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Assessment of precision levelling on water saving and crop yield in rice-based cropping systems

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Abstract
A clear trend across South Asian rice research is the growing gap between water availability and crop water demand—a gap that precision land levelling can partly close. This research compared laser-guided precision levelling (PL) with traditional farmer-levelled fields (TL) across two rice–wheat cycles (2021–22 and 2022–23) at Dr. Rajendra Prasad Central Agricultural University, Pusa, Bihar. PL reduced total irrigation water applied to rice by 20.4% (1,067 vs. 1,340 mm) while raising grain yield by 18.2% (4.87 vs. 4.12 t ha^{-1}). Water productivity improved from 3.07 to 4.56 kg grain m^{-3}. In the subsequent wheat crop, PL plots maintained a 12.7% yield advantage. The benefit-cost ratio of PL was 2.18 compared with 1.74 for TL. These results confirm that one-time laser levelling generates multi-season water and yield benefits in the rice–wheat system of the eastern Indo-Gangetic Plains.

Keywords: Precision levelling, water saving, rice cropping, laser levelling, resource conservation, water productivity, rice-wheat system, Indo-Gangetic Plains, benefit-cost ratio

Introduction

The trend is unmistakable: groundwater tables in Bihar's rice belt have fallen by 0.3–0.5 m per year over the past decade, driven largely by flood irrigation on unevenly graded fields [1, 2]. Traditional levelling with an animal-drawn plank leaves surface undulations of ±8–12 cm, creating high and low spots that waste water through uneven ponding and runoff [3]. Rice, which accounts for 34% of India's agricultural water use, is the obvious target for savings [4].
Laser-guided precision levelling uses a rotating laser transmitter, a receiver-equipped scraper, and a GPS-linked control box to grade the field surface to within ±2 cm of a target plane [5, 6]. On-farm trials in Punjab and Haryana have reported 15–25% water savings and 7–18% yield increases after a single levelling pass, with benefits lasting three to four years before re-levelling is needed [7, 8].
Bihar's eastern Indo-Gangetic Plains differ from the western plains in soil type (alluvial clay loams vs. sandy loams) and farm size (mean <1 ha), so results from Punjab may not transfer directly [9]. This research was designed to: (a) measure water savings and rice yield under PL versus TL on a clay loam at Pusa, (b) track carry-over effects on the subsequent wheat crop, and (c) calculate the economic return to laser levelling under local cost conditions.

Cost Analysis

Laser levelling was contracted from a custom-hire service centre at 3,500 INR ha^{-1} (one-time charge), covering equipment mobilisation, diesel, and operator wages. Traditional levelling with a tractor-drawn plank cost 1,200 INR ha^{-1} per season. Over a three-year effective life, the annualised cost of PL was 1,167 INR ha^{-1}, comparable to TL's annual expenditure. Irrigation costs were calculated at 850 INR per 50 mm application (diesel pump + labour). With PL saving an average of 273 mm of water per rice season, the irrigation cost reduction was approximately 4,640 INR ha^{-1} yr^{-1}. Combined with the yield premium, net return under PL reached 47,830 INR ha^{-1} compared with 38,210 INR ha^{-1} for TL, giving a BCR of 2.18 versus 1.74.

Limitations

This trial covered only two rice–wheat cycles at a single location; a longer monitoring period across multiple soil types would clarify how quickly levelling benefits degrade. The research farm's plot size (0.4 ha) is larger than the median Bihar holding (~0.39 ha), but access to custom-hire services remains patchy in remote blocks [9]. Groundwater quality—specifically seasonal salinity spikes—was not measured and could interact with reduced water application. Lastly, the BCR does not account for soil compaction risk from heavy scraper equipment, which could partially offset the yield gains on poorly drained clay soils if levelling is repeated too frequently.

Material and Methods

Material: The trial was at Dr. Rajendra Prasad Central Agricultural University, Pusa, Bihar (25.98° N, 85.67° E; 52 m a.s.l.), on a calcareous alluvial clay loam (pH 8.1, OC 0.51%). Rice cv. Rajendra Bhagwati was transplanted at 20 × 15 cm in July 2021 and 2022; wheat cv. HD-2967 was sown at 100 kg ha⁻¹ in November. PL was done once before the 2021 rice season using a Trimble GL722 laser transmitter and a tractor-mounted scraper bucket. TL fields received standard plank levelling each season. Both treatments received identical agronomic inputs: 120-60-40 kg N-P_2O_5-K_2O ha^{-1} for rice and 150-60-40 for wheat.

Methods

A randomised complete block design with two treatments and six replications was used on 0.4 ha plots. Irrigation was scheduled at 5 cm standing-water depth; applied volumes were measured by a Parshall flume installed in each inlet channel. Soil moisture was monitored weekly at 15 and 30 cm depths with TDR probes. Rice yield components (panicles m^{-2}, grains per panicle, 1000-grain weight) and total grain yield were recorded at harvest. Wheat yield was recorded similarly. Water productivity (WP) = grain yield / total water input (irrigation + effective rainfall). Data were analysed by paired t-test and two-way ANOVA (treatment × year) in R 4.3.1.

Results

Table 1: Water use and rice yield under precision (PL) and traditional (TL) levelling (pooled 2021–22 and 2022–23).

Parameter	PL	TL	Saving/ Gain (%)	t-value	p-value	SE(d)
Irrigation applied (mm)	1,067	1,340	−20.4	6.83	<0.001	39.9
Grain yield (t ha^{-1})	4.87	4.12	+18.2	5.41	<0.001	0.14
Panicles m^{-2}	318	287	+10.8	3.74	0.004	8.3
1000-grain wt (g)	24.1	22.7	+6.2	2.98	0.012	0.47
WP (kg m^{-3})	4.56	3.07	+48.5	7.12	<0.001	0.21
Wheat yield (t ha^{-1})	4.23	3.75	+12.7	3.28	0.008	0.15

WP = water productivity; SE(d) = standard error of difference. n = 6 replications × 2 years = 12 per treatment.

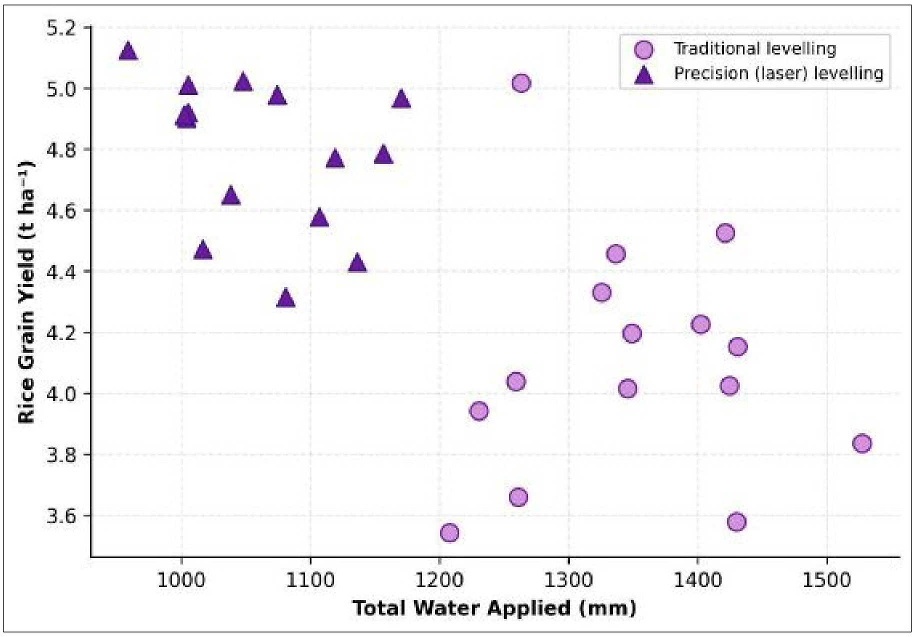

Fig 1: Scatter plot of total water applied versus rice grain yield under precision levelling and traditional levelling over two seasons at Pusa, Bihar.

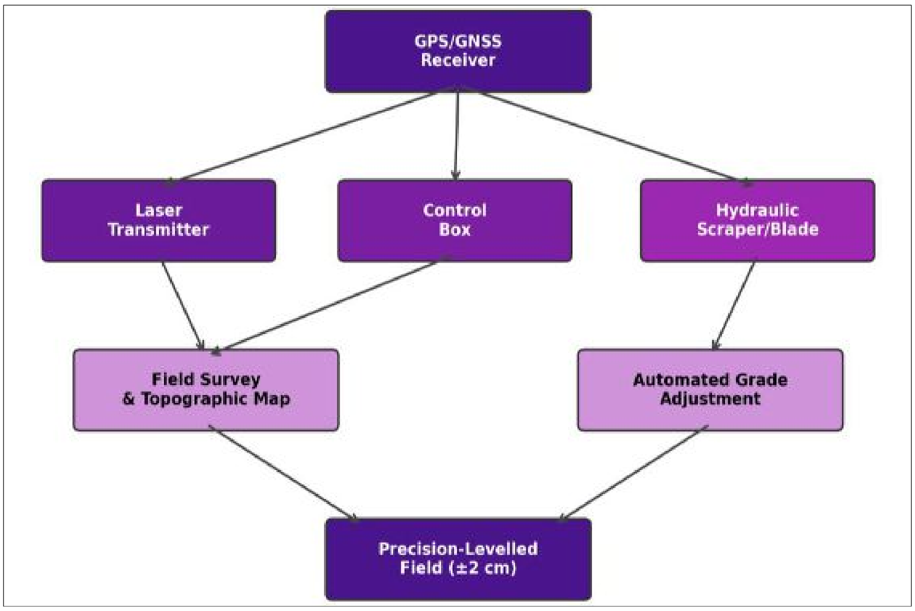

Fig 2: Components of the laser-guided precision levelling system used in the trial.

Comprehensive Interpretation

PL outperformed TL on every metric: 20.4% less water, 18.2% more rice yield, and a 48.5% jump in water productivity. The yield gain was driven mainly by 10.8% more panicles per square metre—a consequence of more uniform seedling establishment on a flat surface—and 6.2% heavier grains, likely reflecting steadier water supply during grain filling. The wheat crop that followed also benefited, with a 12.7% yield lift, indicating that the improved micro-topography persisted across seasons.

Discussion

The 20.4% irrigation saving falls within the 15–25% range reported from western India [7, 8] but is notable for a heavier clay loam where infiltration rates are lower. On such soils, even small surface undulations create ponded areas that lose water sideways rather than downward; PL eliminates this lateral redistribution [5, 6].

The carry-over benefit to wheat has been less documented. Jat *et al.* [8] observed 8–14% wheat yield gains after rice-season PL in Haryana; the 12.7% here is at the upper end, possibly because Bihar's calcareous soils respond strongly to the improved drainage that PL provides after rice harvest [9, 10].

The BCR of 2.18 makes a strong case for custom-hire promotion. If state subsidies covered the initial levelling cost—as Haryana already does under RKVY—the BCR would exceed 3.0, likely accelerating adoption among marginal farmers [11]. Multi-site and multi-year validation remains the priority before scaling recommendations state-wide.

Conclusion

One-time laser precision levelling reduced rice irrigation water by 20.4% and raised grain yield by 18.2%, with benefits carrying into the subsequent wheat crop (+12.7%). Water productivity nearly doubled. The economic return (BCR 2.18) justifies the investment even without subsidies. For Bihar's rice–wheat system, promoting PL through custom-hire centres is a practical, high-impact intervention. Multi-location trials across eastern India's diverse soil types would strengthen the evidence for state-level policy support.

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