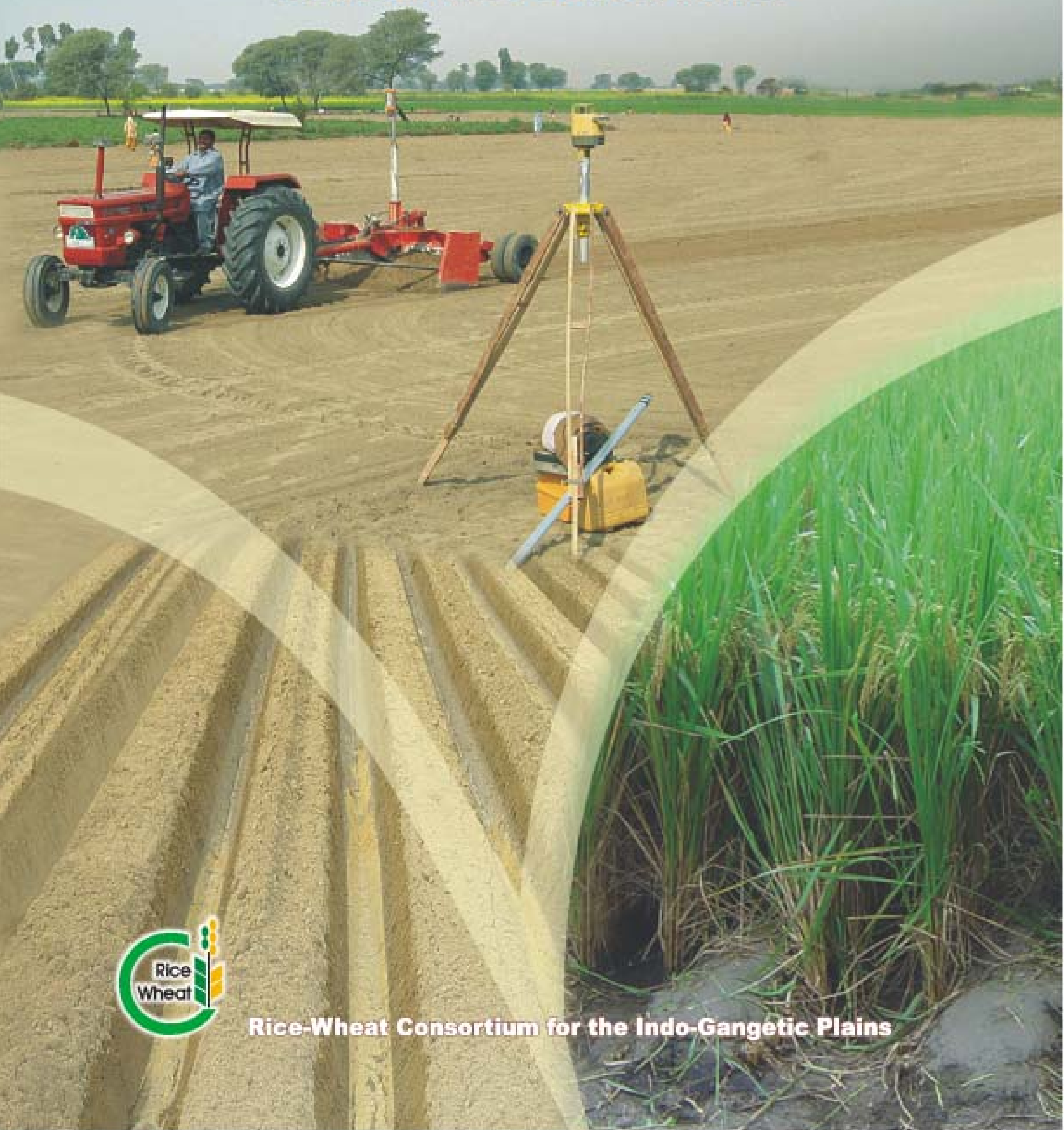
Rice-Wheat Consortium Technical Bulletin 7

Laser Land Leveling: A Precursor Technology for Resource Conservation



Rice-Wheat Consortium for the Indo-Gangetic Plains

Citation: M.L. Jat, Parvesh Chandna, Raj Gupta, S.K. Sharma and M.A. Gill. 2006. Laser Land Leveling: A Precursor Technology for Resource Conservation. Rice-Wheat Consortium Technical Bulletin Series 7. New Delhi, India: Rice-Wheat Consortium for the Indo-Gangetic Plains. pp 48.

The initial support from the Asian Development Bank (ADB) and International Fund for Agricultural Development (IFAD) provided the groundwork for establishment of the RWC in 1994 and formalizing the collaborations between the NARS, IARCs and ARIs. The NARS-driven strategic ecoregional research initiatives with financial support from the Government of the Netherlands, Development Fund for International Development (DFID), UK, New Zealand, Australia and the US Agency for International Development (USAID) and the World Bank have grown over the years into a dynamic agenda of resource conservation technologies appropriate to different transects of the Indo-Gangetic Plains. The on-going successes in scaling-up resource conservation technologies for enhancing productivity and sustainability of the rice-wheat systems are beginning to create a revolution and favorably benefit large areas and more numbers of farm families.

The laser land leveling initiative has been supported by USAID-India funded project "Accelerating the Tillage Revolution in the Indus-Ganges Basin: Fostering Adoption of Resource Conserving Technologies to Promote Economic Growth, Resource Conservation and Food Security"

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2006

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Acknowledgements

We express our gratitude and sincere thanks to Dr. Joesph Rickman from International Rice Research Institute for developing a technical manual on laser land leveling, providing a laser unit and training researchers and service providers on various aspects of this technology; Dr. Musthaq Ahmed Gill, Director General, On-farm Water Management, Lahore, Pakistan for providing another laser leveling unit to Rice-Wheat Consortium for experimentation on farmers' fields; and the USAID-India for the financial support provided through the project "Accelerating the Tillage Revolution in the Indus-Ganges Basin: Fostering Adoption of Resource Conserving Technologies to Promote Economic Growth, Resource Conservation and Food Security" for up-scaling and development of agribusiness with private entrepreneurs. We thank Dr. TBS Rajput, Principal Scientist, WTC, IARI, New Delhi for technical editing of the document. We also gratefully acknowledge the encouragement and logistic support provided by Indian Council of Agricultural Research in promoting laser land leveling technology.

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Laser Land Leveling: A Precursor Technology for Resource Conservation

Abstract

South Asian countries, comprising of India, Pakistan, Nepal and Bangladesh having a total geographical area of only 401.72 million hectares (Mha.), hold nearly half the world population of 3.1 billion (FAO, 1999). Nearly half of this land area is devoted to agriculture which provides livelihood and food security for 59% of the world population. There is a growing realization that agriculture of the post-Green Revolution will be guided by the need to produce more of quality food at reduced cost from the marginal quality lands and water resources. In the face of increasing resource constraints (land, labor, and water), new resource conserving technologies must be developed and adopted in both irrigated, and rainfed ecosystems to meet the food needs of a growing population. Particular attention has to be given to practices that increase water productivity and protect the environment.

Rice and wheat are the two principal food crops in the region that contribute 80%, in the food pool of the region. These crops are grown in sequence on 13.5 million hectares of the Indo-Gangetic Plains. The total water requirement for rice-wheat system is estimated to vary between 1382 mm to 1838 mm in the Indo-Gangetic Plains, accounting to more than 80% for the rice growing season. Thus to save on water, saving must be effected during rice growing season, the major water user in RW system. Future food security in this region is severely threatened by unsustainable groundwater use and inappropriate water management practices. For the rice-wheat systems of the Indo-Gangetic Plains, Rice-Wheat Consortium in collaboration with its NARS partners has been developing several water-saving technologies for water-short irrigated environments which besides the development of irrigation schedules and frequency, crop choices and their appropriate cultivars also included the precursor technology known as precision land leveling. In irrigated and rainfed environments, precision land leveling improves uniform application of water, betters the crop stands and helps reduce abiotic stress intensities, enhancing survival of young seedlings and robustness of the crop to withstand stress and stabilize yields through improved nutrient-water interactions.

Laser-assisted precision land leveling saves irrigation water, nutrients and agro-chemicals. It also enhances environmental quality and crop yields. In spite of the known benefits of precision land leveling, Indian farmers are unable to take full advantage of it and have to rely on traditional methods of land leveling which are labor-intensive and crude, and do not achieve a high level of smoothness of land surface. Laser land leveling technique is well known for achieving higher level of accuracy in land leveling. The technology described (laser leveling) offers a great potential for water saving, better environmental quality and higher grain yields. In India, about 1000 farmers have adopted the technology and covered more than 10000 acres in western Uttar Pradesh and Haryana through efforts of the Rice-Wheat Consortium and Project Directorate for Cropping

Systems Research under the aegis of USAID project. This study provides an overview of the technology, experience sharing, agronomic aspects, and economic gains along with farmers' views about the technology.

It is estimated that extension of laser-assisted precision land leveling system to just two million hectares of area under rice-wheat system could save 1.5 million hectare-meter of irrigation water and save diesel up to 200 million liters (equal to US $1400 million), and improve crop yields amounting to US$ 500 million in three years and reduce GHG emissions equivalent to 500 million kg. Laser-assisted precision land leveling system is also likely to increase the cultivable area in the range of 3-6% (due to reduction in bunds and channels in the field). Furthermore, on laser-leveled fields, the performance of different crop establishment options such as of zero tillage, raised bed planting, and surface seeding are known to improve significantly.

1. Introduction

The Indo-Gangetic Plain (IGP) of South Asia, formed by the fluvial action of the Indus and Ganges System, is one of the world's major food-grain producing regions. The region comprising of Bangladesh, India, Pakistan and Nepal supports world's most densely populated areas with more than 562 millions people (Census 2001 India, CIA estimates 2005) dependant mainly on the rice-wheat cropping system. In order to feed and provide livelihoods in South Asia, these countries have devoted nearly half of their total land area of 401.72 million hectares (Mha) to agriculture (FAO, 1999). For these nations, intensively cultivated and irrigated rice-wheat system of the IGP is of great significance as it represents 32% of the total rice area and 42% of the wheat area (Ladha et al. 2000; Hobbs and Morris, 1996) and contributes more than 80% of the total cereal production (Timsina and Connor, 2001). Rice-wheat system thus is the mainstay of the food security of the region, and is fundamental for providing employment, income and livelihoods for hundreds of millions of rural and urban poor in the IGP of South Asia (Evans, 1993; Paroda et al. 1994).

During the last few decades, high growth rates for foodgrain production (wheat 3.0%, rice 2.3%) in south Asia, have kept pace with population growth (APAARI, 2000). The food projections for the region on demand and supply of rice and wheat for 2020 (Rosegrant et al. 2001) suggest that South Asian demand and supply for rice will match nearly at 158 million tonnes. However, projected demand for wheat in 2020 will fall short of the supply by nearly 20 million tonnes (Table 1).

Table 1. Projections on demand and supply of rice and wheat in South Asia by 2020* in tonnes

Country	Projections for wheat		Projections for rice	
	Supply	Demand	Supply	Demand
Bangladesh	2185	4885	26270	27070
India	94780	100595	120100	120976
Pakistan	25963	33517	6524	4826
South Asia**	127370	147060	157940	158710

* Simulations by most recent IMPACT model of IFPRI. For more details on IMPACT, please refer to Chapter 3 in Rosegrant, M.W., M.S. Paisner, S. Meijer, and J. Witcover. 2001. Global food projections to 2020. Emerging trends and alternative futures. International Food Policy Research Institute, Washington DC. (http://www.ifpri.org/pubs/books/globalfoodprojections 2020.htm)
** Includes Bangladesh, India, Pakistan, Nepal, Afghanistan, Maldives and Sri Lanka.

India, a major foodgrain producer country of the region, is also facing the challenge of meeting the future demand of foodgrains due to diversion of land and water resources to other sectors of economy. With the current estimations, India would need 37% more rice and wheat by 2025 with 9 to 10% less water available for irrigation (Fig. 1) compared to year 2000. The future requirements of foodgrains and water have to be met through vertical growth by intensification, resource conservation, mechanization, and introduction of new genotypes for sustaining the growth of food production in the region. Utilization of underutilized/fallow lands in eastern gangetic plains would provide some relief to the overall situation in coming years

India has invested heavily in the development of irrigation water resources from a mere 26 million hectares in 1952 to more than 92.7 million hectares during 2004-05. However, there is a wide gap (17 mha) between the created (92.7mha) and utilized (82.7 mha) irrigation potential in the country. This gap is mainly due to inefficient water management. It is estimated that only by bridging the gap; an additional area of about 10 million hectares can be brought under assured irrigation - leading to an additional foodgrain production of about 60 million tonnes per annum. Most of the area in the country is irrigated by surface application methods such as flood irrigation, check basin, border strip and furrow irrigation. The application efficiency of these methods has been found to be only 30 to 50 percent as compared to attainable level of 60 to 80 percent. This is due to the mis-match in water application methods with the stream size, soil type, field size, and slope etc. In surface irrigation, land leveling is essential for high application efficiency that ensures high water-use efficiency and crop yield.

Indo-Gangetic plain is a region of gently slopping fertile alluvial soils. It is sometimes mistaken that these lands are naturally well leveled and do not require precision land leveling. However, the fact is that land slopes are varying from transect I to transect V. The average field slope in transect I and II (includes Pakistan Punjab, Indian Punjab and Haryana and western Uttar Pradesh) ranges between 1 and 3 degrees. The average field slopes range between 3 and 5 degrees in transect IV and V. The uneven field lead to accumulation of water on low-lying spots leading to nutrient losses, poor crop stand and low yields. Land holding size range varies from 1.45 to 2.67 ha in Punjab, 0.23 to 0.63 ha and 0.63 to 1.45 ha in eastern Uttar Pradesh and Bihar, and West Bengal respectively (Fig. 2). Size of land holding in Bangladesh is similar to that in West Bengal. Land holding size in Pakistan Punjab

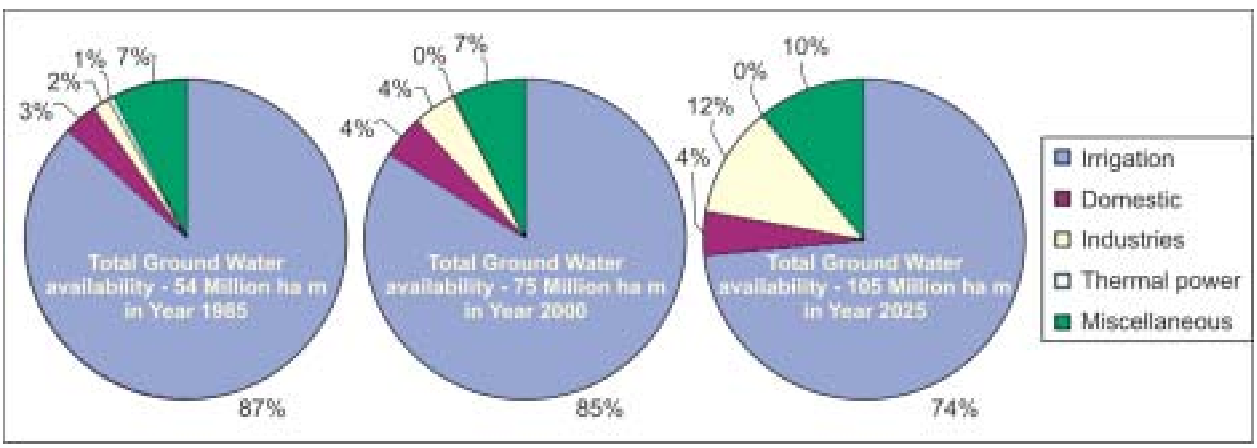


Figure 1. Projection of ground water availability in India, Source: CWC, 1992

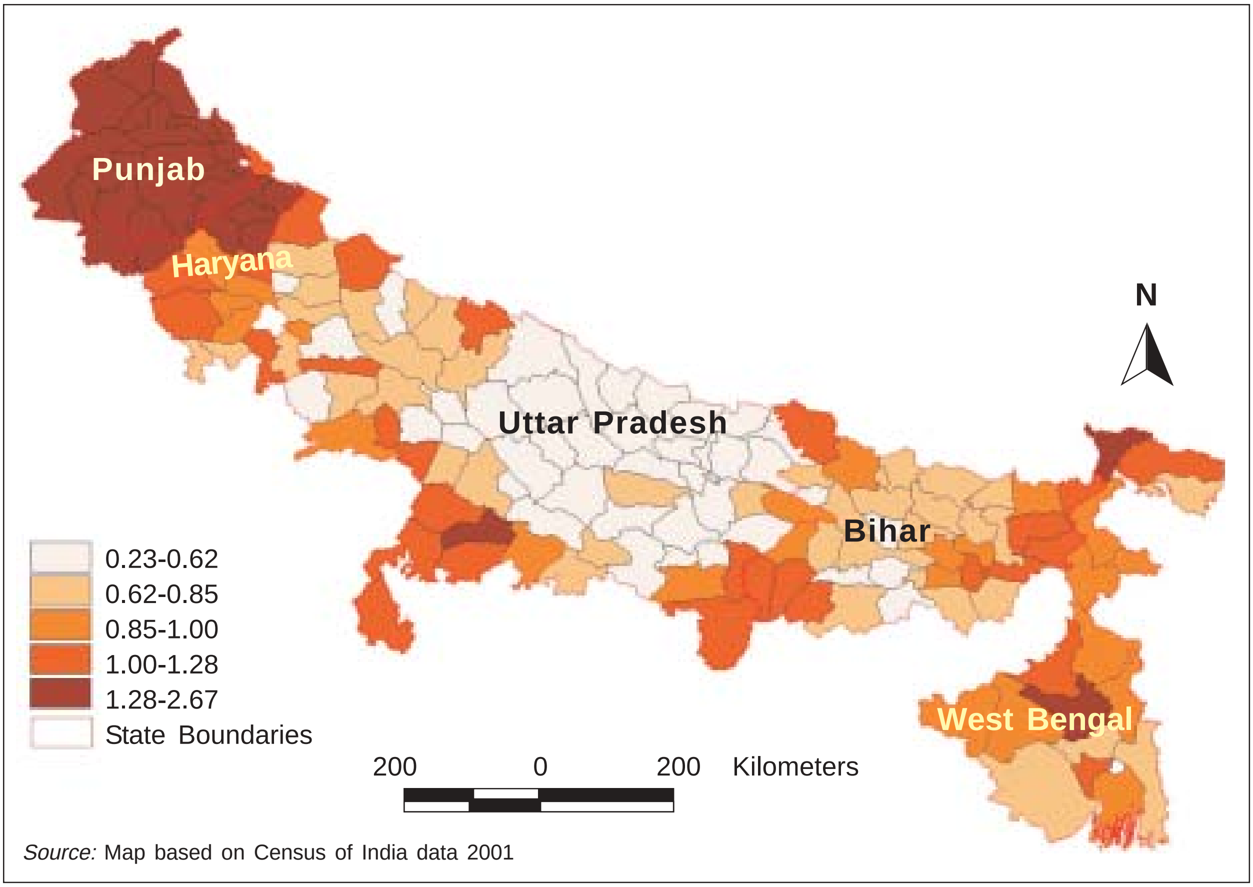


Figure 2. Map showing variation in farm size (ha) per cultivar in the IGP states in India

is much bigger than that in Indian Punjab. Small and marginal farm size leads to small sized field plots which is a major reason of low adoption of mechanization in eastern parts of the IGP. Therefore, leveling and consolidation of land is an urgent need for this region to increase the plot size for better water and nutrient-use efficiencies and higher crop yields.

Declining irrigation water availability and crop productivity and increasing food demand necessitate quick adoption of modern scientific technologies for efficient water management. The water and food productivity are low in the region, causing serious concerns for food security. Farmers have been practicing irrigated and intensive agriculture on alluvial soils of the IGP, for many years. Use efficiency of water at the field level has been poor in the IGP due to water loss in conveyance, application and distribution. Modern intensive agriculture relies on the timely planting for enhanced crop yields and profits. For high crop yields, farmers must ensure good seedling emergence, better crop stand and early crop vigor. Smoothness of land surface meets the objectives of achieving better crop stand, saving irrigation water and improving the use efficiency of precious inputs. Traditionally farmers level their fields using animal-drawn or tractor-drawn levelers (Fig. 3). These levelers are implements consisting of a blade acting as a small bucket for shifting the soil from higher to the low-lying positions. It is seen that even the best leveled fields using traditional land leveling practices are not precisely leveled (Fig. 4) and this leads to uneven distribution of irrigation water.

The common practices of irrigation in intensively cultivated irrigated areas are flood basin

Figure 3. (a) Traditional method of land leveling using animal-drawn wooden log. (b) Mechanised land leveling using tractor-drawn planker

and check basin irrigation systems. These practices on traditionally leveled or unleveled lands lead to waterlogging conditions in low-lying areas (Fig. 5) and soil water deficit at higher spots (Fig. 6). Significant amounts (10-25%) of irrigation water is lost during application at the farm due to poor management and uneven fields (Kahlown et al. 2000). Conservation agriculture practices coupled with precision land leveling facilitate uniform water application and reduce deep percolation losses of water.

Precision land leveling is known to enhance water-use efficiency and consequently water productivity. Conventional surface irrigation

Figure 5. Waterlogging in a wheat field

Figure 4. Uneven distribution of irrigation water under traditional land leveling

Figure 6. Non-uniform crop stand in an undulated field

practices in unleveled bunded units normally result in over irrigation (Corey and Clyma, 1973). This results in excessive loss of irrigation water through deep percolation and reduces the application efficiency up to 25% (Sattar et al. 2003). Precision land leveling helps even distribution of soluble salts in salt-affected soils (Khan, 1986), increases cultivable land area up to 3-5% (Choudhary et al. 2002; Jat and Chandana, 2004), improves crop establishment, reduces weed intensity (Rickman, 2002) and results in saving in irrigation water (Jat et al. 2003; Khattak et al. 1981; Ali et al. 1975).

Precision land leveling must be treated as a precursor technology for improving crop yields, enhancing input-use efficiency and ensuring long-term sustainability of the resource base in intensively cultivated areas.

2. Leveling: A prerequisite for other farming operations

Surface irrigation methods depend on gravity and slope that make the water flow in a field. The water retention characteristics of the soil generally have spatial variability within the fields. Ideally, irrigation should apply water in a manner that accounts for field spatial variability. Land leveling is a prerequisite for better agronomic, soil and crop management practices as it has a direct bearing on all the farming operations. All major farming operations from land preparation to seedbed preparation, seed placement and germination require an optimal soil moisture condition. The traditional method of leveling is not cost effective. An assumption is normally made that the soil water deficit at the time of irrigation is uniform over the whole field. This leads to the requirement that irrigation systems apply water in a manner that results in uniform infiltrated depth throughout the field. This is rarely achieved in practice as it depends on stream size, land conditions and soil type. The non-uniformity of application depth markedly affects efficiency of utilization of irrigation water. Higher levels of uniformity of irrigation water application may be achieved by precise land leveling and using appropriate stream sizes based on infiltration rate of the soil. (Khepar et al. 1982)

The advanced method to level or grade the field is to use laser-guided leveling equipment. Laser leveling provides a very accurate, smooth and graded field. This allows for ideal control of water distribution with negligible water losses. Laser leveling improves irrigation efficiency and reduces the potential for nutrient loss through better irrigation and runoff control. Laser land leveling facilitates uniformity in the placement of seedlings by the rice transplanter which helps in achieving higher yield levels. The precisely leveled surface leads to uniform soil moisture distribution which results in good germination, enhanced input-use efficiency and crop yields, whereas undulated land conditions lead to consumption of more energy, and ultimately to higher cost of production.

The general practice of nitrogen application in India is through broadcasting of urea. Under the uneven soil surface conditions, the applied nitrogen is washed away from higher levels to lower levels with irrigation water and is leached down to low-lying depressions, resulting in low fertilizer-use efficiency. On the other hand, perfectly leveled field leads to uniform distribution of nitrogen which further results in better fertilizer-use efficiency and higher yields.

3. Land leveling: Concepts and techniques

Land leveling is done to enhance use efficiency of water and fertilizer nutrients, and to improve the crop stand and yields. However in the initial years crop yields at times are adversely affected, that can be avoided if some of the relevant conditions described below are taken into considerations.

- **Level maintenance:** With appropriate tillage practices
- **Fertilizer needs of cut areas:** Cut areas require additional nutrition. Compound fertilizer (N and P) can be applied at around 50 -100 kg/ha
- **Subsoil considerations:** Make sure that exposed subsoil is not problematic (acidity, salinity, sodicity, higher percolation rate, etc.) while going for heavy cuts
- **Efficiency:** Identify higher and lower level grades in the field to minimize soil movement
- **Operator's skill:** Efficient land leveling depends on operator's skill and experience

3.1 Land leveling techniques

3.1.1 Conventional leveling

Conventionally, farmers use plankers drawn by draft animals or by small tractors. However, farmers in Punjab, Haryana and Uttar Pradesh use iron scrappers or leveling boards connected to 4-wheel tractors. Traditional land leveling includes field survey, staking and designing the field, calculation of cuts and fills and then using a scraper and a land plan to even the land. Despite all these labor-intensive efforts, desired accuracy is not achieved. These leveling practices are crude and do not achieve a precise land leveling. Different land leveling techniques require different tools and conditions varying in operating times and accuracy. (Table 2)

Bulldozers

Bulldozers are effective in highly undulated fields for initial leveling across larger areas, especially in cases where the terrain is rocky and the soil is hard. However, they should not be seen as presenting the perfect solution to precise leveling. Precise leveling can be achieved using advanced methods (such as application of laser technologies, as described below) that complement and refine bulldozer-leveling.

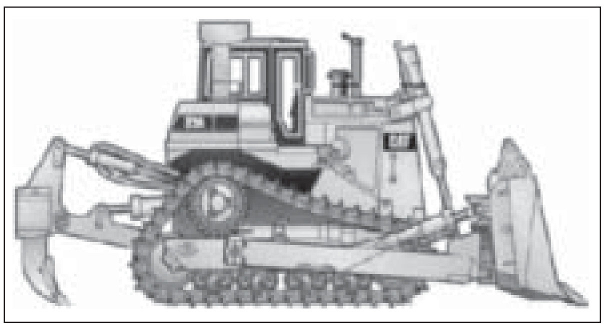


Figure 7. Bulldozers are used for initial leveling in highly undulated fields

3.1.2 Laser land leveling

Laser leveling is a process of smoothening the land surface (± 2 cm) from its average elevation using laser equipped drag buckets to achieve

Table 2. Time required and suitability of different land leveling techniques

Land leveling techniques	Capacity * (ha/day)	Leveling accuracy (cm)	Suitable for plot area (ha)
Animal	0.08	+/- 4-5 cm	< 0.25
Hand tractor	0.12	+/- 4-5 cm	< 0.25
Blade	0.5-1.0	+/- 4-5 cm	< 0.50
Bucket	0.5-1.0	+/- 4-5 cm	> 0.10
Laser	up to 2 ha	+/- 1 cm	> 0.10

** Capacity depends on farm size and shape, crop residue, soil, type and, moisture conditions and the operator's skill.*

precision in land leveling. Precision land leveling involves altering the fields in such a way as to create a constant slope of 0 to 0.2%. This practice makes use of large horsepower tractors and soil movers that are equipped with global postioning systems (GPS) and/or laser-guided instrumentation so that the soil can be moved either by cutting or filling to create the desired slope/level. (Walker, Timothy et al. 2003)

3.2 Considerations in land leveling

There are certain prerequisites for land leveling to achieve high precision with less cost. The following should be considered for precise land leveling

3.2.1 Field slope

A slope of 0 to 0.2% is good for optimum water flow. A small channel (e.g., 10-15 cm deep) placed in the middle of the field serves to collect the drainage water and deliver it to a drain. Good drainage characteristics add to harvest efficiency as well as create a large window for practices that need to be followed in the succeeding crop season.

3.2.2 Infiltration

It is important to check infiltration rates of the subsoil. In areas where a large amount of soil is moved and hard pans are removed, excessively high infiltration rate may lead to increased rates of nutrient and chemical leaching. Infiltration rate of the subsoil should at least match that of the soil surface.

3.2.3 Cost of leveling

The initial cost of land leveling using tractors and scarpers is high. The cost varies according to the topography, the shape of the field and the equipment used. Table 3 shows a cost comparison for leveling one hectare of land using animals and machines (Bell and Rickman, 2000).

The cost of leveling one hectare of land using tractors is between Rs. 1,840 and Rs. 2,000. This cost varies with the volume of soil to be moved and the soil type. Studies over many sites have shown that the actual cost ranges from Rs. 120 to Rs. 200 per 10 mm of soil moved per hectare.

3.2.4 Maximum possible soil cut and soil fertility

Soil cut differs from field to field with dissimilarity of subsurface fertility and soil depth. Therefore, it is necessary to encompass knowledge about immediate subsurface fertility before using laser leveling. Infertile soil should not replace

Table 3. Cost of leveling per ha using animals and machines

Item	Animal + leveling board	2-wheel tractor + harrows	4-wheel tractor + blade
Purchase price (Rs.)	20,000	40,000	4,80,000
Time (days)	12	7	0.5
Operating cost (Rs./ha)			
Labor cost (Rs.)	600	360	10,000
Fuel & oil cost(Rs.)	-	880	1,300
Repair cost (Rs.)		200	300
Pumping costs (Rs.)	240	240	-
Fixed cost (Rs./ha)			
Depreciation or replacement cost (Rs.)	480	480	300
Total cost (Rs./ha)	1,320	1,840	2,000

fertile top layer, which may result in decreased yield in approaching seasons. Observations from 71 field sites (Fig. 8) in Ghaziabad and Meerut districts have revealed that yield losses are minimal when soil cut is less than 10 cm, and yield losses increase with the deepening of the soil cut. "*Cut*" areas may be less fertile than the fill areas where the top soil has been shifted. Farmers have reported that use of poultry and farmyard manure in cut areas helps to reduce yield variability in the first season.

(upto to 5.0 ha) and large farmers (more than 5.0 ha). A total of 36 informants from different categories were selected. The farmers were requested to rank different leveling technologies adopted in and around the village on pre-determined criteria. On the basis of matrix ranking using weightage score index, it was observed that the most favorite leveling equipment in the slected villages was a tractor-drawn leveler, followed by wooden plank, puddler, Singh *patela* and ditcher/ trencher (Table 4).

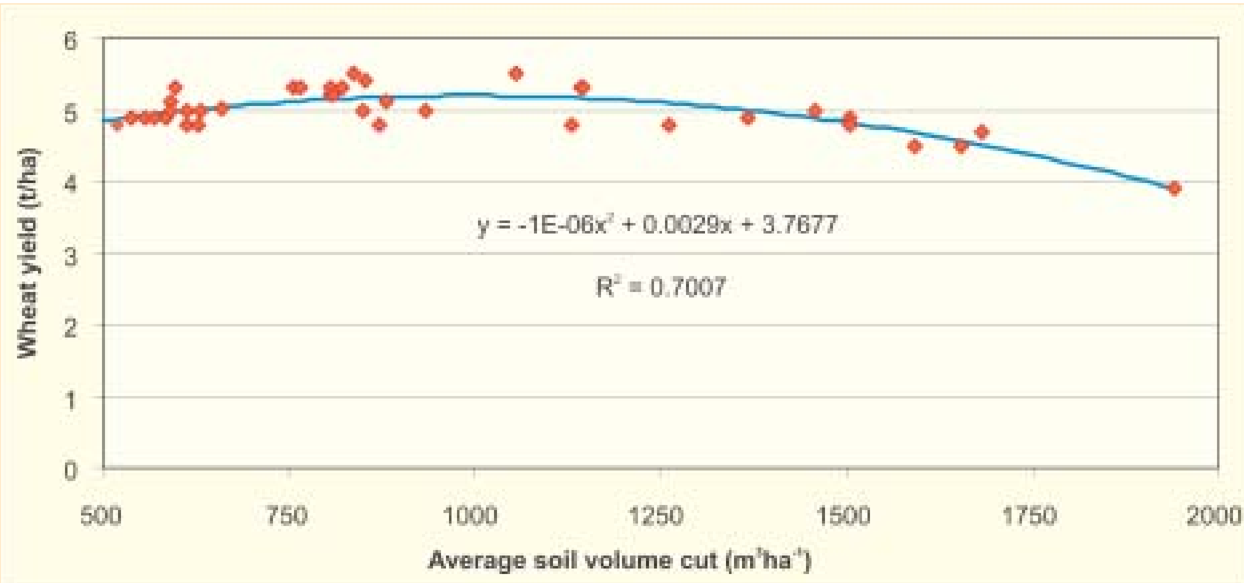


Figure 8. Relationship between average soil volume cut and crop yield

3.3 Quantification of existing land leveling practices

Participatory rural appraisal (PRA) study was carried out in 10 villages of western Uttar Pradesh. Matrix ranking technique of PRA was adopted to analyze the farmers' decision and behavior towards adoption of leveling technology (Rajput & Patel, 2005). To understand the differences in the farming practices amongst farmers belonging to different economic levels, their socio-economic analysis was also done. Farmers were classified into three categories on the basis of the size of their land holding namely, small (up to 2.5 ha), medium

Generally, rice farmers believed that their lands were level and needed little or no further improvements. But grid survey data has indicated, that most rice fields were not adequately leveled and required further land leveling (Fig. 9). A relationship was developed relating the soil surface with the resulting water-use efficiency.

3.4 Estimation of leveling indices

The land leveling grading reflects the precision of the leveled fields. This precision depends on the volume of soil in the cut or fill in relation to the desired slope, thus representing a quantitative value

Table 4. Ranking of different land leveling equipments adopted by the farmers

Criteria	Wooden plank	Singh patela	Tractor-drawn leveler	Puddler	V-ditcher/ A-trencher
Least cost of equipment	9.00	7.33	7.00	6.67	5.00
Easy availability	8.33	6.00	8.67	8.00	4.67
Precision in leveling	7.67	7.00	9.00	6.67	5.00
Less maintenance	9.00	8.00	7.34	6.67	6.00
Easy in operation	8.00	7.00	9.00	6.67	5.67
Availability of repair facility	7.67	6.67	9.00	7.00	5.34
Easy to transport	7.33	6.67	9.00	7.33	5.67
Total	57.02	48.68	59.01	49.02	37.35
Overall rank	**II**	**IV**	**I**	**III**	**V**

Note: Buck scraper did not find any place in the ranking

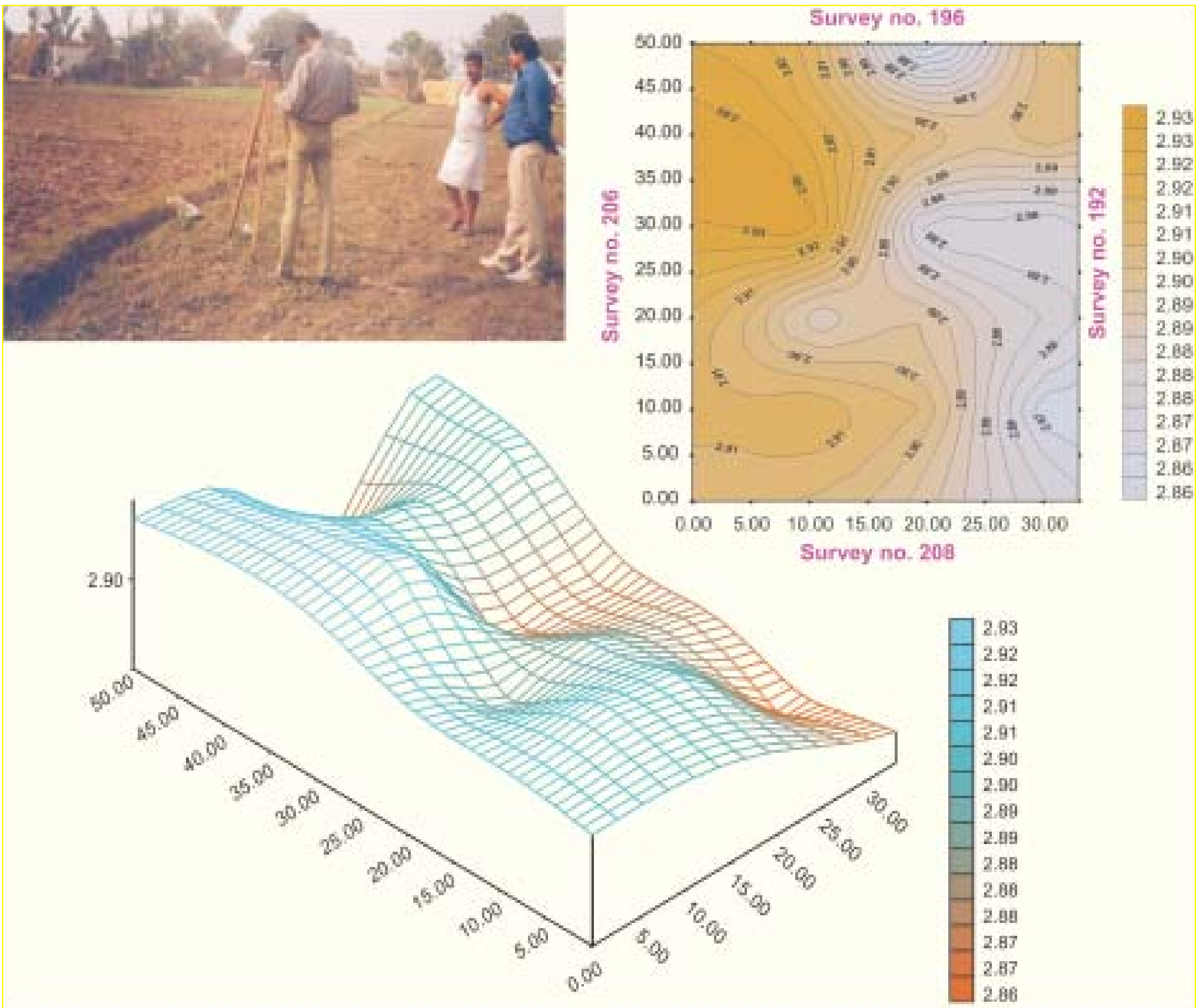


Figure 9. Topographic survey, contour map and digital elevation model of village Lakhan, Ghaziabad

.Leveling index (LI) and Land uniformity coefficient (LUC) were calculated to assess the smoothness of the land surface. LI was taken as the average numerical variation between the proposed or designed levels and the existing average field level (Agrawal and Goel, 1981) as follows;

$$LI = \frac{\sum |DL_i - AL_i|}{N} \quad \text{..............................} (1)$$

Where,

DL_i = designed grid level at point i, cm

AL_i = existing grid level at point i, cm

N = total number of grid points

The lower limit of LI is zero, and LI of zero indicates to perfect leveling of the field. Increasing values of LI reflect poorer quality of field leveling which results in low irrigation efficiency. The second leveling index selected for the study was Land uniformity coefficient (LUC) (Tyagi and Singh, 1979). LUC represents the magnitude as well as the frequency of occurrence of successively larger undulations in the field. The highest value of LUC is 1.0, which reflects a perfectly level surface. Decreasing values of LUC represent successively poorer quality of land leveling. The LUC is defined as:

$$LUC = \left(1 - \frac{\sum |DL_i - AL_i|}{\sum DL_i}\right) \quad \text{..............................} (2)$$

A perfect relationship was recorded between LI and field size and the LI was found increasing linearly with increase in the land area (Fig. 10). The relationship between LUC and land area, however, showed inverse relationship i.e. increase in area caused decrease in LUC values. Increase in LI with land area and decrease of LUC with plot size reflect to increase in unevenness of field surface. Similar results have been reported earlier by Kulshrestha and Shukla (1980). Farmers generally take decision about the leveling operation on the basis of their visual inspection of the fields. In small fields, the chances of amendments are more than in the larger fields. Therefore larger fields are more undulated than smaller fields. Results indicate that all three efficiencies (application, storage and distribution) were highest in case of fields having least LI and these efficiencies decreased with successively higher values of LI, in comparatively unleveled fields (Fig. 11). The application, storage and distribution efficiencies in the fields having the least value of LI of 2.9 cm were 82.0%, 35.1% and 19.7% higher respectively, as compared to a field having 13.0 cm LI.

The study indicates significant increase in irrigation efficiencies of wheat and rice through

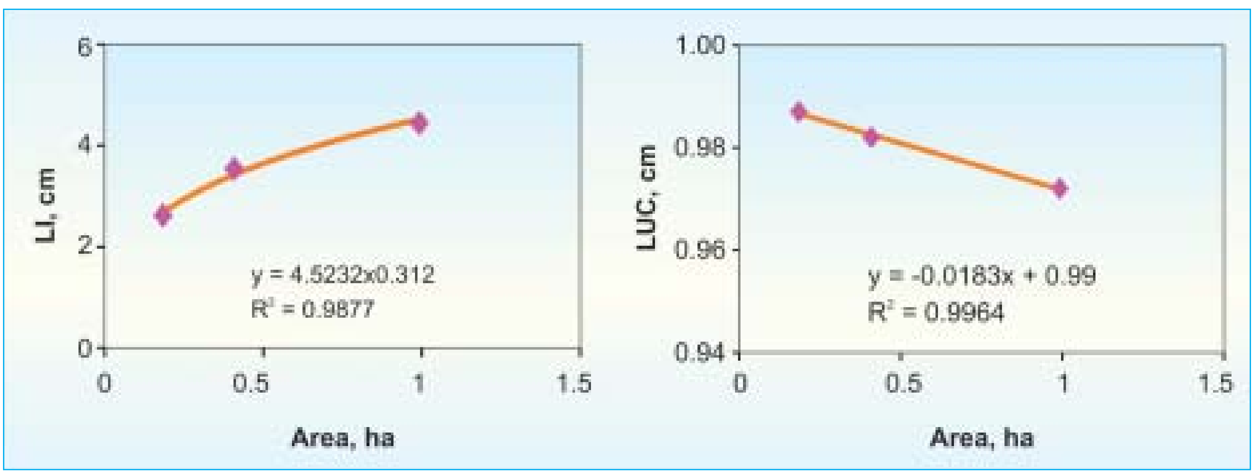


Figure 10. Relationship between leveling indices and farm area

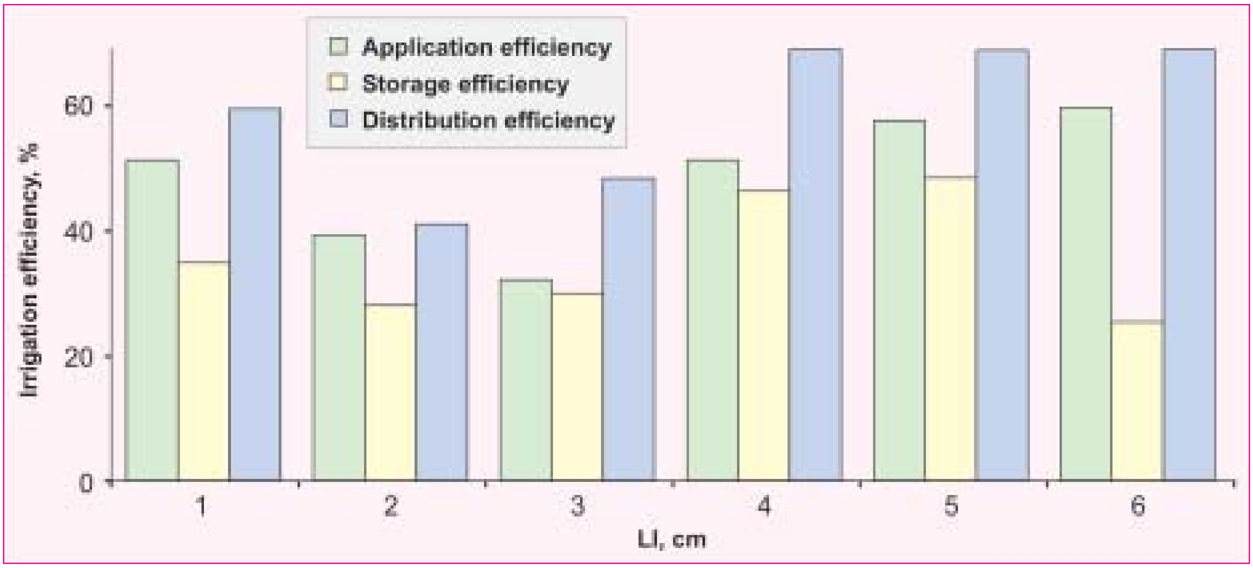


Figure 11. Relationship between LI and irrigation efficiencies of different fields in village Masauta, Ghaziabad

precision leveling using laser land leveler (Rajput and Patel, 2004). Laser leveling, thus will not only save precious irrigation water but will also help achieve high water use efficiency through more uniform water application.

4. Laser land leveling

The introduction of laser leveling in the 1970's produced a silent revolution that has raised potential of surface irrigation efficiency to the levels of sprinkler and drip irrigation (Erie and Dedrick 1979). Laser-controlled land leveling equipment grades fields to contour the land for different irrigation practices. With sprinklers, a perfectly level field conserves water by reducing runoff and allowing uniform distribution of water. Furrow irrigation systems need a slight but uniform slope to use water most efficiently. Laser leveling can reduce water use by 20-30% and increase crop yields by 10-20%. The quality of land leveling in zero-slope fields can be estimated through the standard deviation (SD) of soil surface elevation. A field leveled with conventional equipment can attain a standard deviation of 20-30 mm, while using laser leveling the technical limit extends upto 10 mm. Figure 13 presents the evaluation of the water application efficiency (AE) in a particular case as a function of SD (Playán et al. 1996). The figure reveals that the introduction of laser leveling can result in more than 10%

Figure 12. Laser-leveled field prepared for rice transplanting

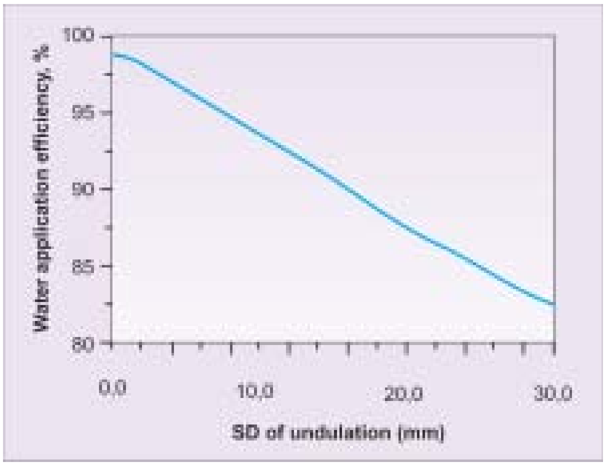


Figure 13. Simulated effect of the quality of land leveling (characterized by the standard deviation of soil surface elevation) on water application efficiency

increase in application efficiency, while the cost of the leveling operation is two to three times that of a standard tillage operation.

Before starting the laser land leveling process, the field should be ploughed and a topographic survey be carried out. One of the measures to improve irrigation efficiency is zero-grade leveling for crop production. Zero-slope fields can be flushed or drained more quickly. Level fields allow for a more uniform flood depth, using less water (Figs. 14 & 15) and reducing pumping costs. Benefits from precision leveling of land extend for many years, although some minor land smoothing may be required from time to time due to field operations and weather conditions. Laser-controlled precision land leveling helps to:

- Save irrigation water
- Increase cultivable area by 3 to 5% approximately
- Improve crop establishment

Figure 14. Direct seeded rice in a laser-leveled field

Figure 15. Wheat on furrow irrigated raised bed system (FIRBS) in a precisely leveled field

- Improve uniformity of crop maturity
- Increase water application efficiency up to 50%
- Increase cropping intensity by about 40%.
- Increase crop yields (wheat 15%, sugarcane 42%, rice 61% and cotton 66%)
- Facilitate management of saline environments
- Reduce weed problems and improve weed control efficiency

4.1 Types of laser land levelers

4.1.1 Manual leveling lasers

Set-up of a laser leveling instrument requires the operator to manually level the unit by using the units' screws and bubble vials. These lasers rely on tubular bubbles for leveling. The user needs to level the laser in both the X-axis and Y-axis and rely on the bubbles for accuracy. These lasers can achieve a maximum accuracy of 1 cm at 100m.

4.1.2 Semi self-leveling lasers

These lasers adjust themselves automatically within a range using a compensator. To get to a prescribed range, the laser is equipped either with a circular bubble with a bull's eye, or electronic lights that turn green when you reach the self-leveling range. These lasers are very accurate and have a shut-off feature if the laser is bumped or goes out of the self-leveling range. They can achieve accuracy of at least 1 cm at 100 m.

4.1.3 Fully self-leveling lasers

These lasers automatically find and maintain level within a specified range. These lasers are equipped with an electronic level vial and servomotors. The servo motors level the instrument electronically and when leveled, the laser starts spinning. They are the easiest to use and can achieve accuracy of up to 2.5 mm at 100 m.

4.1.4 Split-beam lasers

These lasers emit simultaneous horizontal and vertical beams to establish both level and plumb reference lines.

4.2 Components of laser land leveling system

The laser leveler involves the use of laser (transmitter), that emits a rapidly rotating beam parallel to the required field plane, which is picked up by a sensor (receiving unit) fitted to a tractor towards the scraper unit. The signal received is converted into cut and fill level adjustment and the corresponding changes in the scraper level are carried out automatically by a hydraulic control system. The scraper guidance is fully automatic; the elements of operator error are removed allowing consistently accurate land leveling. The set-up consists of two units. The Laser transmitter, which is mounted on a high platform. It rapidly rotates, sending the laser light in a circle like a lighthouse except that the light is a laser, so it remains in a very narrow beam. The mounting has an automatic leveler built into it, so when it's set to all zeros, the laser's circle of light is perfectly level.

A laser-controlled land leveling system consists of the following five major components:

(i) Drag bucket

(ii) Laser transmitter

(iii) Laser receiver

(iv) Control box

(v) Hydraulic system

(i) Drag bucket

The drag bucket can be either 3-point linkage mounted on or pulled by a tractor. This system is preferred as it is easier to connect the tractor's hydraulic system to an external hydraulic ram than to connect the internal control system used by the 3-point-linkage system. Bucket dimensions and capacity will vary according to the available power source and field conditions (Fig. 16). Different bucket dimensions from 2 m width to 5.5 m width with matching requirements of tractors are presented in Table 5.

Table 5. Selection of tractor and scraper size

Tractor size Min/Max (HP)	Scraper width Min/Max (m)
30-50	2.0
50-100	2.0-3.0
100-125	3.0-3.5
125-150	3.5-4.0
>150	4.0-5.5

(ii) Laser transmitter

The laser transmitter mounts on a tripod (Fig. 17A & B), which allows the laser beam to sweep above the field. Several tractors with laser unit and drag bucket can work from one transmitter with guidance from laser receiver.

(iii) Laser receiver

The laser receiver is a multi-directional receiver that detects the position of the laser reference

Figure 16. Drag bucket

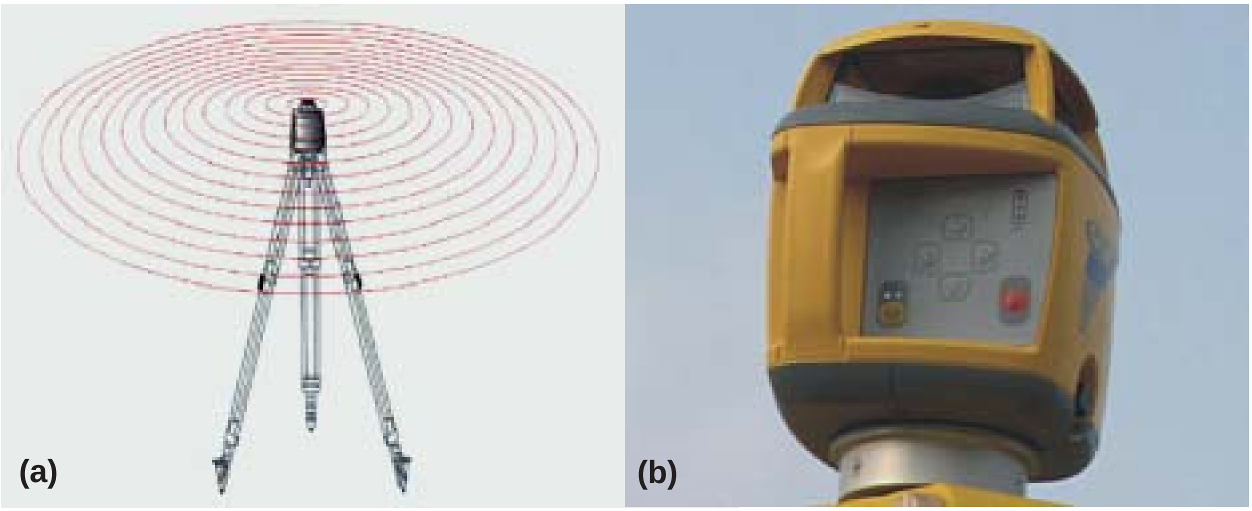


Figure 17. (a) A laser transmitter mounted on a tripod allows laser beam to sweep over the field (b) A close-up view of a laser transmitter

plane and transmits this signal to the control box. The receiver is mounted on a manual or electric mast (Fig. 18) attached to the drag bucket. It is mounted on the scraper. A set of controls allow the laser receiver to control the height of the bucket on the scraper. The operator can adjust the settings on the receiver, and he can override the receiver when he needs to pick up a bucketful of soil and transport it to another section of the field.

Figure 18. Laser receiver

(iv) Control box

The control box (Fig. 19) accepts and processes signals from the machine mounted receiver. It displays these signals to indicate the drag buckets position relative to the finished grade. When the control box is set to automatic, it provides electrical output for driving the hydraulic valve. The control box mounts on the tractor within easy reach of the operator. The three control box switches are

Figure 19. Control panel

ON/OFF, Auto/Manual and Manual Raise/Lower (which allows the operator to manually raise or lower the drag bucket.

(v) Hydraulic control system

The hydraulic system of the tractor is used to supply oil to raise and lower the leveling bucket (Fig. 20). The oil supplied by the tractor's hydraulic pump is normally delivered at 2000-3000 psi. As the hydraulic pump is a positive displacement pump and always pumps more oil than required, a pressure relief valve is needed in the system to return the excess oil to the tractor reservoir. If this relief valve is not large enough or malfunctions, damage can be caused to the tractors hydraulic pump.

Figure 20. Hydraulic control system

4.3 Operational aspects of laser land leveler

Laser-controlled grading technology is currently the best method to grade a field. The system includes a laser-transmitting unit that emits an infrared beam of light that can travel up to 700m in a perfectly straight line. The second part of the laser system is a receiver that senses the infrared beam of light and converts it to an electrical signal. The electrical signal is directed by a control box to activate an electric hydraulic valve. Several times a second, this hydraulic valve raises and lowers the blade of a grader to keep it following the infrared beam.

Laser leveling of a field is accomplished with a dual slope laser that automatically controls the blade of the land leveler to precisely grade the surface to eliminate all undulations tending to hold water. Laser transmitters create a reference plane over the work area by rotating the laser beam 360 degrees. The receiving system detects the beam and automatically guides the machine to maintain proper grade. The laser can be level or sloped in two directions. This is all accomplished automatically without the operator touching the hydraulic controls (Fig. 21).

4.4 Steps in laser land leveling

A. Ploughing of field

Ploughing of a field should start from the center outwards. It is preferable to plough the field when the soil is slightly moist, because if the soil is ploughed dry a significant increase in tractor

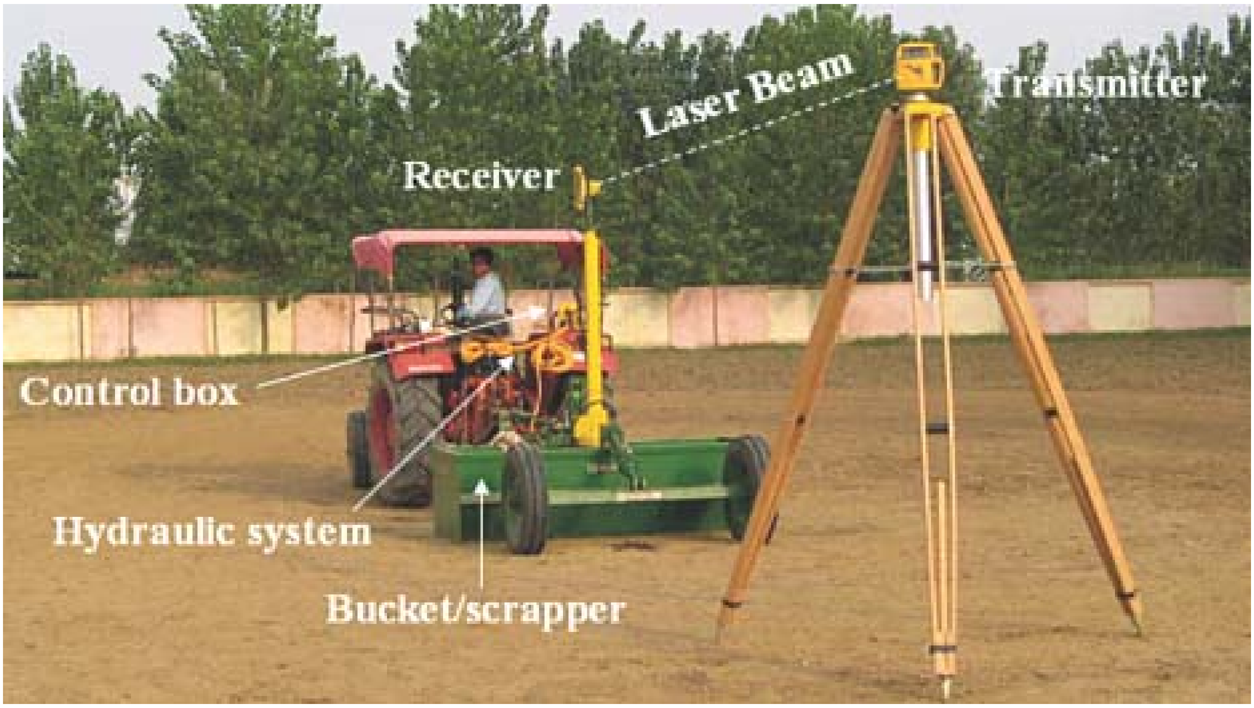


Figure 21. Functioning of laser land leveler

power is required and large clod sizes may remain. If the soil is very dry, a one-way disc or mould board plough may be used. Disc harrow implements are ideal for second workings. All surface residues need to be cut up or removed to facilitate the transport of soil.

B. Topographic survey

After ploughing, a topographic survey can be conducted to record the high and low spots in the field. Adjust the individual positioning of the tripod legs until the base plate is level. Attach the laser transmitter to the base plate. If the laser is not well leveled, adjust the individual screws on the base of the transmitter to get the level indicator (bubble) at the center. Most lasers will not rotate unless the transmitter is level. When transmitter is level, attach the receiver to the pole and activate the alarm to take field observations.

All measurements should be recorded in a field book. The mean height of the field is calculated by taking the sum of all the readings and dividing by the number of readings taken. It is advisable to take the reading at a regular interval of 15 m x 15 m to achieve greater precision in land leveling.

C. Laser leveling of field

- Set the average elevation value of the field in the control box.
- The laser-controlled bucket should be positioned at a point that represents the mean height of the field.
- The cutting blade should be set slightly above ground level (1.0-2.0 cm).
- The tractor should then be driven in a circular direction from the high areas to the lower areas in the field.
- To maximize working efficiency, as soon as the bucket is near filled with soil the operator should turn and drive towards the lower area. Similarly as soon as the bucket is near empty the tractor should be turned and driven back to the higher areas.

- When the whole field has been covered in the circular manner, the tractor and bucket should then do a final leveling pass in long runs from the high end of the field to the lower end.
- The field should then be re-surveyed to make sure that the desired level of precision has been attained.

5. Tillage practices to maintain the level of field after leveling

Traditional tillage practices often move the soil in one direction — outward from the center of the field. Over time, such soil movement creates an uneven soil surface resulting in a low spot in the centre of the field. The center of the field often remains wetter and tillage operations will often be delayed with high incidence of weeds.

After leveling, the field should be ploughed beginning from the center and working out toward the field boundary (Fig. 22).

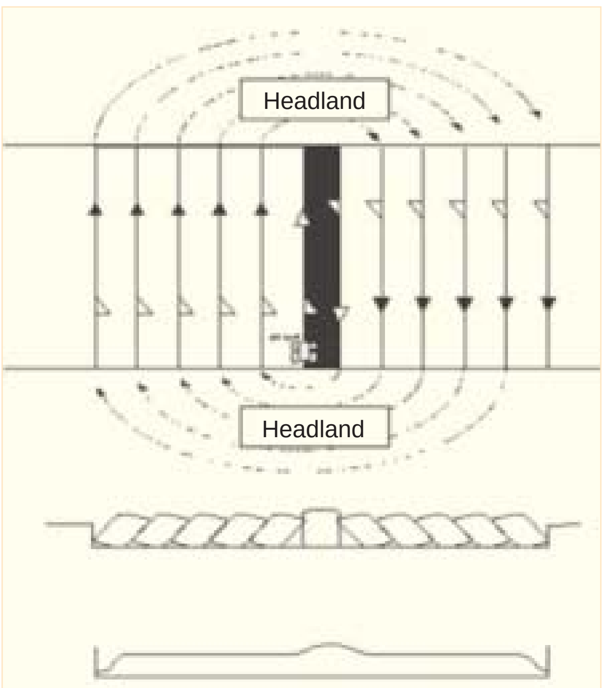


Figure 22. Correct ploughing practice after laser leveling

Initially, a single pass should be made in the centre of the field to move the soil to the right. The tractor is then repositioned at the end of the first run so as to plough the second run outwards from the furrow created. The third plough run then moves the previous ploughed soil back into the depression in the center of the field. The fourth run then refills the remaining furrow leaving the center of the field level. The field should then be ploughed on either side of the land until a margin equal to the width of the headland is left. The remainder of the field is then ploughed in a continuous pattern with the final run leaving a drainage furrow beside the bund.

6. Experiences with the laser land leveling technology

6.1 Adoption and spread of laser leveling technology: A success story of Western Uttar Pradesh, India

The laser land leveling was introduced in western Uttar Pradesh during 2002 by providing a laser leveler unit procured from Pakistan to a farmer of Ghaziabad (U.P.). It was used to demonstrate benefits of land leveling to farmers where participatory research trials on resource conserving technologies were in progress. To accelerate the pace of adoption of laser leveling technology, several in field training programmes, demonstrations, farmers' meets and traveling seminars were organized by RWC-CIMMYT-PDCSR under the aegis of USAID project. With growing awareness about laser leveling, some farmers bought their own laser systems and turned into custom service businesses in 2003. This proved as a milestone in adoption of this technology. As of February 2006, 37 farmers own laser levelers units only in western Uttar Pradesh (Appendix I). With in 3 years of introduction of laser leveling technology, the acrage has gone upto 10,000 acres spread over 10 districts of western Uttar Pradesh

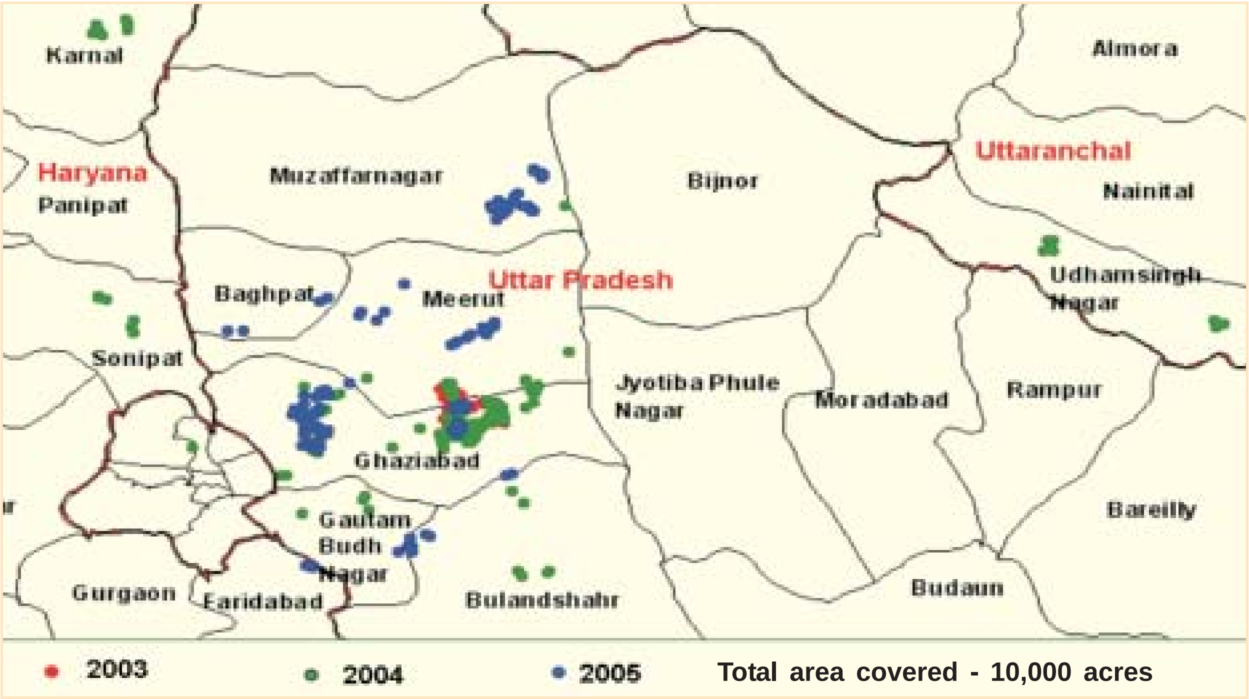


Figure 23. Year wise diffusion of laser land leveling technology in western Uttar Pradesh, India

and one district each in Haryana and Uttaranchal (Fig. 23).

Laser land leveling in Punjab, Pakistan

The Government of the Punjab Province of Pakistan initiated precision land leveling work during 1976-77. Water Management wing of the Agriculture Department has carried out precision land leveling on nearly 850,000 acres in the Punjab Province of Pakistan till year 2005. This includes an area of about 168,000 acres leveled using laser technology. With the initiatives of Dr. Mushtaq Ahmed Gill (Director General, On-Farm Water Management, Lahore Pakistan), this technology has been extended to 30 districts of the Punjab Province.

One of the major reasons of wide adoption of laser land leveling in the Punjab Province, Pakistan, is priority setting on irrigation water and well planned financial support by Provincial Government for this technology. Eighty six laser units were provided by the Provincial Government to District Governments under Devolution Plan 2001. The District Governments also added 40 more such units to their fleet for improving provision of laser land leveling services. Presently 187 laser units are working all over the Punjab Province of Pakistan (Fig. 24.)

Keeping in view the importance of the laser land leveling technology, declining water tables and deficit rainfall over the years, the Provincial Government has approved a project “Strengthening of Laser Land Leveling Services in the Punjab, Pakistan”. This project will provide 1500 laser units in next three years (2006-08) in the irrigated areas of the Punjab Province, which will further add 0.77 million acres under laser land leveling and will save about 0.57 million acre feet (MAF) irrigation water during the project implementation period. Laser land leveling of about 0.450 million acres every year, after project completion, will result in annual incremental water savings of

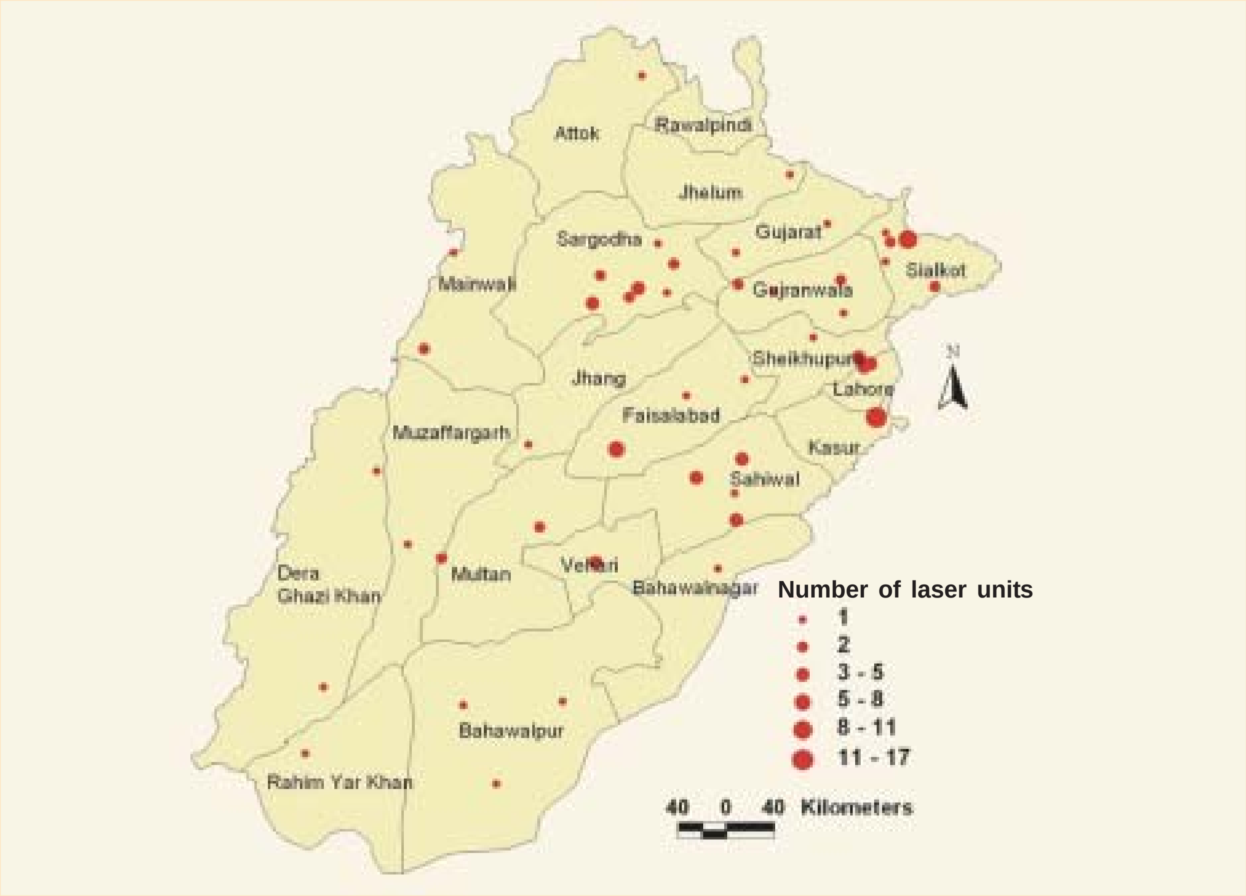


Figure 24. Spread of laser units in the Punjab Province of Pakistan till December 2005

approximately 0.34 MAF at the farm level. This implies that laser land leveling of about 4.50 million acres within a period of 10 years (economic life of equipment) will lead to cumulative water saving of about 3.40 MAF in the province to mitigate adverse effects of shrinking water resources to a great extent.

6.2 The benefits of laser land leveling

The benefits of laser land leveling over other land leveling methods include the following:

- Precise level and smoother soil surface
- Reduction in time and water required to irrigate the field
- Uniform distribution of water in the field
- Uniform moisture environment for crops
- Good germination and growth of crops
- Less seed rate, fertilizer, chemicals and fuel requirements
- Improved field traffic ability (for subsequent operations)

6.2.1 Increase in cultivable area

Smoothness of the land surface permits larger plot sizes for irrigation. This helps in saving precious land, and also adds additional land after removal of extra bunds and channels. Plot sizes in different villages have increased from 33 to 80% when laser leveled as compared to original plot sizes. The plot size for the wheat crop increased from 50 m x 12 m (before leveling) to 50 m x 20 m (after laser leveling) (Table 6). In rice crop plot size increased from 50m x 25m to 50m x 50m (Rajput and Patel, 2003). In another investigation, it was found that 2 to 3% addition in the cultivable area is possible due to laser land leveling (Khan, 1986). Rickman (2002) had also reported that about 5 to 7% cultivable area could be increased due to precision land leveling. Increasing field size from 0.1 ha to 0.5 ha results in the increase of the farming area between 5% and 7%. This increase in farming area gives the farmer the option to reshape the farming area that can reduce operating time by 10 to 15% (Rickman, 2002).

Another study conducted under USAID project at the farmers' fields in western Uttar Pradesh, revealed that about 3 to 6% additional land areas could be brought under cultivation in canal and tube well irrigated areas respectively, (Fig. 25). However, the area increase varies from field to field depending on plot size and divisions. (Tables 6 & 7)

6.2.2 Saving in irrigation water

A significant reduction in total water use in wheat as well as rice was recorded due to precision land leveling compared to traditional land leveling. The total water use in wheat and rice in laser-leveled field was reduced to 49.5% and 31.7%, respectively (Jat et al. 2003). The estimated total water use of wheat crop was 5270 m^3 ha^{-1} and 3525 m^3 ha^{-1} in traditionally leveled field and laser leveled fields respectively (Fig. 26).

In raised bed planted wheat, about 26% water can be saved through laser land leveling (Fig. 27). In rice, total water use was estimated as 6950 m^3 ha^{-1} and 9150 m^3 ha^{-1} under precision land leveling and traditional land leveling respectively (Fig 28).

From other on-farm investigations on wheat in villages Masauta and Lakhan, 338 to 808 m^3 ha^{-1} saving in total water use was found (Rajput & Patel, 2003). Studies conducted by RWC and

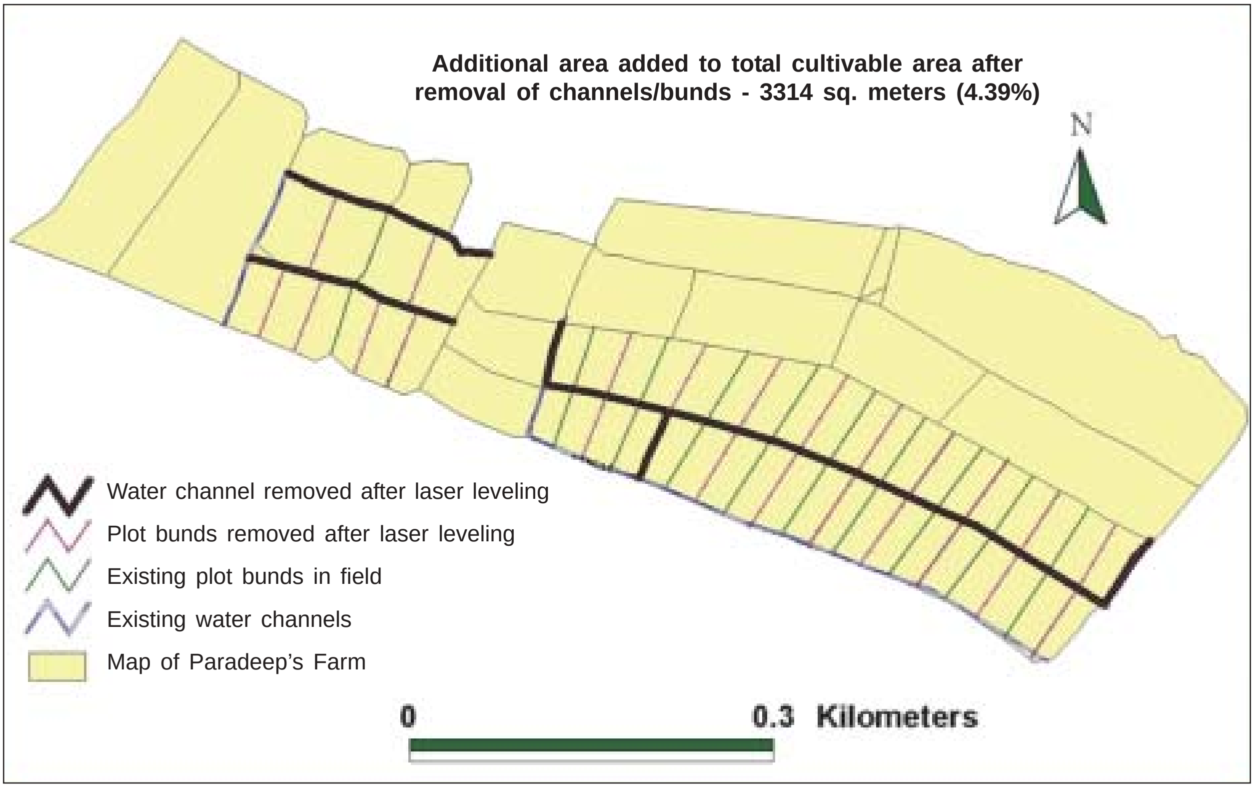


Figure 25. Map showing the increase in total cultivable area after laser land leveling

Table 6. Effect of laser land leveling on plot size for wheat and rice

Village	Field No.	Wheat		Rice	
		Plot size before leveling (m x m)	Plot size after leveling (m x m)	Plot size before leveling (m x m)	Plot size after leveling (m x m)
Lakhan	516	50 x 12	50 x 20	50 x 25	50 x 50
	456	30 x 12	50 x 12	50 x 10	50 x 25
	745	25 x 14	45 x 14	40 x 15	60 x 25
Masauta	364	60 x 11	60 x 20	60 x 15	80 x 25

Table 7. Estimated additional area which can be brought under cultivation by precision land leveling in selected farmers' fields in western Uttar Pradesh

Parameters	Traditional land leveling		Precision land Leveling	
	Canal irrigated	Tube well irrigated	Canal irrigated	Tube well irrigated
Basin size, m x m	40 x 30	30 x 20	50 x 50	40 x 30
Basin area, m^2	1200	600	2500	1200
Area under bunds & channel, m^2 ha^{-1}	600	1200	300	600
Additional land area brought under cultivation,%	-	-	3	6

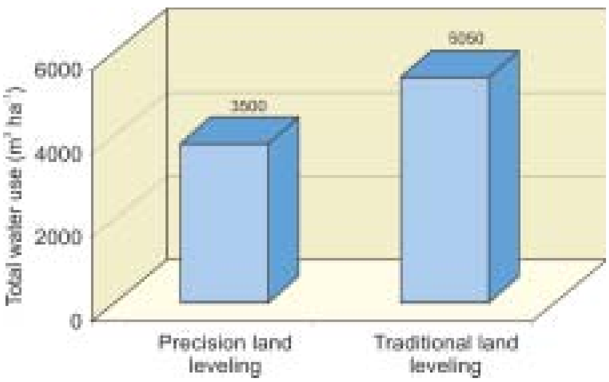


Figure 26. Total water use (m^3 ha^{-1}) in wheat under precision and traditional land leveling

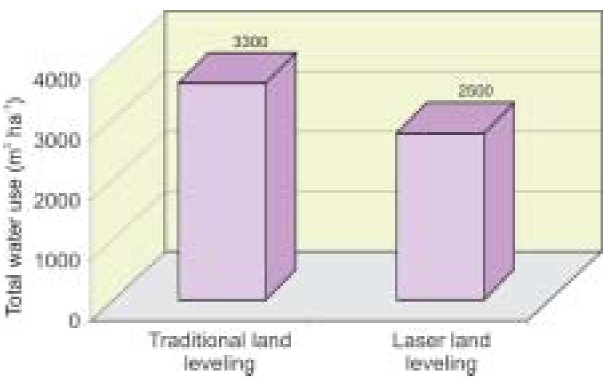


Figure 27. Effect of laser land leveling on total water use (m^3 ha^{-1}) in raised bed planted wheat

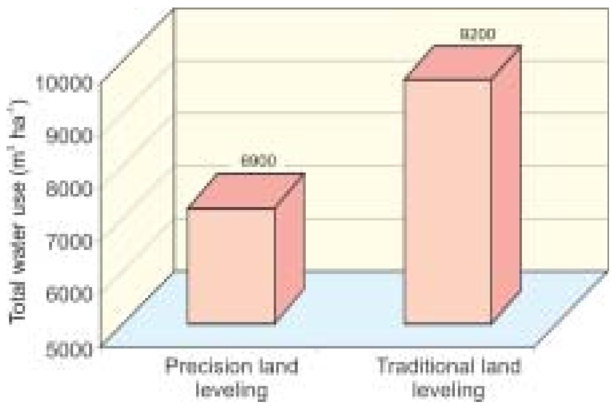


Figure 28. Effect of land leveling on water use (m^3 ha^{-1}) of rice in a sandy loam soil

PDCSR, Modipuram at the 71 farmers' fields of western Uttar Pradesh revealed that more than 61 farmers saved about 5-10 ha-cm water in wheat crop and about 10-15 ha-cm water in transplanted rice crop (Fig. 29).

Tyagi (1984) reported the application depth values of 3.9 and 9.7 cm at leveling index (LI) of 0.75 cm. and 6.75 cm, respectively in wheat crop under sodic soils of Haryana.

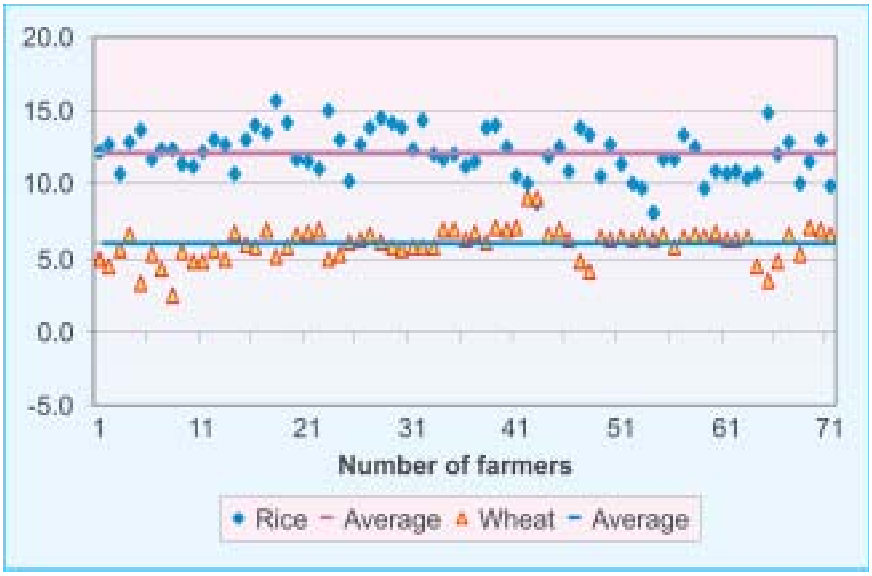


Figure 29. Water saving in rice and wheat crops

water in wheat in sandy loam soil was significantly higher under precision land leveling compared to traditional leveling (Jat et al. 2003) (Fig. 30). The application and distribution efficiencies of applied water were improved significantly under precision land leveling compared to traditional leveling (Sattar et al. 2003 and Rajput et al. 2004) (Fig. 31).

Further, the distribution efficiency obtained with various depths of application (4 to 12 cm) showed that distribution was more uniform (> 90%) in plots with an average LI of 0.75 cm and poor (< 50%) in plots with an average LI of 6.75 cm. However, with increasing depth of water application, the distribution improved in poorly leveled plots as well.

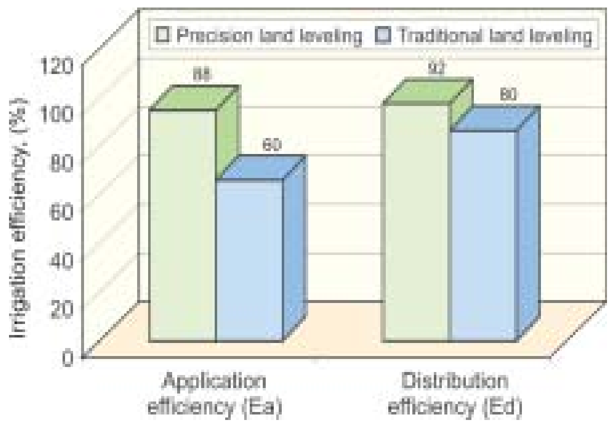


Figure 31. Effect of land leveling on irrigation efficiencies in wheat

6.2.3 Improvement in irrigation efficiency

The foremost objective of laser land leveling is to improve application and distribution efficiencies of irrigation which ultimately leads to higher water productivity. The distribution efficiency of applied

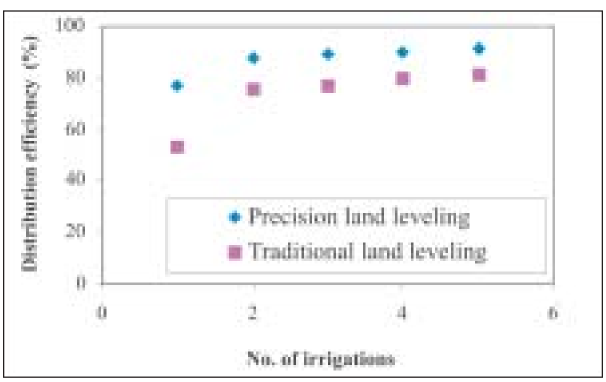


Figure 30. Water distribution efficiency in laser leveled and traditionally leveled field

6.2.4 Enhancement of water productivity

In an on-station investigation at PDCSR, Modipuram, a significant reduction in water use, and marked improvement in water productivity in rice-wheat cropping system was recorded due to precision land leveling compared to traditional leveling. It was recorded (Jat et al. 2005) that with similar fertility levels and land configurations, the water productivity of rice and wheat increased from 0.55 and 0.82 to 0.91 and 1.31 kg grain m^{-3} water, respectively (Table 8). Raised bed planting further improved the productivity of wheat in laser-leveled fields (Fig. 32). On-farm investigations carried out under USAID project in Meerut,

Table 8 .Yield and water productivity of rice-wheat system with similar fertility levels and land configurations but with different TCE methods

Treatments		Land	Yield (kg ha^{-1})		Water productivity (kg grain m^{-3})	
Leveling	Soil fertility	config.	Rice	Wheat	Rice	Wheat
Precision	High	R-Beds	-	5007a	-	1.90a
Precision	High	Flat	6325a	4618b	0.91a	1.31b
Traditional	High	Flat	5033b	4321b	0.55b	0.82c
Traditional	Low	Flat	4100c	2688c	0.45c	0.51d

Numbers with different letters (a,b,c) refer to statistical significance at 5% level

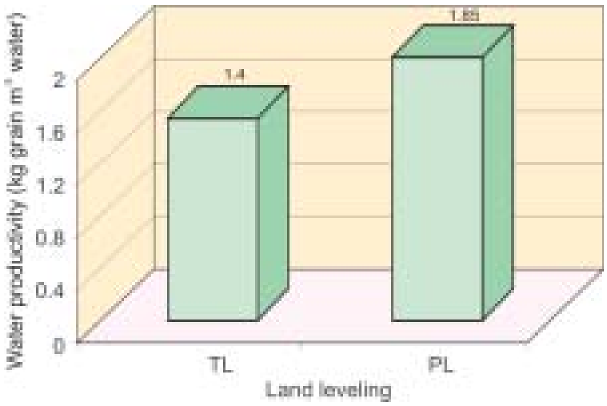


Figure 32. Effect of laser leveling on water productivity of raised bed planted wheat

Baghpat, Muzaffarnagar and Ghaziabad districts of western Uttar Pradesh in a rice-wheat cropping system revealed significant improvement in water productivity of rice and wheat under laser land leveling compared to traditional land leveling.

Field trials were conducted in rice season to evaluate the interactive effects of rice planting methods and land leveling on 16 farmers' fields in Western Uttar Pradesh. Results presented in Table 9 indicate that precision land leveling improves the yield and water productivity of rice grown as puddled transplanted or unpuddled direct seeded rice. The total saving in irrigation water in DSR rice over the puddled transplanted rice was nearly 25cm-ha shared equally between direct seeding and precision land leveling.

The descriptive statistical analysis of 71 locations revealed that the coefficient of variation in water productivity decreased in rice and wheat from 10.84% and 8.97% to 9.72% and 7.89% respectively due to precision land leveling. Further, the average irrigation water productivity of rice and wheat was increased from 0.49 and 1.02 to 0.61 and 1.22 kg grain m^{-3} water (Table 10).

As a consequence of precision land leveling, significant increase in water-use efficiency of seed cotton was observed from 36.9 to 63.1% (Sattar et al. 2003). The increase in WUE was attributed to less requirement of irrigation under precision leveling (54.80 cm) as compared to traditional leveling (74.65 cm). Choudhary et al. (2002) also reported higher water use efficiency (1.67) under precision leveling compared to conventional leveling (1.10) under on-farm investigations.

Table 9. Effect of planting methods and precision leveling on rice yield and saving in irrigation water

Crop establishment techniques	Rice grain yields (t/ha)†		Water productivity (kg m^{-3})	
	Laser leveling	Traditional leveling	Laser leveling	Traditional leveling
DSR (ZT)	5.25	5.10	0.468	0.409
TPR (puddled)	5.41	4.98	0.394	0.331

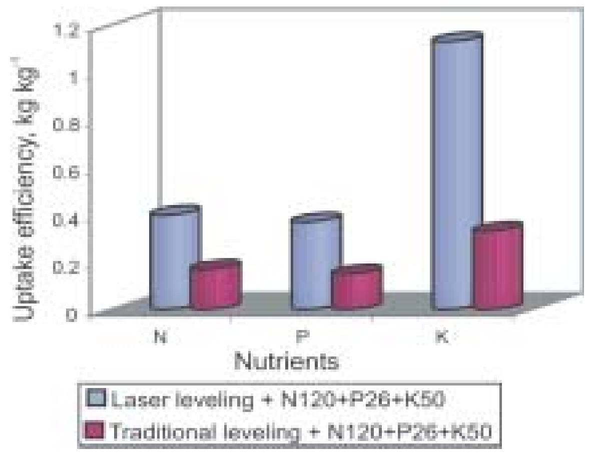
†Mean yields of trials conducted on 16 farmers' fields

Table 10. Water productivity of rice-wheat cropping system due to land leveling in western Uttar Pradesh

Statistical parameters	Water productivity (kg grain m^{-3} water)			
	Rice		Wheat	
	Laser leveling	Traditional leveling	Laser leveling	Traditional leveling
Number of farmers	71.00	71.00	71.00	71.00
Minimum	0.49	0.38	1.00	0.83
Maximum	0.73	0.60	1.38	1.18
Mean	0.61	0.49	1.22	1.02
Kurtosis	-0.685	-0.79	-0.90	-0.97
Skewness	-0.264	0.003	-0.21	-0.13
SD	0.059	0.054	0.097	0.091
SE	0.007	0.006	0.012	0.011
CV (%)	9.72	10.84	7.89	8.97

6.2.5 Enhancement of nutrient-use efficiency

Improved use efficiency of the applied nutrients is an obvious consequence under laser land leveling as uniform application of water under irrigated condition create an opportunity for uniform distribution of nutrients. In homogeneous seedbed, uniform distribution of nutrients improves crop growth. The information on increased nutrient-use efficiency resulting from laser land leveling demonstrated its beneficial effects. The uptake of applied nutrients in a sandy loam soil increased significantly under precision land leveling compared to traditional land leveling A significant increase in the uptake efficiency as well as apparent recovery fraction of the applied N, P and K in a typic *Ustochrept* in rice (Fig. 33) was observed due to due to precision land leveling (Pal et al. 2003). Choudhary et al. (2002) observed higher fertilizer-use efficiency in wheat in fields under laser land leveling compared to conventional leveling. Agronomic efficiency was also significantly improved in laser-leveled field in comparison to traditional leveled field in a rice-wheat cropping system. In on-farm investigations carried out at 71 locations in western Uttar Pradesh, significant



Source: Precision Farming Project (NATP)

Figure 33. Effect of precision land leveling on uptake efficiency of N, P and K in rice

improvement in nitrogen-use efficiency in rice-wheat cropping system was recorded and increases in NUE were found from 45.11 to 48.37 and 34.71 to 36.90 kg grain kg^{-1} applied nitrogen in rice and wheat, respectively (Fig. 34).

6.2.6 Increase in crop yield

A considerable increase in yield of crops is possible due to laser land leveling. Results of an experiment carried out at PDCSR, Modipuram showed a perceptible yield advantage of laser land

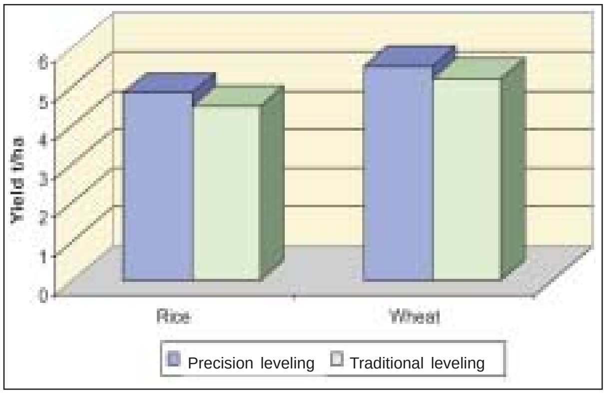


Figure 34. Nitrogen use efficiency of rice and wheat under precision and traditional land leveling

leveling over traditional leveling (Jat et al. 2003). They reported that the grain yield of wheat increased from 4.3 t ha^{-1} under traditional leveling to 4.6 t ha^{-1} through precision leveling. The improvement in yield of wheat under 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-leveled field. In another investigation at Modipuram, Pal et al. (2003) reported a significant improvement in growth and yield of upland paddy due to precision land leveling compared to traditional land leveling. Farmers' participatory research under USAID project in western Uttar Pradesh revealed a marked yield improvement in rice-wheat cropping system due the laser land leveling. The average yield levels of rice and wheat respectively, being recorded 4.84 and 5.53 t ha^{-1} under laser land leveling were markedly superior to traditional land leveling being 4.51 and 5.21 t ha^{-1} (Table 11). Further, the coefficient of variation in yield of rice (9.58%) and wheat (7.86%) between farmers was decreased with laser land leveling compared to traditional land leveling being 10.24 and 8.82%, respectively.

Findings of a long-term study (Rickman, 2002) showed 24% increase in yield of rice due to precision land leveling over traditional land leveling at the same level of variety and fertilizer use. Further, a strong correlation was found between the levelness of the land and crop yield. Sattar et al. (2003) reported a reduction in the yield of seed cotton up to 20.1% on traditionally leveled (TL) fields compared to precision leveling (PL) due to (i) low plant population in TL, (ii) greater variation in plant height from average plant height (tallness and shortness of the plants within the TL field declined fruit bearing capacity of the plants), and (iii) late crop maturity or prolonged vegetative growth due to excessive water applied to the

Table 11. Grain yield of rice and wheat under precision and traditional land leveling in western Uttar Pradesh

Statistical parameters	Grain yield (t ha^{-1})			
	Rice		Wheat	
	Laser leveling	Traditional leveling	Laser leveling	Traditional leveling
Number of farmers	71.00	71.00	71.00	71.00
Minimum	3.90	3.50	4.60	4.20
Maximum	5.70	5.44	6.21	6.12
Mean	4.84	4.51	5.53	5.21
Kurtosis*	-0.63	-0.62	-1.09	-0.931
Skewness*	-0.29	-0.07	-0.24	-0.093
SD	0.46	0.462	0.435	0.460
SE	0.055	0.055	0.052	0.054
CV (%)	9.58	10.24	7.86	8.82

* For measurers of Kurtosis and Skewness see Glossary

TL fields. Choudhary et al. (2002) demonstrated the effect of laser land leveling on the productivity of wheat sown on different dates. In general, as the time of sowing delayed, the yield decreased. But, the marginal decrease in the yield due to delayed seeding (from 1st to 2nd and 2nd to 3rd date of seeding) was much higher in traditionally sown wheat (774.5 and 1425.5 kg ha^{-1}) compared to seeding under laser land leveling (346 and 581 kg ha^{-1}). Tyagi (1984) reported that the yields were higher by 50% in precision-leveled plots compared to traditional leveled plots. In a similar study Khepar (1982) observed a decrease of 270 kg ha^{-1} for each unit increase in topographic index from 0.5 to 2.82 cm. It can, therefore, be concluded that precision leveling is the most effective technique to improve productivity of surface irrigated crops and it is of critical importance if the crop is raised in sodic soils.

6.2.7 Weed-control efficiency

Laser land leveling results in uniform moisture distribution to the entire field and allows uniform crop stand and growth, thus resulting in lesser weed infestation. Unleveled fields, on the other hand, frequently exhibit patchy growth. The areas with sparse plant populations are zones of higher weed infestation because weeds are mostly C_4 plants and possess the inherent genetic capability to suppress crop growth. Reports on reduction of weed population by laser land leveling indicate beneficial effects. The reduction in weed population results in improvement in weed management efficiency as removal of less number of weeds manually requires less time. A reduction of 75% in labour requirement for weeding was reported due to precision land leveling (Rickman, 2002). Reduction in weed population in wheat after 30 days of sowing was recorded under precisely leveled fields in comparison to traditional leveled fields (Fig. 35) (Jat et al. 2003).

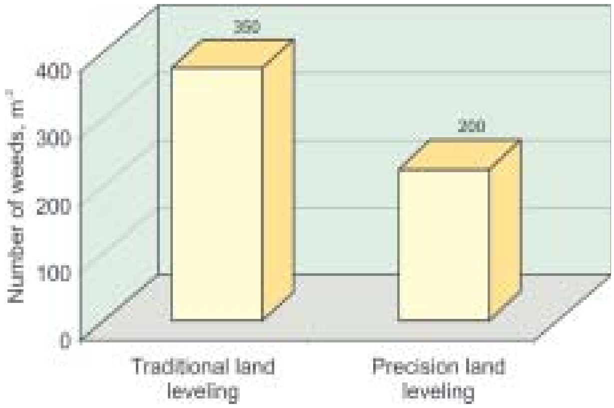


Figure 35. Total number of weeds (m^{-2}) in wheat at 30 days after sowing under precision leveled and traditionally leveled field

6.2.8 Custom services: An additional source of employment and income generation

The awareness of the farmers and pace of adoption and spread of laser leveling technology during the past three years have shown tremendous potential as an alternate source of employment for rural youth and income to the farmers through custom services on laser leveling. The farming window in the irrigated eco-regions under varying crops and cropping systems is about 90-110 days wherein laser custom services can be used. Due to shorter window in the irrigated eco-region, the custom service providers used to operate the laser units for 24 hours a day through 3 shifts of operators. Thus, it is estimated that one laser unit can provide an employment opportunity of 270 to 330 mandays in a year. The average savings through custom services is estimated at Rs. 1000/- per working day and if it works effectively for 100 days a year, a net profit of Rs. 1.0 lakh can be earned by a custom service provider. Thus, the laser custom services have a tremendous potential as an alternate source of employment and income.

6.3 Limitations of laser leveling

- High cost of the equipment/laser instrument
- Need for skilled operator to set/adjust laser settings and operate the tractor
- Less efficient in irregular and small sized fields

7. Cost of laser land leveling

The time required for precision land leveling depends upon the area, length and slope of the field and the volume of earthwork. The cost of land leveling mainly depends on the length and slope of the field. Precision leveling of the fields with larger length and slope are more costly per unit of earthwork. The time and cost for one acre land leveling are determined on the basis of elevations recorded at each grid point of the field using the laser, and the desired elevation of the field is worked out by averaging all the grid points. The values of the grid points above and below the desired elevation are averaged. The average height of cut is determined from the grid points and is further used for determining the volume of soil cut.

A large variation in average soil volume cut was recorded under on-station investigations in western Uttar Pradesh that indicates wide variability of landscape across the sites. The average soil volume cut at 71 sites varied from 108.27 to 6135.73 m^3 ha^{-1} (CV=87.84%). This was mainly due to length and slope of the fields. The cost per tonne of cut-fill work varied from Rs. 0.26 to Rs. 18.96. This wide variability (CV=101.64%) in cost was mainly due to variation in length and slope of the fields. The time taken for earthwork varies from 3.80 to 277.10 seconds t^{-1}. The cost per unit cut height area varied from Rs. 0.33 to Rs. 218.75 per cm per acre (Table 12). It is evident from the current study that before laser leveling of a field, it is very important to decide the length and slope of the field for cost effective leveling of the field. Greater length of the field leads to more costs to level.

By and large, the cost of land leveling with laser guided bucket on custom hiring comes up to INR 1500 - 2000 per ha in gently slopping fields. Rickman (2002) reported that although the initial cost of land leveling is convincingly high, a cash flow over a period shows that financial benefits do result from land leveling. Rajput and Patel (2003) reported that on custom hiring basis laser land leveling for wheat production was found beneficial even in the first year itself (Table 13). The additional cost and benefits of precision land leveling over an eight-year period reveal that there are major economic benefits to be gained through land leveling. The costs allow for extra fertilizer in the

Table 12. Earthwork, time and cost analysis of laser land leveling

Variable	Average soil volume cut (m^3 ha^{-1})	Time taken for per tonne of soil cut (Sec.)	Cost per tonne cut-fill soil (Rs.)	Cost per cm cut-fill per acre (Rs.)
Number of cases	71.00	71.00	71.00	71.00
Mean	1214.88	33.41	2.24	65.39
Minimum	108.27	3.80	0.26	0.33
Maximum	6135.73	277.10	18.96	218.75
Kurtosis	7.81	37.34	38.85	1.60
Skewness	2.63	5.50	5.65	1.05
SD	1067.19	33.58	2.28	40.37
SE	126.65	3.98	0.27	4.79
CV (%)	87.84	100.49	101.64	61.73

Table 13. Net profit in the first year of laser land leveling on custom hiring

Village	Plot no.	Additional amount of wheat produced due to laser land leveling (Rs.)	Expenditure in laser land leveling (Rs.)	Net profit (Rs.)	Saving in irrigation water (m^3)
Lakhan	516	1750	945	805	584.6
	456	2000	945	1055	406.8
	745	1750	945	805	338.4
Masauta	364	2125	2025	100	807.6

Source: Rajput and Patel (2003)

first and second years. The benefits include reduced weeding costs of 40%. Choudhary et al. (2002) reported an increase in net return of Rs. 5125 ha^{-1} from wheat grown under laser-leveled field compared to conventional leveling. The respective B/C ratio of 2.71 and 2.04 with a difference of 0.67 was recorded under laser leveling and conventional leveling (Table 14).

8. Environmental benefits of laser land leveling

Laser land leveling can certainly minimize yield variability at farm level, optimize input-output relation and save resources like soil, water and energy. If adopted on a large scale, the laser leveling would help in improving the quantity and quality of ground water because of improved water productivity and less accumulation and deep percolation of water-soluble pesticides and chemicals, especially nitrate. It is estimated that adoption of precision land leveling system to just two million hectare of area under rice-wheat system could save 1.5 million hectare-meter of irrigation water and improve crop yields amounting to US$ 500 million in three years.

Rickman (2002) reported 10-15% reduction in operating time of agricultural machinery in the laser-leveled fields as compared to traditional leveling. Laser leveling thus may prove to be an important technology in reducing the consumption of fossil fuel for various farming operations, which will bring a direct tangible and intangible benefit to farmers. It is estimated that extension of laser-assisted precision land leveling system to just two million hectares of area under rice-wheat system could save save diesel up to 200 million liters (equal to US $1400 million) and reduce GHG emissions equivalent to 500 million kg.

Table 14. Comparative economics (per ha) of wheat production under different land leveling techniques

Land leveling techniques	Mona				OFWM			
	Cost (Rs.)	Gross return (Rs.)	Net return (Rs.)	B/C return	Cost (Rs.)	Gross return (Rs.)	Net Return (Rs.)	B/C return
Laser leveling	11243	41685	30442	2.71	12779	38596	25817	2.02
Conventional leveling	12413	37730	25317	2.04	12114	31482	19368	1.60
Difference	1170	3955	5125	0.67	665	7114	6449	0.42

Source: Choudhary et al. (2002)

9. Conclusions and recommendations

Laser leveling of agricultural land is a recent resource-conservation technology initiative in India. The results are quite encouraging. 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.

Popularisation of this technology among farmers in a participatory mode on a comprehensive scale, therefore, needs appropriately focused attention on priority basis along with requisite support from researchers and planners. The change in our vision of future agriculture in relation to food and nutritional security, environmental safety and globalisation of markets demands improving resource-use efficiency considerably to reach the desired growth levels in food production and agricultural productivity. Laser leveling is evidently one of the ways by which we can address these issues to a great extent.

10. Future thrust

In spite of several direct and indirect benefits derived from laser land leveling technology, it is yet to become a popular farming practice in the developing and the underdeveloped countries. For accelerating its popularisation and large-scale adoption, it requires a number of well-considered and synchronized research, extension, participatory, economic and policy initiatives keeping in view the long-term sustainability of our production systems. In recent years, there has been a great change in the dynamics of agricultural research, production mechanisms and strategies. The urgency and need for resource conservation has become an inescapable universal imperative and a global mandate for all future research and development in agriculture. Resource conservation technology improvements in farming operations at the farm level in a participatory mode are considered to be on of the most important sources of enhancing input-use efficiency and growth in total factor productivity. A judicious blending of appropriate research and policy strategies in conjunction with various resource conservation technology options have the necessary potential to bring about a significant change in agricultural production scenario of a developing country like India.

Research on the evaluation of the performance of laser land leveling, an important resource conservation technology, is still in a stage of infancy and needs to the strengthened further to explore and utilize its full potentional for enhancing the productivity of critical inputs. The thrust of future research and development of laser leveling technology should focus on the following areas on priority basis for its full impact and exploitation.

- Design and development of user friendly laser land leveling system
- Development of component technologies for nutrient and water requirement of crops/ cropping system with precision land leveling in various agro-ecological regions
- Long-term effect of precision land leveling on ground water recharge and its quality
- Environmental impact of laser land leveling on sub-eco-regional/regional basis
- Crop diversification through laser land leveling
- Long-term economic evaluation

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Annexure I

Custom Service Providers on Laser Leveling in Western UP (up to February 2006)

S. No	Name of the service provider/farmer	Address district	Phone	No. of laser units	Year of purchase
1	Shiv kumar Tyagi	Vill & Po., Atarada, Distt-Meerut	09358432538 0122-2381631	01	May 2004
2	Sukant Kumar	Vill-Akhapur, PO-Simbhawali, Distt-Ghaziabad	09412469133	01	June 2004
3	Pawan Kumar	Vill-Lalpur, Po- Babugarh Cantt, Distt-Ghaziabad	09897592305 0122-2333691	01	August 2004
4	Adesh Kumar	Vill-Lalpur, Po-Babugarh Cantt, Distt-Ghaziabad	09837104704	01	June 2005
5	Pawan Kr. Tyagi	Vill-Mohammadpur, Po-Mubarakpur, Distt-Ghaziabad	09837681826 0122-2342307	01	October 2004
6	Tikam Singh	Vill-Dadayara, Po-Hapur, Distt-Ghaziabad	09837710171 0122-2336396	01	July 2004
7	Neeraj Choudhary	Vill-Chhapkoli, Po-Babugarh Cantt, Distt-Ghaziabad	09837778060	01	September 2004
8	Sushil Tyagi	Vill-Bayana, Po-Dasana, Distt-Ghaziabad	09837453133	01	March 2005
9	Veerpal Singh	Vill & Po-Tatarpur, Hapur, Distt- Ghaziabad	09899245477 09827754091	02	April 2005, October 2005
10	Yashpal Sharma/ Gajendra Singh	Vill-Dadayara, Po-Hapur, Distt-Ghaziabad	09719038668	01	June 2005
11	Mithlesh Maheshwari	Vill- Meerapur, Distt-Muzaffarnagar	0987693960 09897693866	01	May 2005

(*Contd.*)

Annexure I (Contd.)

S. No	Name of the service provider/farmer	Address district	Phone	No. of laser units	Year of purchase
12	Surendra Singh & Munish kumar	Vill-Jarothi, Hapur, Distt-Ghaziabad	0122-2334144 0122-2334544 09412118638	01	June 2005
13	Harendra Singh	Vill- Bagarpur, Hapur, Distt-Ghaziabad	09719209395	01	September 2005
14	Vinod Kumar	Vill-Patana, Muradpur, Hapur, Distt-Ghaziabad	09927011308	01	December 2006
15	Rajendra Singh	Vill-Behlolpur, Mawana, Distt-Meerut	09719849725	01	February 2006
16	Col Deshwal/ LK Yadav	M/S Sunshine Farm, Sikanderabad, Distt-Bulandshahr	09868267636 09837193579	01	April 2004
17	Shoran Singh	Vill-Jarothy, Po-Hapur, Distt-Ghaziabad	09837778060	01	October 2005
18	Satish Kumar	Vill-Chhapkoli, Babugarh Cantt, Distt-Ghaziabad	09927011473 09927011474	01	October 2005
19	Pramod Tyagi	Vill-Bayana, Po-Dasana, Distt-Ghaziabad	0120-2767697	01	May 2000
20	Dharmendar Kumar	Vill-Akhapur, Po-Simbhawali, Distt-Ghaziabad	05731-229014	01	January 2006
21	Subodh Tyagi	Ghaziabad	09897981462	01	May 2005
22	Harendra Singh	Vill-Shahpur Choudhary, Tehsil-Garh Mukteshwar, Distt-Ghaziabad	09719209395	01	September 2005
23	Rishipal Singh	Ghaziabad	09319050947 09319050946 09719539768	01	July 2004
24	Kawal Singh	Vill-Dadayara, Po-Hapur, Distt-Ghaziabad	09711322453	01	August 2005
25	Madan pal	Vill-Jhitkari, Saradhana, Distt-Meerut		01	February 2006

(*Contd.*)

Annexure I (Contd.)

S. No	Name of the service provider/farmer	Address district	Phone	No. of laser units	Year of purchase
26	Subhash	Vill-Muradpur (Nizampur), Hapur, Distt-Ghaziabad	09412521024	01	December 2005
27	Shree Chand	Vill-bhadar Pur, Po-Karauli, Balabhgarh	09891092703	01	September 2005
28	Latoor Singh	Vill-Pawati, Po-Sadulpur, Distt-Ghaziabad	05731-263072	01	October 2005
29	Rajesh Kumar	Vill & Po-Rasulpur, Distt-Ghaziabad	09719331162	01	February 2006
30	Ram Mehar Singh	Vill & Po-Rasulpur, Distt-Ghaziabad	09719318945	01	December 2005
31	Sobir Singh	Vill-Saha Kalipur, Hapur, Distt-Ghaziabad		01	January 2006
32	Sunder Singh	Vill & Po-Atola, Distt-Meerut	09219768076	01	December 2005
33	Rishipal Singh	Vill- Harnathpur, Kotta, Hapur, Distt- Ghaziabad		01	February 2005
34	Kalu Singh	Vill- Harnathpur, Kotta, Hapur, Distt- Ghaziabad	0122-2345050	01	January 2005
35	Sodan Singh	Vill & Po-Mehmoodpur, Hapur, Distt-Ghaziabad	09927112254	01	October 2005
36	Mukesh Yadav	Vill & Po-Dankaur, Distt-Gautam Budh Nagar	09873237870 09350846776	01	January 2006

Total number of units=37

Glossary

Agronomic efficiency (AE): It refers to kilogram of produce per kilogram of plant nutrient added through fertilizers.

Digital Elevation Model: The digital cartographic representative of the surface of the Earth or a subsurface feature through a series of three-dimensional coordinate values: a continuous variable over a two-dimensional surface by a regular array of z values referenced to a common datum. Digital elevation models are typically used to represent terrain relief; a model of terrain relief in the form of a matrix consisting of a data file of a topographic surface arranged as a set of regularly spaced X,Y,Z coordinate locations where Z represents surface elevation.

Earth work: It involves total volume of shifting of soil in a field (plot) through cut and fill operations involved during land leveling.

FIRBS: Furrow Irrigated Raised Bed Planting System is the system of planting wherein the crops are grown of the top of the beds and the furrows are used as irrigation channels.

Grid: The grid is defined by identifying one of its corners (lower left usually), the distance between nodes in both the X and Y directions, the number of nodes in both the X and Y directions, and the grid orientation.

Infiltration: Downward movement of water in to the soil is known as infiltration.

Irrigation efficiency: It is the ratio expressed in percentage of water stored in the root zone depth of the soil to the water delivered in the field from the farm supply source.

Kurtosis: Kurtosis is a measure of whether the data are peaked or flat relative to a normal distrubution. That is, data sets with high kurtosis tend to have a distinct peak near the mean, decline rather rapidly, and have heavy tails. Data sets with low kurtosis tend to have a flat top near the mean rather than a sharp peak. A uniform distribution would be the extreme case.

Land uniformity co-efficient (LUC): It represents the magnitude as well as frequency of occurrence of successively larger undulations in the field.

Leveling Index (LI): Leveling index is an indicator for the levelness of the land surface, which is the difference in desired and achieved levelness of the field.

Leveling: The tillage operation in which the soil is moved to establish a desired soil elevation slope.

Nutrient-uptake efficiency: It refers to kilogram of nutrients uptake by the crop per kilogram of plant nutrient added through fertilizers.

Nutrient use efficiency: It refers to the part of the applied nutrients recovered by the crop.

Precision: It denotes relative or apparent nearness to the truth.

Skewness: Skewness is a measure of symmetry, or more precisely, the lack of symmetry. A distribution, or data set, is symmetric if it looks the same to the left and right of the center point.

TCE: Tillage and crop establishment methods

Water-application efficiency: Water application efficiency is the measure of efficiency with which water delivered to the field is stored in the root zone.

Water-distribution efficiency: The extent to which water is uniformly distributed in an irrigation system. Or, it is defined as the per cent of difference from unity of the ratio between the average numerical deviations from the average depth stored during the irrigation.

Water-storage efficiency: The water storage efficiency refers to how completely the water needed prior to irrigation has been stored in the root zone during irrigation.

Water-use efficiency: The amount of dry matter that can be produced from a given quantity of water.

Diffusion: Denotes to “movement” from area of higher concentration to an area of lower concentration

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* All other publications not listed here can be downloaded from the website : **www.rwc.cgiar.org**

Rice-Wheat Consortium for the Indo-Gangetic Plains

The Consortium is an Ecoregional Program of the Consultative Group on International Agricultural Research (CGIAR), managed by CIMMYT, involving the National Agricultural Research Systems, the International Agricultural Research Centers, and the Advanced Research Institutions. Its main objective is to promote research on issues that are fundamental to enhance the productivity and sustainability of rice-wheat cropping systems in South Asia.

These objectives are achieved through:

- Setting priorities for focused research on problems affecting many farmers.
- Promoting linkages among rice-wheat research specialists and other branches of research and extension.
- Encouraging interdisciplinary team approach to understand field problems and to find solutions.
- Fostering quality work and excellence among scientists.
- Enhancing the transfer of improved technologies to farmers through established institutional linkages.

Financial support for the Consortium's research agenda currently comes from many sources, including the Governments of Netherlands, New Zealand, Australia and the Department for International Development (DFID), the International Fund for Agricultural Development (IFAD), the United States Agency for International Development (USAID), the World Bank and the Asian Development Bank (ADB).

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ISSN: 0972-2084