International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-9 Issue-8, June 2020

Laser Land Levelling for Higher Water Productivity in Rice-Wheat System

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Abstract**: Awareness of water conservation has been increasing and understandings of conservation technologies have made headway in the world agriculture. Enhancement in water productivity has been the key objective of planners and the stakeholders. Many water conservation techniques or technologies help in enhancing the water productivity also prevent salt build-up and land degradation. Laser land levelling is one of the many such techniques, which has popularized to a certain extent. Yet its spread has not been significant. Realizing the potential of laser land levelling, the ICAR-Central Soil Salinity Research Institute (ICAR-CSSRI), Karnal, Haryana, India had imported a laser operated land leveller some three decades back. Few research and field evaluation studies have been made in the context of on-farm water savings as well as to judge the impact of this technology on small and marginal farmers. The present study highlights an on-farm as well as observations made in the farmers' fields, on the basis of scientific observations of information collected at the ICAR-CSSRI farm on the smoothness of the soil surface achieved, uniformity of soil moisture distribution, water requirement for irrigation, as well as saving of time yield differentials of the crops in conventionally levelled and laser levelled fields. A total of 19 farmers' fields were studied in Pundrak, Zarifa and Kalayat villages in Haryana besides two controlled studies at ICAR-CSSRI farm, Karnal. The values of Levelling Index (LI) for before and after conventional levelling have been evaluated as 3.0 cm and 2.1 cm respectively, whereas in the laser levelled fields, these were 1.93 cm and 0.85 cm respectively. The application time for irrigation in laser levelled fields has reduced to 3.5-4.5 hours from about 6 hours required in conventionally levelled fields for 0.4 ha (1 Acre). The average values of water productivity in conventional and laser-levelled fields have been evaluated at 1.5 and 2.4 kg/m^3, respectively for wheat and 0.4 and 0.5 kg/m^3 respectively for rice. For the fields having LI of 0.75 cm, the application efficiency has been as high as 90% in comparison to 45% for the field having LI of 6.75 cm. The estimated net profit ranged Rs. 1000 – 1200 for the first year, which rose to Rs. 4000 – 5000 in the second year onwards, during the study for the laser levelled fields. Besides the technical appraisal, the paper highlights the limitations such as necessity of repeat application of laser land levelling once in three years. Fortunately more than 500 custom hiring units have already appeared in the North Indian states due to sensitization through trainings and demonstrations of this technology.

***Keywords** : Coefficient of land uniformity, laser land levelling, levelling index, Rice-Wheat System, and Water Productivity.*

I. INTRODUCTION

Water is a renewable but finite and scarce resource. In spite of the fact that everyone is aware of the hard times ahead yet the resource is used very lavishly in all the sectors. Water and food would be among the top few challenges before the world in the second quarter of the 21st century. The world population may grow beyond 9 billion by the year 2050. Studies indicate that the production of food in the world must increase by 50% by 2030 and 100% by 2050 from its current levels to feed the growing population (Kaledhonkar et al., 2013; Saxena and Rao, 2018). A major challenge before the country particularly in the agricultural sector is to convert it into a commercial business by reducing the cost of cultivation by improved input use efficiency and by higher returns to the farmers through quality production (Saxena et al., 2013; Saxena et al., 2015; Nayak et al., 2018). Although the available land and water resources has been decreased over time. The cultivated land has reduced to 0.12 ha in 2015 from 0.31 in 1961 (World Bank, 2018; Saxena et al., 2019). The agricultural sector consumes about 83% of the total water used, is the most lavish user of the resource (Rao et al., 2018). The availability of water was above 5300 m^3 in 1951 which got reduced to 1588 m^3 in 2010, and likely to be lesser than 1500 m^3 in the year 2025 (Bajpai and Saxena, 2017; Saxena et al., 2017; Saxena et al., 2018). Modern precision agricultural methods like irrigation systems, advanced tillage and soil management, and land levelling could be some of the technological interventions in agriculture that has substantial positive impact on increased water use efficiency (Saxena and Gupta, 2004; Pandey et al., 2010; Kishore et al., 2016). Unfortunately, a major part of the excessive amounts of water applied to the crops go waste and leads to many environmental problems including water logging, soil salinization and pollution of surface and groundwater resources (Saxena and Gupta, 2006 a & b; Waghaye et al., 2018). On-farm water management, therefore, should receive greater attention to save water in this sector. While on-farm could have wide connotations yet the on-farm development (OFD) has been implemented as a practice for on-farm water management (OFWM). OFD has therefore been a part of the Command Area Development Programme (CADP) being implemented in the country.

Revised Manuscript Received on June 30, 2020.
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Although, land levelling as a component of the OFD received much greater attention, farmers failed to realize the importance of precision land levelling.

Besides, lack of awareness, non-availability of precision land levelling equipment, their high cost making them beyond the reach of average farmer, compatibility of the equipment with smaller horse power (HP) tractors commonly available with the farmers and lack of institutional support could be sited as few reasons for the halfhearted response of the farmers. Realizing these problems, precision land levelling equipment were imported in the country with government support and efforts of some research organizations. Now, attempts are being made to manufacture these equipment within the country as well. Since field evaluation of these equipment can play a major role in the design, development and efficient use of such equipment, such studies are increasingly being performed by the research organizations. This paper reports the finding of such an evaluation at a research farm followed by testing and demonstration at the farmers' field in Haryana, India.

II. LAND LEVELLING AND RELATED TERMS

Land levelling, as the term might indicate is not intended to convert a field into a table top level field but is the process of smoothing and grading the land surface to provide a suitable surface for efficient application of irrigation water and uniform leaching of salts. To quantitatively reflect the precision of field levelling, a land levelling index (LI) is used. It has been defined in a number of ways by many investigators. Agarwal and Goel (1982) defined the levelling index, LI, as the average numerical variation (cm) between the proposed or designed levels and the existing average field level. To know the improvement in LI, it is estimated both before land levelling and after the completion of levelling work. Mathematically, LI can be expressed as:

$$LI = \frac{\sum |\text{Difference in design and existing grid levels}|}{\text{Number of grid points}}$$

(1)

Coefficient of land uniformity (LUC), also an index indicating the effectiveness with which land levelling operation has been carried out, has been defined by Tyagi and Singh (1979) as follows:

$$UC = \left[1 - \frac{1}{n}\left|\frac{\sum(LD-LE)}{LD}\right|\right] \quad (2)$$

Here, LUC is the coefficient of land uniformity (dimensionless), LD is the desired elevation at a grid point and LE is the existing elevation at that grid point, and n is total number of observations.

Although both the indexes have been used in the literature, for the present study, LI proposed by Agarwal and Goel (198**2**) has been used to assess the performance of the laser land leveler. Apparently by this definition, an index of zero is the upper limit of the degree of precision. Theoretically it is feasible to achieve such a precision although in practice it may not be possible to achieve such a high precision. As the value of this index increases and approaches 1, the degree of precision would be less.

Besides what has been stated in this section, in establishing a land-grading plan, the designer has to consider factors like soils profile limitations, prevailing and desired land slopes, rainfall characteristics, crops to be grown and irrigation methods to be practiced. For example, in sprinkler and drip irrigation levelling could be quite rough and in many cases could even be dispensed with. The depth of the top soil that can be disturbed without reducing productivity often limits the extent of levelling especially in shallow soils.

Conventional methods of land levelling are good enough to meet only the partial requirement of land levelling. It still leaves the scope of improvement in land levelling in the field. The use of laser technology in the precision land levelling is of recent origin in India. It not only minimizes the cost of levelling but also ensures the desired degree of precision. Modern laser guided land levellers have proved to be better equipment for precision land levelling. In laser land leveller, the hydraulic operation is controlled automatically by a laser beam receiver mounted on leveller that receives signals from laser transmitter for a pre-designated slope in longitudinal/ transverse or in both the directions. As a result, operator's skills do not matter in achieving the quality of land levelling. A study on the effectiveness of laser land leveller was conducted at CSSRI research farm. The land levelling index before and after the laser/manual land levelling were worked out with the help of Eq. (2).

III. MATERIALS AND METHODS

A. Field Study

To study the performance of laser land leveller, two fields at CSSRI farm one of 0.8 ha and another of 1 ha were selected. The fields were divided into two halves one of 0.4 ha and another of 0.5 ha each. Out of these 2 parts, one part was used to level with the help of laser control while the other half was leveled with the conventional leveller. Same time was allotted for levelling the two parcels of the fields. The levelling index as defined by Eq. (1) was assessed with the help of a dumpy level. The levelling index before and after the levelling was estimated to assess the precision of land levelling.

B. ORP on Laser Land Levelling

To study the performance of laser land leveller, two fields at CSSRI farm one of 0.8 ha and another of 1 ha were selected under an Operational Research Project (ORP). The fields were divided into two halves one of 0.4 ha and another of 0.5 ha each. Out of these 2 parts, one part was used to level with the help of laser control while the other half was leveled with the conventional leveller. Same time was allotted for levelling the two parcels of the fields. The levelling index as defined by Eq. (1) was assessed with the help of a dumpy level. The levelling index before and after the levelling was estimated to assess the precision of land levelling.

In order to evaluate and demonstrate the importance of precision land levelling, 10 farmer's fields (total 4.2 ha) were selected and levelled by laser guided land leveller before *rabi* season in Pundrak, Zarifa and Kalayat villages, District Karnal, Haryana, India (Fig. 1 a). Half of the area was leveled by the farmers with their traditional equipment spending almost the same time as was used for laser land levelling. Farmers were advised to cultivate rice and wheat as per their practices. Water applied in each of the irrigation to arrive at the total water used in the crops was monitored.

Crops were monitored to assess the yield of crops in both the laser and conventionally leveled fields (Fig. 1 b).

(a)

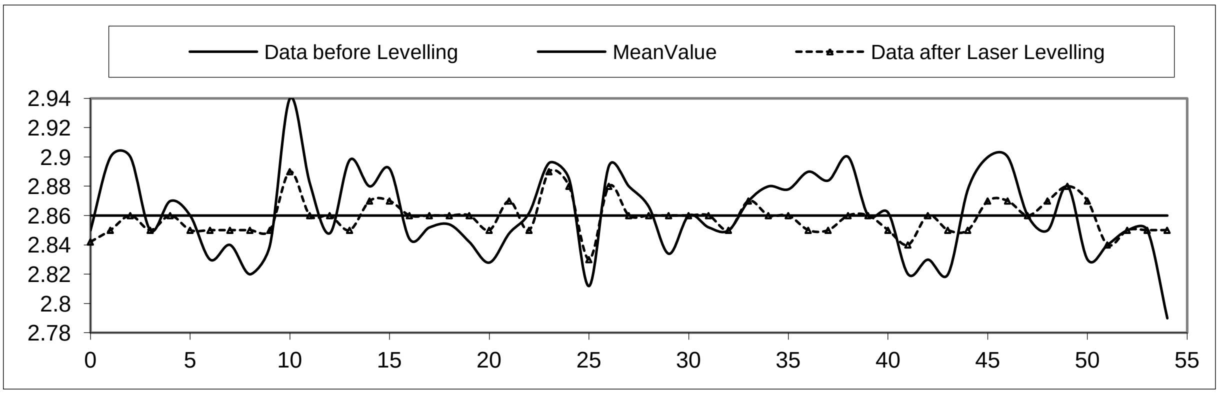
(b)

Fig. 1(a & b). Laser land leveller in operation and comparative crop performance of laser and conventional land levelling.

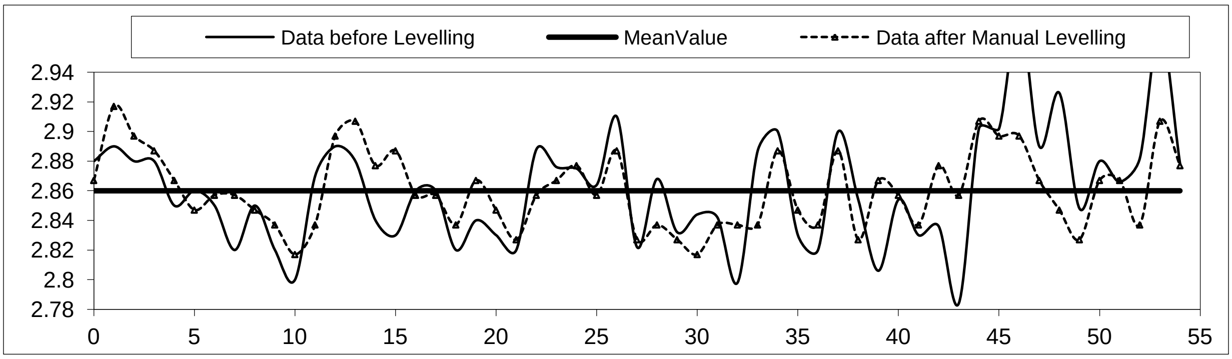
IV. RESULTS AND DISCUSSIONS

A. On-Farm Land Levelling

The land levelling index before and after the laser/manual land levelling were worked out with the help of Eq. (1). The necessary parameters are reported in Table I. Apparently, the range within which the levels deviate from the mean improved after levelling. The improvement was much more significant in the case of laser land levelling than with manual (Fig.2 a and b). The change in LI has also been much more significant in two cases as compared to manual levelling (Table- 1). With laser levelling it could be brought to less than 1 while it remained more than 2.0 in manual levelling. Although initial LI is also higher but certainly the improvement over the initial is much less.



(a)



(b)

Fig. 2. Variation in field levels before and after laser (a) and conventional (b) levelling.

The average levelling index of the selected fields was estimated to be 1.45 after levelling operation against the average of 2.70 before the operation. The analysis of the individual fields have indicated an LI value for two fields as more than 1.5 after laser land levelling mainly due to the reasons of excessive soil moisture and presence of excessive rice straw in the field.

In the farmers' fields, it was further observed that due to precision land levelling, water application time reduced significantly to 3.5-4.5 hrs from generally required time of 6 hrs for 0.4 ha (1 acre) land.

Table- I:. Performance parameters of laser land levelling

Field	Mean value	Range		LI	
		Before	After	Before	After
Laser	2.102	2.055-2.155	2.074-2.124	1.56	0.80
Laser	2.860	2.790-2.940	2.830-2.890	2.29	0.90
Manual	2.860	2.784-2.980	2.817-2.917	3.00	2.10

Table- II: Comparison of conventional and laser guided levelling

Parameters	Conventional levelling	Laser Levelling
Levelling index (cm)	>1.5	<1.5
Irrigation depth (cm)		
Paddy	110-115	90-95
Wheat	30-35	20-25
Pumping requirement (hr/ha/irrigation)		
Paddy	25-27	20-22
Wheat	15-17	9-11
Water productivity (kg/m^3)		
Paddy	0.37	0.47
Wheat	1.50	2.44
Profit over conventional (Rs/ha)		
1st year	-	1000-1200
2nd year onwards	-	4000-5000

This indicated application of relatively shallow depth (4 cm) of water in the field. The comparison of laser levelled with conventional levelled field indicated relatively better crop performance and yield due to non-stagnation of irrigation/rainwater in the field. In order to see the performance of land grading under high water table conditions, 9 more fields were selected in the Kalayat village and levelled by laser leveller before the kharif season (2004) and their average levelling index after levelling operation was 1.7 cm. On the basis of four closely monitored fields, the average water productivity in the conventional and laser-levelled fields was estimated 1.5 kg/m3 and 2.4 kg/m3, respectively for wheat crop and 0.37 and 0.47 kg/m3 for rice crop (Table- II). Therefore, precision land levelling by laser leveller not only saved water and energy but also enhanced crop and water productivity. A comparison of economic analysis of different levelling equipment has been given in Table-II.

Tyagi (1982) had reported that to apply a recommended depth of 4 cm of water per irrigation in alkali soils, the levelling index should be 1.5 or less. Tyagi and Singh (1979) also evaluated 3 secondary land levelling implements to assess the cost of land levelling and to compare the attainable LUC. With the Super Leveller a LUC of 0.96 could be obtained and therefore this implement has been considered as the most precise followed by a combination of blade and float (Table III).

Table- III: Time, cost and land uniformity coefficient for different levelling implements

Implement	Time for common operation (hr)		Time for land shaping operation (hr)	LUC as per Eq. (1)
	Ploughing	Discing		
Levelling blade	10	10	26.4	0.72
Levelling float	10	10	15.0	0.63
Levelling blade and float	10	10	18.5	0.90
Super leveller	10	12	19.5	0.96

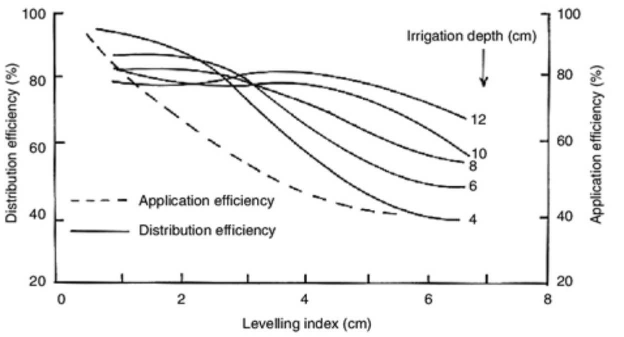


Fig. 3. Irrigation efficiencies at different levelling index

B. Land levelling versus efficiencies

In a field study, it was observed that the system application depth ranged from 4 to 12 cm as the levelling quality decreased (Fig. 3). Higher application depths were associated with lower application efficiencies (Agarwal and Goel, 1982). With a LI of 0.75 cm, the application efficiency was as high as 90% compared with 45% at an LI of 6.75 cm. The non-uniformity in levelling was reflected in a water productivity value of 93.1 kg/ha/cm at LI = 0.75 cm to 59.1 kg/ha/cm at LI = 6.75 cm.

The study further indicated that to ensure a desired system application depth of 5 cm, required to achieve optimum productivity and income, the levelling quality had to be such that the average deviation from the desired depth was less than 3 cm.

C. Necessity for Repeat Levelling

The first field chosen for the study was leveled with the help of laser two years before. Although the initial LI at that time is not known, it seems that due to normal cultivation practices followed, the LI increased over a period of two years. It is proposed to monitor the LI in this field each season of wheat and rice so that need for repeat laser land levelling could be assessed.

Levelling is not a permanent operation. Since the fields are cultivated regularly, minor undulations are created here and there when tillage operations are carried out. In view of this, a question is often asked as to when the repeat levelling operation be performed. Though no study has been made so far yet it is believed that a fine levelling job once accomplished might need repeat levelling after 3 years or six seasons. However, in this operation, no meticulous planning is needed in the initial case would be required. Thus the cost of repeat levelling would be much less. Our assessment shows that it may be about half the cost of first levelling with a laser leveler (Table 4).

Table- IV: Cost of precision levelling (LI<1.5 cm) by different equipment

Implement	Operation Time (hrs/ha)	Cost (Rs/ha)
Levelling blade	26.4	5280
Levelling float	15.0	3000
Levelling float bed	18.5	3700
Super leveller	19.5	3900
Laser land leveller	5.0	2500

D. Cost of Land Levelling

The cost of land levelling depends upon the soil, initial undulations, field size and kind of machinery used and the efficiency of the person carrying out the operation. Land levelling cost is not proportional to the differences in the initial and final levels. With increase in precision, cost of land levelling increases almost exponentially. The cost may vary from a few hundred rupees to several thousands of rupees and therefore, it is necessary to plan and economize on its cost (Table 4).

E. Limitations

A major limitation of land levelling with laser is that in this case cut-fill ratio need to be kept as 1.0. Although, it could be kept more than 1.0 also but in that event the equipment will carry the excess earth and it can not be dropped at any point. Since after irrigation, filled points are likely to get lowered, one can expect minor changes in LI just after one/two irrigation during the cropping season.

V. CONCLUSION

Land levelling has proven to be a precursor to good agronomic, soil and crop management practices. The levelled land surface has a significant influence on the most of the agricultural operations. Precision land levelling could be rated as the second only to breeding HY varieties as one of the few mechanical inputs in intensive agriculture that meets the twin objectives of attaining a better crop production, productivity, save irrigation water and improves the input use efficiency. Laser land levelling technology has been evaluated under different situations have shown potential benefits in terms of reduced pumping (> 25%), yield advantage (> 17 %), and higher water productivity as compared to traditional practices. The laser land levelling also helps in better establishment of crops under conservation tillage practices. It has proven to be cost effective and beneficial. Its propagation to a larger scale could be recommended. The planners may include the technology considering its sustainable benefits to the crop growers and the nation.

ACKNOWLEDGMENT

The authors are thankful to the Director, ICAR-Central Soil Salinity Research Institute, Karnal, Haryana, India for granting the study leave to the first author, as well as other necessary permissions and the facilities.

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