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Original Article

Laser Land Levelling: Pioneering Efficient Water and Soil Management in Agriculture

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INTRODUCTION

Mechanization brings significant benefits to agriculture, but climate change and variability present severe challenges. To address these issues, we need to implement climate-smart agricultural practices and technologies that optimize the use of limited resources like water and energy while boosting yields, incomes, and reducing environmental impacts. By adopting a range of these practices, farmers can better adapt to shifting weather patterns and diminishing natural resources. For example, in north-western India, groundwater levels are rapidly declining due to excessive use of electric pumps, which are subsidized by government electricity schemes, combined with insufficient recharge from inconsistent rainfall. Recent research forecasts that a 1 °C increase in temperature could lead to at least a 10 % rise in irrigation water needs in arid and semi-arid parts of Asia (ccafs.cgiar.org). Given that irrigation is the primary consumer of groundwater in this region, immediate action is required to reverse this trend or farmers will face a future of water scarcity. The need for modern scientific technologies in water management is urgent due to declining irrigation water availability, reduced crop productivity, and rising food demand. Research suggests that global food production must increase by 50% by 2030 and double by 2050 to accommodate the growing population (Saxena and Rao, 2018). Agriculture, which accounts for approximately 83% of total water use, is the largest consumer of this vital resource (Rao et al., 2018). Water availability, which was over 5300 m^3 per person in 1951, dropped to 1588 m^3 per person by 2010 and is projected to fall below 1500 m^3 by 2025 (Saxena et al., 2018). Therefore, enhancing on-farm water management practices is critical to conserve water in agriculture.

Surface irrigation relies on gravity and slope to distribute water across a field, but soil's water retention varies spatially, complicating irrigation practices. Effective irrigation should consider these variations, and proper land levelling is essential for optimizing soil and crop management. Traditional levelling methods are often costly and assume uniform soil water deficits, which rarely align with actual field conditions due to variations in stream size, land topography, and soil type. This inconsistency in water application reduces irrigation efficiency.

Laser-guided levelling technology offers a more precise solution, creating a smooth, graded field that ensures accurate water distribution with minimal waste. This advanced method enhances irrigation efficiency, reduces nutrient loss, and improves seedling placement by the rice transplanter, leading to better germination and higher yields. In contrast, uneven fields can lead to higher energy use and increased production costs. Additionally, in India, the common practice of broadcasting urea as fertilizer can be inefficient on uneven surfaces, as nitrogen can wash away or leach into lower areas. A well-levelled field, however, allows for even nitrogen distribution, boosting fertilizer efficiency and crop yields.

Concept of Laser Land Levelling

Laser levelling is a technique used to smooth out the land surface, typically within ± 2 cm of its average elevation, using drag buckets equipped with lasers. This method involves adjusting the land to establish a consistent slope of 0 to 0.2%. It requires powerful tractors and soil movers fitted with GPS and/or laser-guided systems to either cut or fill the soil and achieve the precise slope or level needed. By eliminating unnecessary depressions and elevated contours, it allows for more efficient use of limited water resources. In the Indo-Gangetic Plains of India, rice and wheat yields increased by 8%, while in Cambodia, rice yields saw a 24% improvement (ghgmitigation.irri.org).

Factors to be considered

To achieve high-precision land leveling at a lower cost, certain prerequisites must be met. The following factors should be taken into account for effective and accurate land leveling.

1. **Slope of the field:** A slope of 0 to 0.2% is ideal for optimal water flow. A small channel, about 10-15 cm deep, positioned centrally in the field helps collect and direct drainage water to an outlet. Effective drainage improves harvest efficiency and provides ample time for preparing the field for the next crop season.

2. **Infiltration rate:** Checking the infiltration rates of the subsoil is crucial. In regions where significant soil movement and removal of hard pans occur, excessively high infiltration rates can result in greater leaching of nutrients and chemicals. Ideally, the subsoil's infiltration rate should be at least equal to that of the soil surface.

3. **Costing:** The initial expense for land levelling with tractors and scrapers is substantial, varying based on factors such as topography, field shape, and equipment used. Levelling one hectare of land with tractors typically costs between Rs. 1,840 and Rs. 2,000. This cost fluctuates depending on the volume of soil to be moved and the type of soil. Research across various locations indicates that the actual cost ranges from Rs. 120 to Rs. 200 for every 10 mm of soil moved per ha.

4. **Soil cut and fertility:** Soil conditions vary between fields due to differences in subsurface fertility and soil depth. Therefore, understanding the immediate subsurface fertility is crucial

before performing laser levelling. Infertile soil should not be used to replace the fertile top layer, as this could lead to reduced yields in subsequent seasons.

Types of Laser Land Levelers

A. Manual leveling lasers

To set up a laser leveling instrument, the operator must manually adjust the unit using screws and bubble vials to ensure it is level. The laser relies on tubular bubbles for this leveling process. The user must level the laser along both the X-axis and Y-axis, using the bubbles for precise alignment. These lasers can achieve a maximum accuracy of 1 cm over a distance of 100 m.

B. Semi self-leveling lasers

These lasers self-adjust within a specified range using a compensator. To reach the desired range, the laser features either a circular bubble with a bull's eye or electronic indicators that turn green when the self-leveling range is achieved. These lasers are highly precise and include an automatic shut-off feature if the laser is disturbed or moves out of the self-leveling range. They can maintain an accuracy of at least 1 cm over a distance of 100 m.

C. Fully self-leveling lasers

These lasers automatically achieve and maintain level within a defined range. They come with an electronic level vial and servomotors, which electronically adjust the instrument to level. Once levelled, the laser begins to spin. These devices are user-friendly and can achieve accuracy of up to 2.5 mm over a distance of 100 m.

D. Split-beam lasers

These lasers project both horizontal and vertical beams at the same time to create reference lines for level and plumb alignment.

Fig. 1: Laser Land Levelling

(Source: https://ccafs.cgiar.org/news/laser-land-levelling-how-it-strikes-all-right-climate-smart-chords)

Components of Laser Land Levelling System

1. **Drag bucket:** The drag bucket can be either mounted on the tractor via a 3-point linkage or towed by it. The latter option is often favored because it simplifies the connection of the tractor's hydraulic system to an external hydraulic ram, compared to the more complex internal control system of the 3-point linkage. The size and capacity of the bucket will depend on the power available and the specific conditions of the field.
2. **Laser transmitter:** The laser transmitter is mounted on a tripod, enabling the laser beam to cover the field. Multiple tractors equipped with a laser unit and drag bucket can operate from a single transmitter, guided by a laser receiver.
3. **Laser receiver:** The laser receiver is a multi-directional device that identifies the position of the laser reference plane and sends this information to the control box. It is mounted on a manual or electric mast attached to the drag bucket or scraper. The receiver features controls that allow the operator to adjust the bucket's height on the scraper. The operator can modify the receiver's settings and override it when needed to scoop up soil and move it to different areas of the field.
4. **Control box:** The control box receives and processes signals from the receiver mounted on the machine. It shows these signals to indicate the drag bucket's position relative to the desired grade. When set to automatic, the control box generates an electrical output to operate the hydraulic valve. It is mounted on the tractor within easy reach of the operator. The control box features three switches: ON/OFF, Auto/Manual, and Manual Raise/Lower, which allows the operator to manually adjust the height of the drag bucket.
5. **Hydraulic control system**: The tractor's hydraulic system powers the raising and lowering of the levelling bucket by supplying oil at pressures of 2000-3000 psi. Since the hydraulic pump is a positive displacement type and typically pumps more oil than necessary, a pressure relief valve is required to divert the excess oil back to the tractor's reservoir. If this relief valve is too small or fails, it can damage the tractor's hydraulic pump.

   The laser system includes an infrared beam that travels up to 700 meters in a straight line. The system's receiver detects this infrared beam and converts it into an electrical signal. This signal is then used by a control box to activate an electric hydraulic valve. This valve adjusts the blade of a grader several times per second to ensure it remains aligned with the infrared beam.

Working Procedure of Laser Land Leveller

The setup for levelling includes an electrical control panel, a twin hydraulic control valve, a laser transmitter mounted on a tripod, a laser receiver attached to the bucket or scraper, a survey receiver for adjusting the ground level, and a laser receiver for distance measurement. The laser receiver on the levelling bucket uses the rotating laser beam from the transmitter as its reference point. The control panel, installed on the tractor, processes the signals from the receiver to control the hydraulic valve, adjusting the bucket's height accordingly. To achieve effective levelling, soil must be moved economically from high areas to low areas. Before beginning the levelling process, fields should be ploughed and a topographic survey should be completed. Generally, following steps are involved:

1. **Ploughing:** The most effective way to plough a field is from the center towards the edges. It is advisable to plough when the soil is moist, as doing so when the soil is dry requires more tractor horsepower and may result in larger clods. If the soil is dry, using a one-way disc or moldboard may be necessary. For subsequent operations, disc harrows or tine implements are preferable. To ensure smooth soil flow from the bucket, any surface residues should be broken up or removed.
2. **Topographic survey**: Once the field is ploughed, a topographic survey should be carried out to pinpoint the high and low areas. By summing all the survey readings and dividing by the total number of measurements, the average height of the field can be determined. This average height, calculated using a field diagram, helps in strategically moving soil from elevated areas to lower ones.
3. **Setting up tripod**: First, unlock the tripod legs and adjust each one individually until the base plate is nearly level. Use the horizon as a visual guide to achieve this. If the laser does not self-level, adjust the screws on the transmitter's base to center the bubble in both circles. Most lasers need the transmitter to rotate for proper levelling. Once the transmitter is level, attach the receiver to the staff and activate the sound monitor. The laser is now ready for height measurements.


Fig 2 & 3: Laser Land Levelling at International Rice Research Institute (IRRI), Philippines. (Source: https://www.irri.org/laser-land-leveling-philippines)

4. **Field Leveling:** The position of the laser-controlled bucket should align with the field's average height, with the cutting blade set just above ground level (1–2 cm). The tractor should be driven in a circular pattern from the higher to the lower parts of the field at a speed of 5 to 6 km/h. As the bucket fills with soil, the operator should turn towards the lower areas to improve efficiency. When the bucket is nearly empty, the tractor should be turned around and driven

back to the higher areas. After completing this circular pattern across the field, the tractor and bucket should make a final levelling pass from the high end to the low end. Once the desired level of precision is achieved, the field should be resurveyed. Care should be taken to fill any wet areas from the edges in a circular motion to avoid bogging down the tractor. High winds and fog can impair the operation of the laser leveller.

Tillage practices to maintain the level of field after Levelling

Start by making a single pass down the center of the field to move soil to the sides. Then reposition the tractor at the end of this first pass and plough the second pass outward from the initial furrow. The third pass should return the previously ploughed soil to the depression in the center. The fourth pass will refill the remaining furrow, ensuring the center of the field is level. Next, plough both sides of the field until only a margin equal to the headland width remains. Finally, plough the rest of the field in a continuous pattern, leaving a drainage furrow next to the bund on the last pass.

Key Advantages of Laser land levelling are as follows:

1. **Enhanced Precision and Accuracy:** Laser land leveling ensures a more even and uniform surface by improving precision and accuracy in land leveling.

2. **Water Efficiency:** By promoting proper water distribution across the field, laser land leveling reduces water wastage and increases water efficiency.

3. **Reduced Soil Erosion:** Creating a smooth, level surface with laser land leveling minimizes soil erosion by preventing water runoff and soil loss.

4. **Increased Crop Productivity:** A uniform surface provided by laser land leveling improves seed-to-soil contact and nutrient uptake, enhancing crop productivity.

5. **Cost Savings:** Laser land leveling decreases the need for manual labor and machinery, leading to cost savings for farmers.

6. **Optimized Irrigation**: It ensures even water distribution, helping to prevent overwatering or underwatering and optimizing irrigation practices.

7. **Efficient Fertilizer Application:** A level surface from laser land leveling improves the efficiency of fertilizer application, reducing uneven distribution and wastage.

8. **Reduced Fuel Consumption and Emissions:** Minimizing machinery use and shortening land preparation time with laser land leveling helps cut fuel consumption and greenhouse gas emissions.

9. **Improved Field Quality:** Laser land leveling enhances the overall quality of the field by removing high and low spots, resulting in a more uniform and visually pleasing landscape.

10. **Reduced Risk of Crop Diseases and Pests:** By eliminating areas of standing water and improving drainage, laser land leveling lowers the risk of crop diseases and pests.

CONCLUSION

Laser leveling is an innovative resource-conservation technology recently introduced in India that shows promising results. It has the potential to revolutionize food production by significantly improving the efficiency of critical resources while maintaining the ecosystem's productive resilience. To maximize its benefits, it is crucial to popularize this technology among farmers through a comprehensive, participatory approach, with strong support from researchers and planners. As we look toward the future of agriculture, which involves ensuring food and nutritional security, environmental protection, and adapting to global markets, enhancing resource-use efficiency is essential for achieving the necessary growth in food production and agricultural productivity. Clearly, laser leveling represents a key solution for addressing these challenges effectively.

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