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Impacts of laser land levelling technology on yield, water productivity, soil health and profitability under arable cropping in alluvial soil of north Madhya Pradesh

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Abstract

The crop productivity in Madhya Pradesh, India is very low as majority of the farmers are still practicing traditional farming techniques. The existing crop production technologies do not offer effective and efficient utilization of natural resources, particularly that of water. Moreover, a significant amount of irrigation water is wasted due to uneven fields and ditches. Unevenness of the soil surface also has a major impact on the germination, stand and yield of crops through nutrient water interaction and salt and soil moisture distribution pattern. Therefore, the water use efficiency along with yield per unit area could be increase by adopting resource conservation technologies like laser land levelling. Samples of 40 growers were selected from Morena district of Madhya Pradesh. Study results revealed that the laser levelled fields exhibited the saving in irrigation water with precision-conservation were 16.36, 14.54, 16.66 and 21.15 % compared to traditional levelling field and 27.27, 27.27, 31.66 and 47.11 % to unlevelled fields. The water-use efficiency was 38.09, 33.78, 46.75 and 50.23% higher in precisely levelled field than control (unlevelled) and 28.57, 20.94, 29.16 and 28.58 % higher than traditional levelling. The average crop productivity in rice, wheat, sugarcane and mustard has improved by 14.35, 10.83, 16.07 and 15.8 % on traditionally levelled fields. The average annual net income from the laser field was Rs. 90380, 72649, 69440 and 195275 ha^{-1} in rice, wheat, mustard and sugarcane higher than from the in comparison to control (unlevelled) fields. After harvest of third year crop compared to unlevelled and traditional levelling increased total soil carbon (TC), Total inorganic carbon (TIC), total soil organic carbon (SOC) 11.93 and 10.73 g kg^{-1} content was recorded at surface depth (0-15 cm). However, WSC, and MBC 27.8% and 35.1% in surface soil and 29.2% and 42.9% in sub surface soil content were recorded in laser levelled and unlevelled fields. Study concluded that adoption of laser land levelling technology helps in reducing the farm input costs, improve water use efficiency and enhance crop productivity.

Keywords: Laser land levelling, water use efficiency, productivity, soil health, profitability

Introduction

Water is a key factor in increasing agricultural production; its increasing scarcity has resulted into the emergence of various innovative and efficient water management techniques. Declining irrigation water availability and crop productivity and increasing food demand necessitate quick adoption of modern scientific technologies for efficient water management. While mechanisation is good news to farmers, climate change and climate variability pose unprecedented challenges to agriculture. We need climate-smart agriculture practices and technologies that save on scarce resources like water and energy but increase yields, incomes and reduce environmental footprints. When practised together, a portfolio of climate-smart practices can equip farmers to adapt to changing weather patterns amidst depleting natural resources. For instance, groundwater in north-western India has been declining at alarming rates because of the overuse of electric pumps, largely by subsidised electricity, and inadequate recharge from erratic rainfall. Increasing temperature, which has been evident in most of the region, accentuates the demand for irrigation water. Recent studies predict that there would be at least a 10 % increase in irrigation water demand with a 1°C rise in temperature in arid and semi-arid regions of Asia (Sivakumar and Stefanski 2011) [29]. Water availability is expected to decline whereas global agricultural water demand is estimated to increase by approximately 19 % by 2050 (U N Water 2013) and thus, water scarcity is becoming a more important determinant of food security than land scarcity (Brown and Funk 2008) [9]. In India, during the period from 2008 to 2012, the total fresh water withdrawal was approximately 761 billion cubic meters; 90 % of this was used for agricultural production, including both irrigated crops and livestock production (World Bank 2013). The groundwater table has been declining in India (Aggarwal *et al*., 2004; Kerr 2009; Kumar *et al*., 2007) [2, 19, 21] and, as irrigation is the largest user of groundwater use of pumped groundwater for irrigation has substantially increased the consumption of energy by the agriculture sector in India (Kumar *et al*., 2011) [22]. Rising demand for food production due to increased population will further amplify the energy consumption by the agriculture sector. Therefore, there is a dire need of technologies that can conserve water resources, increase the efficiency of energy use and enhance agricultural productivity (Ambast *et al*. 2006; Hanjra and Qureshi 2010) [4, 12]. In order to raise farm productivity, several state governments in India have provided electricity for farm use at a subsidized rate. Although this has contributed substantially to national food production, it is one of the major drivers for rapid depletion of groundwater in India (Perveen *et al*., 2012) [27]. Low efficiency of irrigation and poor recovery of water charges are the major problems associated with agricultural water management in India (GOI 2013). In the rice–wheat (RW) system of the Indo-Gangetic Plains (IGP), about 10– 25 % of irrigation water is lost due to poor water management and uneven fields (Kahlown *et al*., 2000) [18]. Laser land levelling (LLL) is an alternative land levelling technology that has the primary benefit of a reduction in the loss of irrigation water occurring due to highly undulating land. Therefore, applying laser land levelling rather than traditional land levelling (TLL) can help reduce the use of irrigation water and save energy through reduced duration of irrigation (Jat *et al*., 2011) [17].

Declining water table and degrading soil health are the major concerns for the current growth rate and sustainability of Indian Agriculture. Thus, proper emphasis is being given on the management of irrigation water usage for adequate growth of agriculture. Keeping in view, the need for judicious use of our natural resources, concerted efforts are being made to enlighten the farmers for efficient use of irrigation water at farm level (Kaur *et al*., 2012) [20]. Generally, in sugarcane-wheat and rice-wheat, rotation farmers believed that their fields are levelled and needed no further levelling. But the digital elevation survey sheet of a field shows that most of the fields are not adequately levelled and requires further precision land levelling. The enhancement of water use efficiency and farm productivity at field level is one of the best options to readdress the problem of declining water level in the state. The planner and policy makers are properly informed and motivated to develop strategies and programs for efficient utilization of available water resources.

Laser land levelling is a method that achieves the desired level of accuracy as it uses laser equipped drag buckets. It also facilitates uniformity in the placement of seeds/seedlings and promotes better crop stands, which eventually contributes to higher crop yields. A uniform field improves irrigation efficiency through better control of water distribution and reduces the potential for nutrient loss through improved runoff control, leading to greater efficiency of fertilizer use and higher yields (Jat *et al*., 2009; Jat *et al*., 2011; Naresh *et al*., 2014) [16, 17, 26]

The use of laser technology in the precision land levelling is of recent origin in India. It does not only minimize the cost of levelling but also ensures the desired degree of precision. However, the laser land levelling was introduced in the Uttar Pradesh in 2001 by Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut (U. P.) in collaboration with Rice-Wheat Consortium, New Delhi under the leadership of Dr. R. K. Naresh. Land levelling of farmer's field is an important process in the preparation of land (Naresh *et al*., 2014) [26]. It enables efficient utilization of scarce water resources through elimination of unnecessary depression and elevated contours (Naresh *et al*., 2011) [24]. It has been noted that poor farm design and uneven fields are responsible for 30% water losses (Asif *et al*., 2003) [6]. Precision land levelling (PLL) facilitated application efficiency through even distribution of water and increased water-use efficiency that resulted in uniform seed germination, better crop growth and higher crop yield (Jat *et al*., 2006) [15]. The scarcity of canal water supplies coupled with unfit ground water has compelled the farmers to utilize available water resources more wisely and efficiently. Under these circumstances, PLL can help the farmers to utilize the scarce land and water resource more effectively and efficiently towards increased crop production (Abdullaev *et al*., 2007) [1]. It was estimated that around 25 to 30% of irrigation water could be saved through this technique without having any adverse affect on the crop yield (Bhatt and Sharma, 2009) [7]. The land levelling have resulted smoother soil surface, reduction in time and water required to irrigate the field, more uniform distribution of water in the field, more uniform moisture environment for crops, more uniform germination and growth of crops, reduction in seed weight, fertilizer, chemicals and fuel used in cultivation, and improved field traffic ability (for subsequent operations). Limitations of laser levelling include high cost of the equipment/laser instrument, the need for a skilled operator to set/adjust laser settings and operate the tractor, and restriction to regularly shaped fields. Farmers, as entrepreneurs are unwilling to adopt new technologies unless they clearly see quick and tangible results in terms of farm profitability. Theoretically, a farmer would opt for a new technology if assurance of earning a net profit were shown. Some economists believe that the net returns must be at least 30% higher than for the traditional technology before farmers would consider adoption. According to an estimate, the number of laser levellers in Chambl division of Madhya Pradesh has increased sharply from mere 01 in the year 2016 to 10 in the year 2020 of this; on farm resource conservation technologies in States like Madhya Pradesh have an edge over other technologies. Land levelling through laser leveller is one such proven technology that is highly useful in conservation of irrigation water and enhancing productivity.

The soil carbon is capable of enhancing agricultural sustainability and serving as a potential sink of atmospheric CO_2. Carbon dioxide abundance in the atmosphere along with other greenhouse gases caused global warming and climate change. Sequestration of carbon in soils may potentially mitigate the negative effect of global warming on agriculture. Intensified rice based cropping systems consume more inputs and thereby release more CO_2 and sequester less carbon in soil (Bhatia *et al*., 2011) [8]. Soil and cop management practices and organic materials that increase the stocks of soil carbon may have profound effects on climate mitigation (Soderstorm *et al*., 2014) [30]. Active (or labile) carbon fractions that indicate microbial activity and microbial biomass carbon (MBC) change seasonally (Franzluebbers and Arshad, 1997) [11]. Although active C fractions in the soil can change more rapidly than the other fractions, these fractions sometime may not be readily changed within a crop growing season due to high variability in soil properties within a short distance in the field or in regions with limited precipitation, cold weather, and a short growing season (Sainju *et al*., 2006b) [28]. The objectives of this study were (i) to determine soil crop water productivity as affected by precision field levelling practices in arable crops in *alluvial* soil of Madhya Pradesh and (ii) to evaluate profitability in adoption of laser land levelling technology over traditional levelling with rice, wheat, mustard and sugarcane crops and (iii) the effect of field levelling on soil aggregation potential and C sequestration increment for future posterity of the arable crops.

Materials and methods

Biophysical, demographic, and socioeconomic profile

Initially, a baseline survey of randomly selected farmers from different villages was conducted to understand their social, economic, and educational status in addition to input use (seed, irrigation, tractor, labour, fertilizer, and pesticide use) and outputs (grain and straw yield) in conventional farmers' practices. The study was conducted for three years from May 2016-17 to May 2018-19 in 40 farmers' fields at Rajmata Vijayaraje scindiya Krishi Vishwa Vidyalaya, Zonal Agricultural Research Station Morena MP sites. Out of 40 farmers, 65 % had land holdings of <2 ha, 25 % had 2 to 4 ha, and 10% had more than 4 ha (Figure 1a). About 10% of the farmers were literate, out of which 36 % were middle-school pass, 43% were high-school pass, and 11% were college pass (Figure 1b). The literacy rate of the selected family was 76.0%. The average family size was 5.8 family members. The large farmers usually lived in joint families; whereas medium and small farmers had a separate nuclear family. Out of 232 family members of the 40 households surveyed, 42% were fully engaged in agriculture and 27% were partly engaged, whereas 31% were students who also helped with agricultural activities during vacation and/or leisure periods (Figure 1c). 65% of the farmers were members of different cooperatives existing in the area. Mustard, wheat, rice, pigeon-pea, potato and sugarcane were the major source of income. Socio economics and demographics of project sites of Morena MP, India.

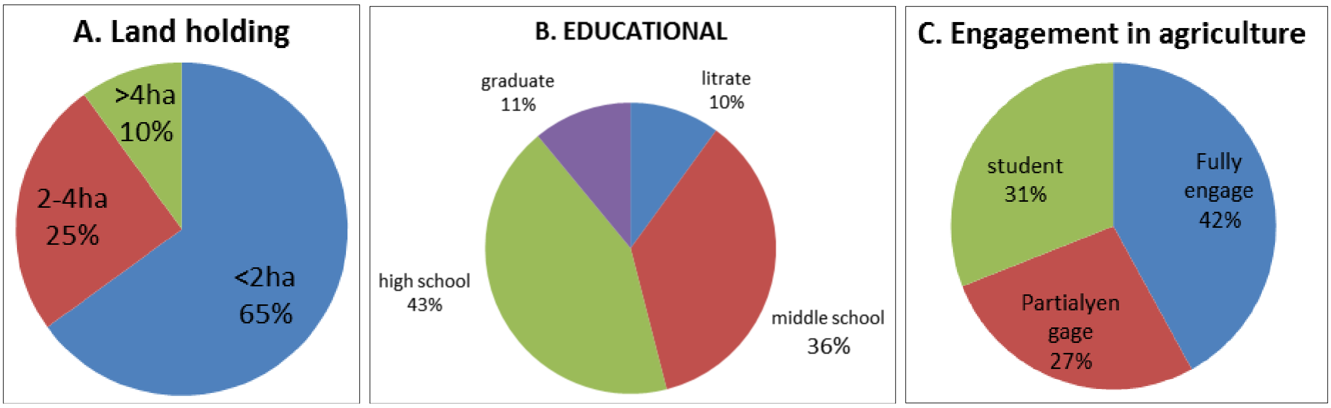
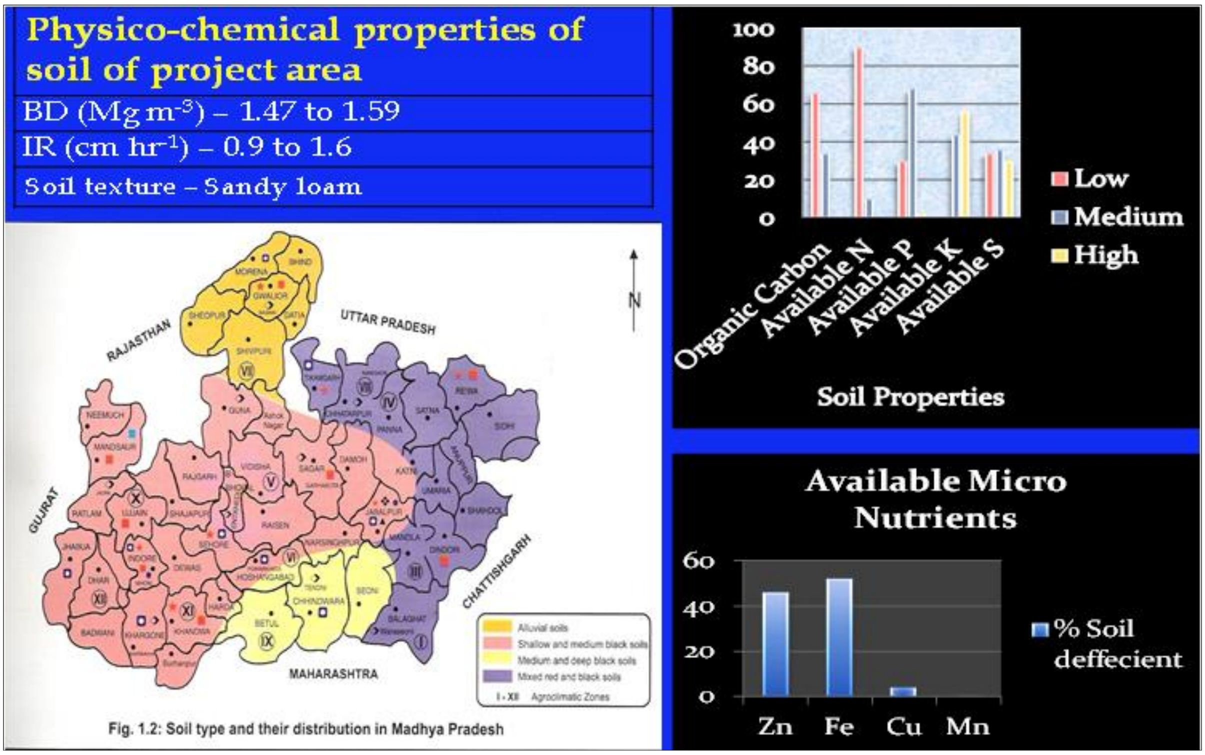


Fig 1: Socioeconomics and demographics of project sites of north Madhya Pradesh, India


Physico-chemical properties of soil of project area

BD ($Mg\ m^{-3}$) – 1.47 to 1.59

IR ($cm\ hr^{-1}$) – 0.9 to 1.6

Soil texture – Sandy loam

An experiment was conducted on mustard, sugarcane and rice-wheat rotation in District Morena in farmers participatory mode in the juridiction of Rajmata Vijayaraje scindiya Krishi Vishwa Vidyalaya, Zonal Agricultural Research Station Morena MP India, (25°15′ to 26^{0}45'N latitude and 70°30′11' E longitude with an altitude ranging from 150 to 240 m. The experiment was farmer-managed, with a single replicate, repeated over many farmers. Therefore, the experimental design was Randomized Block Design in which the number of treatments varied from farmer to farmer, with the farmer as a replicate/block. The treatments consisted of Laser land levelling (T_1), Traditional land levelling (T_2) and Control (Unlevelled) (T_3). In treatments T_1 and T_2 levelling of experimental field was done as per treatment and information on the topography of each experimental unit was compiled. The climate of this area characterized as dry land comes under semi-arid condition, extremely cold during December-January (-1.0°C temperature) and hot during summer months of May-June (49°C temperature). The average annual rainfall of District Morena is 701 mm comes under low rainfall region, mostly concentrated in the months of July and August. Severe droughts are frequently seen in the district. Dry farming cultivation of crops in areas where annual rainfall is less than 750 mm and crop failures due to prolonged dry spells during crop period. District Morena comes under in tropical zone of Madhya Pradesh is more vulnerable to climate shocks where more than 70% population still dependent on agriculture. Climate change is being seen as a serious threat to agricultural productivity and farmer livelihood in the district. Several scientific studies indicated that probability of 10-40% loss in crop production with increase in temperature by 2050 and less water availability. The mid and late rainy season drought, frost, terminal drought extreme events in the last 10 years were seen in the district. The rainfall will become more erratic and reduced number of rainy days; thus increasing the risk of drought damage to crops. The soil of the study area had Entisols of old alluvial plains of India. Soil samples (surface 0-15cm) were collected from selected fields for determining soil properties in the beginning of the experiment and after project duration. Surface soil of experimental field was sandy loam in texture of old alluvial plain and having electrical conductivity (EC) 0.30dS m^{-1}, pH 7.91 of 1:2 soil-water ratio, low in organic carbon (O.C.) content (0.31%), available N (172 kg ha^{-1}), P (11.2 kg ha^{-1}), S (9.8 kg ha^{-1}), and Zn (0.51 mg kg^{-1}), whereas medium in available K (175 kg ha^{-1}), and Cu (0.28 mg kg^{-1}), Fe (6.7 mg kg^{-1}) and Mn (4.8 mg kg^{-1}) above their critical limits for deficiency. The field capacity and permanent wilting point of soil was 33.8% and 11.9% on dry weight basis (w/w) with bulk density of 1.51 Mg m^{-3}. Chambal division Madhya Pradesh has a diversified cropping system, with Pearl-millet, Mustard and Pigeon-pea/rice-wheat the dominant cropping system. The crop was kept free of weeds by chemical spray. Observations on the desired parameters were recorded using the standard procedures. The main source of irrigation was canal water which was supplemented with tube well water as and when needed to meet the crop water requirements in Kharif and Rabi season. The discharge available at outlet was measured every time. The time of irrigation application for each treatment was noted during each irrigation. The applied irrigation depth was calculated from measured discharge applied to known area for recorded time by the following equation:

$$QT = AD$$

Where Q = Discharge (Cusec, ft^3 s^{-1}); T = Time (h); A = Area (acres), and D = Depth (inches). The amount of water (ft^3) applied to each treatment was determined by multiplying the discharge at field outlet with the time of application. The total amount of water so applied was computed for the entire crop season. The amount of water saved was determined by the difference of water applied to precisely levelled, unlevelled and traditionally levelled experimental units. Water use efficiency was computed as follow:

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

Water productivity and economic analysis

Water productivity analysis combines physical accounting of water with yield or economic output to assess how much value is being obtained from the use of water (Abdullaev *et al*., 2007; Bouman *et al*., 2008) [1, 23]. For this analysis, physical water productivity was calculated by:

$$WP = Output/Q$$

Where WP is the productivity of water in kg m^{-3}, output is the mass of crop in kilograms and Q is water resources applied and depleted (m^3). In this study, only physical productivities of the applied and depleted water are analysed. To compare the laser-levelled field to the control field, both gross margin analysis and partial enterprise budgeting techniques were applied for three cropping seasons of 2016-17, 2017-18 and 2018-19. The use of partial enterprise budgets required to evaluate technological innovations compared to old techniques, as the capital costs associated must be discounted over the life of the new investment.

Soil sampling and analysis

Soil samples were collected after mustard, sugarcane, and 3 years of rice–wheat cropping in May 2019 (after wheat harvest) from three replications of each treatment. Soil samples were taken from 0-15 and 15 to 30 cm depth with a soil auger. Composite samples were made air-dried under shade. One portion of the sample was ground and the whole amount was passed through a 0.15 mm sieve. This sample was used for determining total inorganic carbon (TIC), oxidizable organic carbon (OC) and total carbon (TC) in whole soil. Total carbon (TC) was analysed by using CHN Elemental analyser (model Vario EL III); TIC and OC were estimated following the methods of Jackson (1973) [14] and Walkley and Black (1934) [31], respectively.

Microbial biomass carbon

For the estimation of soil microbial biomass C and N by the chloroform fumigation and incubation method Horwath and Paul, (1994) [13] soil moisture was adjusted to 55% field water capacity, pre-incubated at 25°C for 7 days in the dark, and each soil sample was subdivided into two subsamples for fumigated and non-fumigated treatments. For MBC, soil samples, equivalent to 30 g dry weight, were fumigated with $CHCl_3$ for 24h at 25°C. After removing the $CHCl_3$, each soil sample was incubated at 25°C for a period of 10 days in closed tight Mason jar along with vials containing 1.0 ml 2 M NaOH. The flush of CO_2-C released upon fumigation was determined from titration with HCl. The MBC was computed using Eq.:

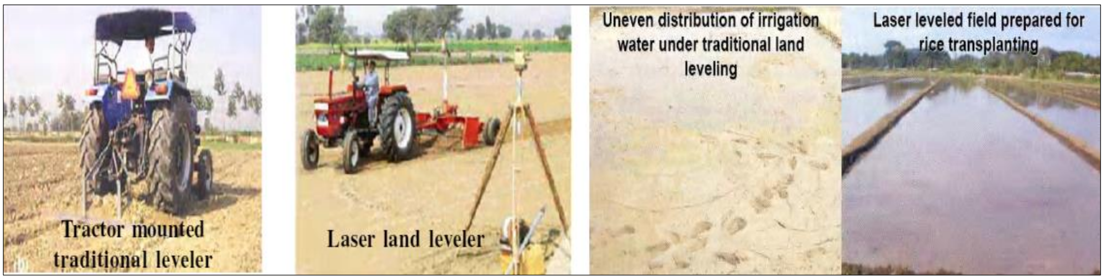
$$MBC\ (mg\ kg^{-1}) = (Fc-UFc)/Kc$$

Where, Fc is CO_2 evolved from the fumigated soil, UFc is CO_2 evolved from the un-fumigated soil, and Kc is a factor with value of 0.41 Anderson and Domsch, (1978).

Results and discussion

Yield and yield components

The laser land levelling significantly affected the yield and yield components of rice, wheat, mustard and sugarcane crop (Tables 1, 3 and 5). The maximum plant height, number of panicle m^{-2} of rice and wheat were recorded in laser levelled field against the minimum in the unlevelled field. Laser land levelling in mustard produced maximum plant height (198.4 cm.), number of branches plant^{-1} (16.58) and yield (2.60 t ha^{-1}) similar trend in sugarcane cane yield (86.6 t ha^{-1}) against the minimum (64.8 t ha^{-1}) in unlevelled field. Significantly higher grain/cane yield over traditionally levelled field and unlevelled field might be attributable to better development of yield components like higher productive tillers m^{-1} row length and more 1000 grain weight due to more efficient use of inputs, uniform internodes length, thicker canes and uniform availability of soil moisture in the effective root zone of the crop. (Naresh *et al*., 2014; Aryal *et al*., 2015; Das *et al*., 2018) [26, 5, 10] attributed higher grain yield in precision land levelling to more uniform "water" conditions that facilitated timely preparation of field and timely sowing of the crop as compared to unlevelled fields. The reason for lower grain/cane yield in unlevelled field might be uneven distribution of water over the field which drastically reduced the yield and yield components in lower and elevated spots.



A View of Laser Land Leveller

Water saving

There was a significant improvement in irrigation performance when the precision laser land levelling was under taken prior to sowing (Tables 2, 4 and 5). The maximum water depth for rice (90.0 mm), for wheat (70.0 mm), for mustard (79.0 mm) and (110 mm) for sugarcane were required to irrigate unlevelled field during each irrigation as against the minimum in the field precisely levelled by laser and followed by traditionally levelled field. On an average, 40 to 20% in rice, 54.91 to 29.5% in wheat, 47.05 to 25.49 in mustard and 26.77 to 13.70% in sugarcane crop as compared to control and traditionally levelled fields reduced the total irrigation duration and water depth in each irrigation 28.57 to 17.14% in rice, 27.27 to 14.54 % in wheat, 31.66 to 16.66% in mustard and 37.5 to 18.75% in sugarcane as compared to control and traditionally levelled fields respectively. Thus, laser levelled field utilized less water per irrigation. The precisely levelled and smooth field showed a positive impact on the total water use resulting in a tangible reduction. At uniform discharge, before and after laser land levelling there was about 32% saving in water over control and 13% over traditional levelled field. Significantly, higher amount of water (14000, 4200, 1580 and 15300m^{3}) were required for unlevelled field than laser levelled field (11000, 3300, 1200 and 10400 m^{3}), which did not differ significantly from the traditionally levelled field. The results further revealed that 3000 m^{3} in rice crop, 900 m^{3} in wheat crop, 380 in mustard crop and 4900 m^{3} in sugarcane crop, that is, about 27.27, 27.27, 31.66 and 47.11% excess volume of water was required to irrigate unlevelled fields as against 16.36, 14.54, 16.66 and 21.15% in traditional levelled field in respective crops. The only reason for excessive water application in control treatments was uneven surface to the unlevelled treatment. The greater variation in surface level on unlevelled and traditional levelled field resulted not only in wastage of water but also reduced crop yield by about 21.70 to12.55% in rice crop, 15.68 to 9.77% in wheat crop, 30.0 to 17.69% in mustard and 26.86 to 13.65 % in sugarcane crop, respectively.

Water use efficiency

Water use efficiency (WUE) was significantly affected by different land levelling techniques (Tables 2, 4 and 5). The highest WUE for rice, wheat, mustard and sugarcane crops (0.42, 1.48, 2.16 and 8.5 kg m^{-3}) were recorded in laser-levelled field against the lowest (0.26, 0.98, 1.15 and 4.23 kgm^{-3}) in unlevelled field while in traditionally levelled field were (0.32, 1.17, 1.53 and 6.17 kg m^{-3}). Overall, the water-use efficiency was 38.09, 33.78, 46.75 and 50.23% higher precisely in levelled field than control and 28.57, 20.94, 29.16 and 28.58 % higher than traditional levelling. This huge difference in water use efficiency was because of reduced grain/cane yield and higher amount of water applied to unlevel and traditional levelled fields. The decrease in water use efficiency in unlevelled fields also reflected the sensitivity of the crop to water excess/deficit, a characteristic of undulating fields' surface of unlevelled fields. The reason for lower WUE in traditionally levelled and unlevelled fields was the inefficient use of the water applied. The result suggests that laser land levelling is more water use efficient, more cost effective and give higher crop yield through efficient utilization of scarce land and water resources. Thus in the light of this study, it is imperative to recommend that laser land levelling should be popularized among the farmers at it not only increase water use efficiency and yield but also ensure better germination, better utilization of water and non water inputs towards increased yield.

Soil health

Water Soluble Carbon

The distribution of soil mass among the size classes of water stable carbon (WSC) was strongly influenced by land levelling in both the soil depths (0–15 cm and 15-30 cm). WSC was found to be 3.74% higher in surface soil than in sub-surface soil (Table 6, 7 and 8). In both the depths, laser land levelling treatment had the highest WSC as compared to the other treatments studied. Compared to unlevelled and traditional levelling increased 23.7% WSC in surface soil and 20.1% in sub surface soil. Among all the treatments, laser land levelling had significantly higher (21.6%) proportion of WSC than the other treatments compared.

Soil microbial biomass carbon

The level of MBC was indistinguishable between the unleveled and traditional leveling regimes and was markedly lower under these regimes than under laser land leveling (Table 6, 7 and 8). Changes in MBC can indicate the effects of management practices on soil biological and biochemical properties. The higher MBC we observed in the laser land leveling and minimum in unleveled plots. The values of MBC increased by 12.1 and 35.1% under traditional leveling and laser land leveling treatment in surface soil over unleveled plots. While, laser land leveling were 29.1 and 26.2% increase of MBC over traditional leveling, respectively. The highest value of MBC due to land leveling might be due to higher turn-over of root biomass produced under laser land leveling treatment. Adoption of laser land leveling is not only required for better growth of the crop but also required for synthesis of cellular components of microorganisms. Therefore, higher root biomass under laser land leveling treatment helped in increasing MBC over other treatments. Although MBC content in soil represent a small fraction i.e. about 2-4% of TOC, however, variation in this pool due to management and cropping systems indicate about the quality of soil, because the turn-over of SOM is controlled by this pool of SOC which can provide an effective early warning of the improvement or deterioration of soil quality as a result of different management practices.

Light fraction of carbon

The labile fraction carbon (LFC) is considered as a useful approach for the characterization of SOC resulting from land leveling practices including different arable crops. The values of LFC in surface soil were 164.5, 137.8; 105.9, 87.4 and 76.6, 67.5 mgkg^{-1} in laser land leveling and traditional leveling and unleveled treatments, respectively (Table 6, 7 and 8). In 15-30 cm layer, the increasing trends in LFC content due to leveling practices were similar to those observed in 0-15cm layer; however, the magnitude was relatively lower (Table 6, 7 and 8).

Different forms of soil carbon

Precision land levelling practices significantly influenced the total soil carbon (TC), Total inorganic carbon (TIC), total soil organic carbon (SOC) and oxidizable organic carbon (OC) content of the surface (0–15 cm) soil (Table 9). Laser land leveling (T_1) and traditional leveling practice (T_2) showed significantly higher TC, SOC content of 11.93 and 10.73 g kg^{-1}, respectively in T_1 and 10.98 and 9.38 g kg^{-1}, respectively in T_2 (Table 9) as compared to the other treatments. There was no significant effect of land levelling practices on different forms of carbon under sub-surface (15–30 cm) soil (Table 9). Consequently, the land leveling makes aggregates more stable, protects C and thus increases C sequestration and not separately. Laser land leveling forms a barrier against evaporation thereby maintaining the water stored in the plant root zone (Lichter *et al*., 2008) [23].

Profitability

Using scarce water resources in rice, wheat, mustard and sugarcane cultivation in a sustainable manner, brought a larger area under rice-wheat, mustard and sugarcane cultivation; the laser land levelling fields irrigation of these crops appeared to be an eco-friendly and economically viable technology. It led to higher productivity in rice, wheat, mustard and sugarcane and increased sucrose content in sugarcane and ultimately increased income for the farmers (Tables 10, 11 and 12). Higher net returns were observed by laser land levelling technology Rs. 90380, 72649, 69440 and 195275 ha^{-1} in rice, wheat, mustard and sugarcane crops in comparison to control (unlevelled) fields. Other benefits include saving on fuel expenses, improvement in fertilizer use efficiency, uniform internodes length, thicker canes, less weed growth and uniform irrigation of rice/wheat/mustard/sugarcane grown on undulated terrains.

Although, laser land levelling is beneficial, there are certain limitations associated with it such as high cost of the equipment/laser instrument and need for a skilled operator. It may be less efficient in irregular and small sized fields. Utilizing these eco-friendly and economically viable options will go a long way in sustaining rice, wheat, mustard and sugarcane productivity and economizing water under conditions of ever-depleting water resources. Over the past decade, researchers in association with farmers and entrepreneurs have been trying to overcome the problems of depleting water resources, diminishing input use efficiency, declining farm profitability, and deteriorating soil health by developing, evaluating and refining conservation and precision agriculture-based resource-conserving technologies for the mustard, rice-wheat and sugarcane system in North Madhya Pradesh. Recently, laser-assisted precision land levelling has shown promise for better crop establishment, water savings and enhanced input use efficiency. This study have shown the effect of rice, wheat, mustard and sugarcane planting on laser levelled fields increased yields (av. of 3 yrs) by 14.35, 10.83, 16.07 and 15.8 % on traditionally levelled fields. The saving in irrigation water with precision-conservation were 16.36, 14.54, 16.66 and 21.15 % compared to traditional levelling field and 27.27, 27.27, 31.66 and 47.11 % to unlevelled fields in rice, wheat, mustard and sugarcane crop, respectively.

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

Treatments	Plants height (cm.)		Effective tiller m^{-2}		No. of grain spike^{-1}		1000 grain wt.(g)		Grain yield (t. ha^{-1})	
	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat
Laser land levelling	128.7	96.4	318	325	132	42.4	24.3	41.7	4.70	4.91
Traditional levelling	123.8	88.2	302	310	121	39.1	23.5	38.6	4.11	4.43
Control (Unlevelled)	110.5	79.4	287	289	115	37.4	21.2	37.6	3.68	4.14
CD(P=0.05)	14.6	11.2	14.2	16.0	6.5	3.8	1.4	3.1	0.26	0.22

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

Treatments	Total duration hr ha^{-1}		Water depth/ irrigation (mm)		Volume of water applied (m $^{-3}$)		WUE(kg m^{-3})	
	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat
Laser land levelling	100	36.6	70	55	11000	3300	0.42	1.48
Traditional levelling	120	47.4	82	63	12800	3780	0.32	1.17
Control (Unlevelled)	140	56.7	90	70	14000	4200	0.26	0.98
CD(P=0.05)	8.5	6.2	07	09	1510	527		-

Table 3: Effect of Mustard yield and its components as affected by laser land levelling and traditional levelling techniques

Treatments	Plants height (cm.)	Branches plant^{-1}	Silique plant^{-1}	1000 grain wt.(g)	Grain yield (mg ha^{-1})
Laser land levelling	198.4	16.58	261	4.64	2.60
Traditional levelling	192.6	15.24	245	4.43	2.24
Control (Unlevelled)	189.7	14.76	231	4.22	1.82
CD(P=0.05)	2.6	0.8	10.2	0.15	0.14

Table 4: Effect of Mustard on Total duration, applied water depth and water use efficiency as affected by laser land levelling and traditional levelling techniques

Treatments	Total duration hr ha^{-1}	Water depth/ irrigation (mm)	Volume of water applied (m $^{-3}$)	WUE (kg m^{-3})
Laser land levelling	30.6	60	1200	2.16
Traditional levelling	38.4	70	1400	1.53
Control (Unlevelled)	45.0	79	1580	1.15
CD(P=0.05)	4.8	5.5	115	0.20

Table 5: Sugarcane yield and total duration, applied water depth and water use efficiencies as affected by laser land levelling and traditional levelling techniques.

Treatments	Total duration hr ha^{-1}	Water depth /irrigation (mm)	Volume of water applied (m^{-3})	Yield (t ha^{-1})	WUE (kg m^{-3})
Laser land levelling	112.4	80	10400	88.6	8.50
Traditional levelling	127.8	95	12600	76.5	6.07
Control (Unlevelled)	142.5	110	15300	64.8	4.23
C D at (0.5)	8.6	12.8	190	7.2	0.15

Table 6: Concentrations of different soil organic matter carbon fractions at different soil depths by laser land levelling and traditional levelling techniques to the RW cropping system

Treatments	0-15 cm			15-30cm		
	WSC (mgkg^{-1})	MBC (mgkg^{-1})	LFC (mgkg^{-1})	WSC (mgkg^{-1})	MBC (mgkg^{-1})	LFC (mgkg^{-1})
Laser land levelling	27.8	481.7	155.2	19.6	294.8	132.6
Traditional levelling	23.9	311.4	81.3	15.7	193.9	65.1
Control (Unlevelled)	17.2	266.7	52.7	13.2	145.9	49.8
C D at (0.5)	4.14	178.33	29.33	4.11	103.27	18.33

WSC = water soluble carbon, MBC = microbial biomass carbon, LFC = labile fraction carbon

Table 7: Concentrations of different soil organic matter carbon fractions at different soil depths by laser land levelling and traditional levelling techniques to the mustard crop

Treatments	0-15 cm			15-30cm		
	WSC (mgkg^{-1})	MBC (mgkg^{-1})	LFC (mgkg^{-1})	WSC (mgkg^{-1})	MBC (mgkg^{-1})	LFC (mgkg^{-1})
Laser land levelling	31.6	343.9	160.5	23.6	267.3	139.7
Traditional levelling	25.9	311.4	107.8	17.8	219.8	94.1
Control (Unlevelled)	23.9	295.2	81.3	15.7	193.9	65.1
C D at (0.5)	5.76	33.93	54.71	5.97	49.51	32.17

WSC = water soluble carbon, MBC = microbial biomass carbon, LFC = labile fraction carbon

Table 8: Concentrations of different soil organic matter carbon fractions at different soil depths by laser land levelling and traditional levelling techniques to the sugarcane crop

Treatments	0-15 cm			15-30cm		
	WSC (mgkg^{-1})	MBC (mgkg^{-1})	LFC (mgkg^{-1})	WSC (mgkg^{-1})	MBC (mgkg^{-1})	LFC (mgkg^{-1})
Laser land levelling	29.2	535.8	177.8	22.6	361.8	141.2
Traditional levelling	26.4	398.6	128.8	20.3	240.9	102.9
Control (Unlevelled)	22.7	306.5	95.7	17.6	187.5	87.6
C D at (0.5)	3.12	93.67	51.33	2.65	55.67	39.33

WSC = water soluble carbon, MBC = microbial biomass carbon, LFC = labile fraction carbon

Table 9: Effect of land levelling practices on distribution of different forms of carbon in soil

Treatments	TC (g kg^{-1})		TIC (g kg^{-1})		SOC (g kg^{-1})		OC (g kg^{-1})	
	0-15 cm	15-30cm	0-15 cm	15-30cm	0-15 cm	15-30cm	0-15 cm	15-30cm
Laser land levelling	11.93	10.40	0.90	0.80	10.73	9.94	8.41	7.38
Traditional levelling	10.98	9.24	0.75	0.60	9.38	9.31	7.59	6.37
Control (Unlevelled)	6.39	6.12	0.30	0.22	4.16	6.82	3.53	3.07
C D at (0.5)	1.03	-	0.18	-	1.45	-	0.89	-

TC=Total carbon; TIC=Total inorganic carbon; SOC=Total soil organic carbon; OC= Oxidizable organic carbon

Table 10: Comparative energy and economics of laser land levelling and traditional levelling techniques.

Treatments	Laser land levelling		Traditional levelling		Control (Unlevelled)	
	Rice	Wheat	Rice	Wheat	Rice	Wheat
Grain yield, t ha^{-1}	4.70	4.91	4.11	4.43	3.68	4.14
Straw yield, t ha^{-1}	6.10	5.89	5.41	5.22	5.17	4.92
Gross income, Rs ha^{-1}	127080	105069	111188	94562	99816	88476
Cost of production, Rs ha^{-1}	36700	32420	37500	33740	34400	34920
Net income, Rs ha^{-1}	90380	72649	73688	60822	65416	53556
B : C ratio	3.46	3.24	2.96	2.80	2.90	2.53

Table 11: Economics of some agronomic measures on mustard production

Treatments	Laser land levelling	Traditional levelling	Control (Unlevelled)
Grain yield, t ha^{-1}	2.60	2.14	1.82
Gross income, Rs ha^{-1}	104000	85600	72800
Cost of production, Rs ha^{-1}	34560	35600	30960
Net income, Rs ha^{-1}	69440	49000	42340
B : C ratio	3.00	2.40	2.35

Table 12: Economics of some agronomic measures on sugarcane production (plant cane)

Treatments	Laser land levelling	Traditional levelling	Control (Unlevelled)
Cane yield, t ha^{-1}	88.60	76.50	64.80
Gross income, Rs ha^{-1}	265800	229500	194400
Cost of production, Rs ha^{-1}	70525	74300	68050
Net income, Rs ha^{-1}	195275	155200	126350
B : C ratio	3.76	3.08	2.85

Rice

Parameter	UL (A)	TL(B)	LLL(C)	Difference (A/B-C)	Percent
Total duration hr ha^{-1}	-	120	100	20	20.0
	140	-	100	40	40.0
Water depth/Irrigation	-	82	70	12	17.14
	90	-	70	20	28.57
Water use efficiency		0.32	0.42	-0.12	-28.57
	0.26	-	0.42	-0.16	-38.09

Wheat

Parameter	UL (A)	TL(B)	LLL(C)	Difference (A/B-C)	Percent
Total duration hr ha^{-1}	-	47.4	36.6	10.8	29.50
	56.7	-	36.6	20.1	54.91
Water depth/Irrigation	-	63	55	8	14.54
	70	-	55	15	27.27
Water use efficiency	-	1.17	1.48	-0.31	-20.94
	0.98	-	1.48	-0.50	-33.78

Mustard

Parameter	UL (A)	TL(B)	LLL(C)	Difference (A/B-C)	Percent
Total duration hr ha^{-1}	-	38.4	30.6	7.8	25.49
	45	-	30.6	14.4	47.05
Water depth/Irrigation	-	70	60	10	16.66
	79	-	60	19	31.66
Water use efficiency	-	1.53	2.16	-0.63	-29.16
	1.15	-	2.16	-1.01	-46.75

Sugarcane

Parameter	UL (A)	TLL(B)	LLL(C)	Difference (A/B-C)	Percent
Total duration hr ha^{-1}	-	127.8	112.4	15.4	13.70
	142.5	-	112.4	30.1	26.77
Water depth/Irrigation	-	95	80	15	18.75
	110	-	80	30	37.5
Water use efficiency	-	6.17	8.50	-2.33	-27.41
	4.23	-	8.50	-4.23	-50.23

UL- Unlevelled TLL = Traditional land levelling LLL = Laser land levelling

Conclusion

Over the past decade, researchers in association with farmers have been trying to solve the problems of declining farm profitability, depleting water resources, and other related concerns by developing, evaluating, and refining various RCTs for the dry land cropping systems of the north Madhya Pradesh, of India. This study was carried out to assess the impact of laser land level technology on irrigation water use and crop productivity based on the field survey in the rice-wheat, mustard and sugarcane arable crops district of Morena, M.P. Laser land levelling has been adopting since last 2 years by some growers in Chambal division, however, necessary data to support its effects on crop yield and water use efficiency are scarce. It was therefore, felt imperative need to evaluate the effect of laser and traditional land levelling technologies on rice, wheat, mustard and sugarcane productivity land and water use efficiency and soil health in rice-wheat system and mustard, sugarcane crops of Chambal division.

Laser land levelling has shown promise for better crop establishment, water savings, improve soil health and higher farm profitability. Present study in rice-wheat, mustard and sugarcane crops have showed that laser land levelling increased farm income by Rs. Rs. 90380, 72649, 69440 and 195275 ha^{-1} as compared to control (unlevelled) fields through improving system productivity and uniform discharge, before and after laser land levelling there was about 32% saving in water over control and 13% over traditional levelled field. Significantly, higher amount of water (14000, 4200, 1580 and 15300m^3) were required for unlevelled field than laser levelled field (11000, 3300, 1200 and 10400 m^3), which did not differ significantly from the traditionally levelled field. Laser-assisted precision land levelling is a promising option to sustain dry lands intensive arable crops cropping systems on a long-term basis. Overall, the water-use efficiency was 38.09, 33.78, 46.75 and 50.23% higher precisely in levelled field than control and 28.57, 20.94, 29.16 and 28.58 % higher than traditional levelling. Studies on the integration of precision land levelling with conservation agriculture (CA) for evaluating their long-term impacts on yield, energy savings, groundwater table, groundwater pollution, and soil health are strongly recommended under different agro ecologies for their large-scale adoption. Laser land levelling has been shown to improve water management, crop stand and productivity. With laser levelling, significant savings in irrigation water, improved efficiency of inputs, higher yields, improved soil health, increase in cultivated area, and better operational efficiency can be achieved. Therefore, this study confirms that Precision-Conservation Agriculture (PCA) based crop management solutions seem to be promising options to sustain the mustard, sugarcane and rice-wheat systems of north M.P., on a long-term basis.

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