system of the scraper bucket was simplified for easy, simplified and leak proof operation and machine working. The main intention was to authenticate the replicated trial's results (in terms of water saving and better yields etc.) with the farmer's managed fields. Then more efforts were made for the popularization of this technology by organizing trainings for farmers, contractors and Govt officials, demonstrations, field days and workshops for all the stake holders. Machinery manufacturers were also enrolled into the potential future growth of the technology to maintain the price & quality simultaneously (Lohan et al 2014). In both states (Punjab and Haryana) number of laser levellers increased and exponential growth curves fitted in each case showing in Figure 3. Increasing trend showed this technology is highly adapted in both states.

Irrigation water conservation in different crops: A significant reduction in total water use in wheat as well as rice was recorded due to precision land leveling compared to traditional land levelling. Kaur et al (2012) emphasized the adoption of laser level technology the paddy cultivation. The study shown that with laser levelling farmers could save irrigation water and energy by 24 percent and water productivity improved by 39 percent (Pradeep et al 2014). It has a great potential for optimizing the water-use efficiency in paddy cultivation without any disturbing and harmful effect on

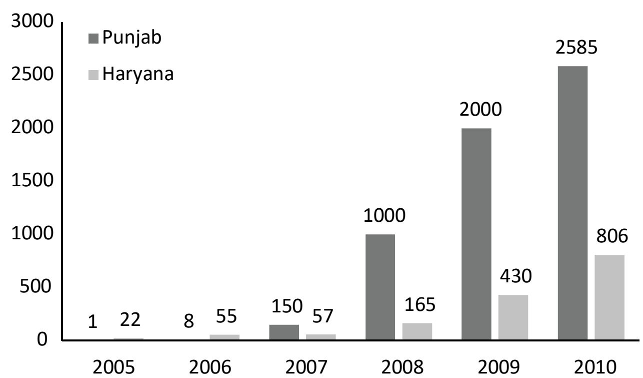

Fig. 2. Year wise availability of laser leveller in Punjab and Haryana

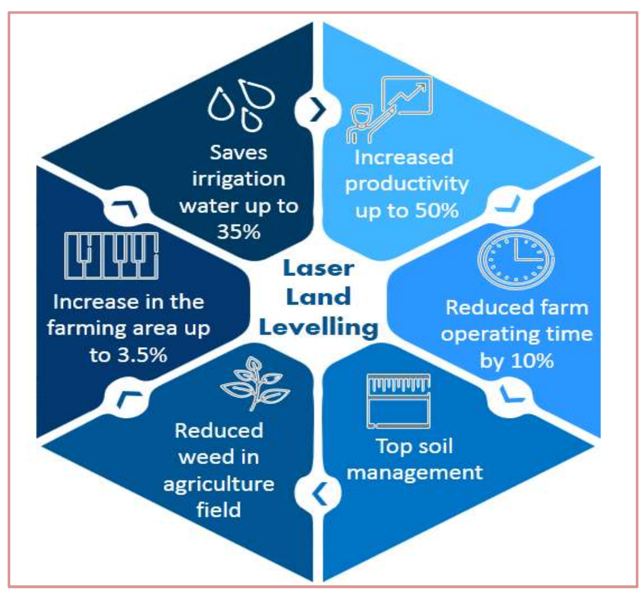

Image courtesy: Parihar et al 2021

Fig. 3. Benefits of laser land levelling

its productivity. On wheat and cottons crops it was observed that about 21 percent of irrigation water may be saved by the adoption of laser levelling technology and also obtained higher yield and profit margins comparatively traditional methods (Shahani et al 2016). In the pearl millet cultivation with laser land levelling technology, It has been observed that it saves 32.18 percent of irrigation water (Ahuja et al 2016). Kanannavar et al (2016) suggested laser levelling technique recorded 63.68 percent more water productivity over traditional levelling, indicating more production with less irrigation water. It was established that laser land levelling technology saves precious water and results in the highest water productivity in groundnut production also. Land levelling with laser leveller is a recent resource conservation technology and has been proven to save water and energy over the conventional methods (Table 2).

Reduced weed emergence: Laser land levelling results in uniform moisture distribution to the entire field and allows uniform crop stand and growth, thus resulting in lesser weed infestation. On the other hand, unlevelled fields frequently exhibit patchy growth. The areas with sparse plant populations are zones of higher weed infestation because weeds are mostly C4 plants and possess the inherent genetic capability to suppress crop growth. Reports on reduction of weed population by laser land leveling indicate beneficial effects in term of reduction in weed population. Also results in enhanced weed management efficiency as removal of less number of weeds manually requires less time. Moreover a 75% reduction of labour and cost of weeding can be achieved through precision land leveling (Rickman 2002). Reduction in weed population in wheat after 30 days of sowing was recorded under precisely levelled fields in comparison to traditional levelled fields (Jat et al 2006). Ahuja et al 2016 studies the weed occurrence in pearl millet cultivation using laser land levelling, it was observed that weed occurrence reduces by 27.81 percent (Table 2).

Crop production: A considerable increase in yield of crops is possible due to laser land leveling. Results shows that a perceptible yield advantage of laser land leveling over traditional leveling. Jat et al. 2003 reported that the wheat production increased from 4.3 to 4.6 t ha^{-1} under laser leveling. The improvement in crop production through laser land leveling was associated with overall improvement in the growth and yield attributing characters of the crop due to better environment for the development of the plants under well-levelled field. In another investigation, Pal et al 2003 reported a significant improvement in growth and yield of upland paddy due to laser land leveling compared to traditional land levelling. Ahuja et al 2016 studied the pearl millet cultivation with laser land levelling. It was reported that pearl millets yield and net profit increased by 52.77 percent and 141.57 percent respectively. The above studies indicate that laser levelling is prominent technology for achieving favourable environmental conditions for the crop establishment which leads to better crop growth and production (Table 2).

Cost of crop production: Rickman (2002) reported that although the initial cost of land leveling is convincingly high,

Table 2. Influence of laser levelling technology over traditional levelling method

Reported authors	Irrigation water conservation	Increased cultivable area	Increased yield	Uptake efficiency of fertilizer	Reduced weed	Reduced irrigation cost/Energy saving	Crop	Location
Sapkal et al 2019	-	-	12%	-	-	-	Paddy	Haryana
Kanannavar et al 2016	63.68%	-	-	-	-	-	Groundnut	Karnataka
Shahani etal 2016	21%	-	-	-	-	-	Wheat and cotton	Sindh, Pakistan.
Ahuja et al 2016	32.18%	-	52.77%	-	27.81	-	Peal millet	Haryana
Aryal et al 2015	10–12%	-	7-9	-	-	-	Wheat	Punjab and Haryana
Kaur et al 2012	39%	-	4%, 42 %	-	-	44 %	Paddy, Sugarcane	Punjab
Jat et al 2011	50%	-	16.6%	Significantly improved	-	-	Wheat	Uttar Pradesh
Sidhu and Vatta 2010	36.19 cm	-	0.78 t/ha.	-	-	-	Paddy	Punjab
Bhatt and Sharma 2009	25-30%	-	-	-	-	-		Punjab
Jat et al 2006	25%	3-6 %	4%	-	-	25%	Paddy	Haryana
Rickman 2002	-	-	24%	-	up to 40	-		Punjab
Pal et al 2003	-	-	7.30 %, 6.10%	-	-	-	Paddy, Wheat	Uttar Pradesh

however a conclusive financial benefit observed from land leveling. The additional cost and benefits of precision land leveling over long period that the irrigation cost was reduced by 44 percent over the conventional practice. It has a great potential for optimizing the water-use efficiency in paddy cultivation without any disturbing and harmful effect on its productivity in long term. The incremental per hectare increase in gross margins of the technology adopters has been to the tune of 3244 Rs/ha (Ahuja et al 2016). The adoption of this technology has reduced irrigation cost by 720 Rs/ha which is about 44 percent over the conventional practice. Also, enhance the cultivable area by of 3-6 per cent this is due to a reduction in bunds and channels in the field. Undoubtably, laser land levelling technology is a proven resource conservation technology which reduces the overall cost of the production. The effect of laser land levelling toward the resource conservation has presented in the Table 2.

Benefits of laser land levelling: Laser land levelling is a recognized technology that has been developed in order to solve some of the problems faced by conventional levelling methods. It is more accurate, and it can be used on a wide variety of soil types, while conventional levelling can only be used on the most suitable soil types. The advantages of laser land levelling over conventional levelling techniques are that it improves crop establishment, reduces weed infestation, and improves uniformity of crop maturity. It also increases cropping intensity because it helps farmers to use their time more efficiently. Laser land levelling is an innovative technique that has been used in India for quite some time now (Suthakar et al 2008). It is a cost-effective and efficient way to prepare the land for irrigation purposes and can be done with less water than conventional levelling techniques. Conventional levelling techniques require a lot of water while laser land levelling needs less. It also increases the size of the field as it eliminates bunds. Some of the key benefits of the laser levelling over conventional levelling method shown in the Figure 3.

Challenges to adopting this technology: In order to understand the poor adoption of this technology several surveys conducted to identify the reasons behind it. Financial constraints and lack of knowledge about the technology are important limiting factors in the adaption of this technology. In other words, cash constraints at time of sowing are known to be a major limitation in adaption of technology. The main factors that are significantly associated with adoption of this machine are farm size and government connections. Also, there are very few subsidised programmes running by state government for promoting laser levelling technology. On the other hand, at least 2 skilled persons required to operate it in the field. Where skilled persons are not readily available in the agricultural field for operating such machineries. Besides, this technology requires more maintenance compare to other traditional levelling techniques and is less efficient in uneven and small sized fields. Most of the manufacturer and dealers are from Punjab and Haryana hence, states namely Madhya Pradesh, Uttar Pradesh, Bihar, Jharkhand and West Bengal have poor availability of dealership at block level (Pradeep et al 2014). Alternatively, adoption of this technology might be low if farmers are misinformed or unaware of benefits of laser land levelling. Studies about of technology adoption provide some evidence of breakdowns in flow of information in some regions where farmers complain that they are underserved by official information channels, such as visits from agricultural extension officers and technology demonstrations.

CONCLUSION

The laser land levelling is very promising technology because it has many advantages over the traditional ploughing methods, such as irrigation water saving, increased cultivation area, reducing the weed problems and increase the crop yield. This method is also more time efficient and requires less labour which makes it seem like an attractive to farmers. The effectiveness of laser land levelling technology is determined by its suitability for different types of crops, adoption of this technology promotes agricultural productivity, energy use efficiency, and water use sustainability. IGP having scope to use and test this technology for resources conservation, where conditions are very different on agroecological and social fronts. The laser level technique is costly for marginal and small farmers. The availability of institutional support and provision of technical knowledge to the farmers needs to be given more attention to the adoption of this technology.

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Received 21 July, 2022; Accepted 22 October, 2022