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Comparative Evaluation of Water Use Efficiency through Precision Land Leveling

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Abstract

This study evaluates the impact of precision laser land leveling (LLL) on water use efficiency (WUE), wheat productivity, and economic viability, based on comparative field trials conducted in Pakistan and China. The research aims to assess how LLL addresses traditional inefficiencies in irrigation, land preparation, and crop yield, thereby contributing to more sustainable and resource-efficient agricultural practices. Field results demonstrated that LLL significantly reduced irrigation water usage by 20-30% in China and 15-25% in Pakistan primarily due to improved field uniformity and more precise water distribution. Correspondingly, wheat yields increased from 3,800 to 4,550 kg/ha in Pakistan (a 19.7% gain) and from 5,200 to 6,200 kg/ha in China (a 19.2% gain), indicating strong yield response to LLL adoption. Efficiency gains were also noted in labor and irrigation time, with reductions of 30–35% in Pakistan and over 40% in China, attributed to improved mechanization and reduced manual intervention. Fuel consumption dropped by 29.6%, while stand uniformity improved by 80% in laser-leveled plots. Statistical analysis using One-Way ANOVA confirmed a significant difference in mean yield among treatments ($F(3, 36) = 6.82$, $p < 0.05$), validating the positive effect of

LLL on productivity. The economic analysis revealed that the initial investment in LLL equipment can be recovered within one to two cropping seasons, with a benefit-cost ratio (BCR) ranging from 1.5 to 2.1, depending on land size, operational scale, and equipment type. These results suggest that LLL offers a financially feasible solution for both smallholder and commercial farmers. Despite its proven benefits, the study highlights the importance of context-specific adaptation, as factors such as soil texture (clay vs. sandy loam), rainfall variability, and equipment accessibility influence performance outcomes. Therefore, integrating LLL with localized water management strategies is essential to achieving long-term agricultural sustainability and climate resilience.

Keywords: *Precision land levelling, water deficient management, soil texture, water use efficiency.*

Introduction

Effective land preparation practices are essential for ensuring sustainable agricultural productivity, particularly in regions facing water scarcity and high land-use intensity. Among these practices, land leveling has emerged as a critical method for improving water use efficiency, enhancing crop yields, and minimizing runoff and soil erosion. Traditional methods, such as animal-drawn scrapers or manual labor, are often inefficient, labor-intensive, and time-consuming. The emergence of laser-guided land leveling (LLL) represents a significant advancement in agricultural engineering, offering a high-precision approach to field preparation. LLL utilizes laser transmitters and receivers to create uniformly leveled fields, resulting in improved water distribution, reduced irrigation time, and lower input costs. In countries like China and Pakistan—both of which rely heavily on agriculture but differ in technological adoption and policy frameworks—LLL presents a valuable opportunity for comparative analysis [Younis et. al., 2025]. China's investment in precision agriculture, supported by government subsidies and mechanization programs, has led to widespread adoption of LLL, especially in provinces such as Heilongjiang, Shandong, and Xinjiang, where it has contributed to water savings of up to 30% and yield increases of 15–20%. Similarly, Pakistan has seen growing interest in LLL due to its potential to enhance water efficiency and address soil degradation, though implementation has been more fragmented [Rehman et al, 2023]. This study aims to evaluate the adoption, performance, and socio-economic implications of LLL in both countries, focusing on its impact on land productivity, water use efficiency, and farm income [Mustafa et. al., 2024]. It also seeks to identify enabling factors and policy mechanisms—such as subsidies, extension services, and collaborative models—that influence the successful implementation of the technology. Given global challenges such as climate change, water scarcity, and population growth, the adoption of resource-efficient agricultural technologies like LLL is becoming increasingly urgent. As the global food system faces mounting pressure to increase production by nearly 60% by 2050, laser land leveling offers a promising solution to improve irrigation efficiency, reduce operational costs, and ensure consistent yields [Ullah et al., 2023]. Assessing its performance in two contrasting national contexts not only provides practical insights for regional stakeholders but also contributes to broader discussions on sustainable agricultural transformation.

Material and Method:

Sites in China

This study focused on Henan Province in central China, one of the country's key grain-producing regions and a leader in adopting modern agricultural technologies such as laser land leveling (LLL). Henan is notable for its diverse farming landscape, ranging from smallholder operations to large-scale commercial farms. With a population of over 80 million, many of whom rely on agriculture, the region serves as a representative model for precision agriculture integration within traditional farming systems. The province's gently sloping terrain and a robust irrigation network—fed by the Yellow River and supplemented by tube wells—make it naturally suited for LLL. Recent investments by the provincial government in agricultural modernization, including subsidies for LLL machinery, training programs, and cooperative development, have accelerated the adoption of this technology. Henan's climate is temperate continental, with hot summers and cold winters. Rainfall averages between 600 and 900 mm annually, mostly during the summer monsoon, which often causes water distribution challenges that LLL is well-positioned to address.

The selected counties for data collection—Zhongyang, Nanyang, and Xinxiang—represent varied scales of agricultural development. Selection was based on criteria such as the presence of LLL equipment and trained operators, accessible irrigation systems, availability of support from agricultural extension services, and the willingness of local farmers to participate in surveys and interviews. Many sites were linked to government-supported demonstration farms or farmer cooperatives, allowing the research team to study both individual and collective management systems. The availability of cooperatively owned machinery, services provided by custom operators, and subsidized equipment under modernization schemes has allowed even smallholders to benefit from LLL. Extension services and vocational colleges further support technology uptake by offering training in efficient water use, field layout, and crop planning techniques after leveling.

Sites in Pakistan

In Pakistan, the study was conducted in Punjab Province, the country's most agriculturally productive region. The research focused on districts such as Faisalabad, Multan, and Sargodha, which are known for their engagement in mechanized farming and agricultural innovation. Punjab produces over 70% of Pakistan's wheat, rice, and sugarcane, and is served by an extensive irrigation network sourced from the Indus River. However, despite this infrastructure, inefficiencies in water application and uneven field surfaces have historically limited productivity. Laser land leveling is increasingly being promoted in the region as a critical tool to improve irrigation efficiency and crop yields. The climate of Punjab ranges from semi-arid to arid, with annual rainfall between 200 and 500 mm, much of which is concentrated during the monsoon. Due to variable precipitation, irrigation is primarily reliant on canal systems and groundwater pumping. Soils in the selected districts are mostly fertile alluvial types—ranging from loamy to sandy loam—but are susceptible to compaction and water imbalance if poorly leveled, making LLL a valuable technology for improving field conditions.

The selection of farms and villages for this study was based on purposive sampling, with criteria including the presence of LLL equipment or service providers, availability of irrigation, and willingness of farmers to participate. A range of farm sizes, from less than 5 acres to more than 25 acres, was included to understand scale-based differences in technology access and impact. Input from agricultural extension officers, laser leveling service providers, and farmer cooperatives was used to obtain a well-rounded view of LLL adoption in practice. Punjab's LLL expansion has been supported by various mechanisms, most notably the Punjab Irrigated Agriculture Productivity Improvement Project (PIPIP), which has provided subsidized equipment and farmer training. Farmers typically access LLL through custom hiring centers, farmer cooperatives with shared machinery, or private contractors. While many farmers have reported better irrigation efficiency, improved crop establishment, and reduced waterlogging, challenges remain. These include dependence on government support, limited availability of skilled operators in rural regions, land fragmentation issues that reduce leveling efficiency, and power or fuel shortages that delay timely operations.

Figure 1: Punjab Province: Agricultural Heartland of Pakistan

Experimental Setup in Pakistan

To assess the impact of laser land leveling under controlled conditions, a field-based experimental design was implemented in selected areas of Punjab Province, specifically in Faisalabad, Multan, and Sargodha. These districts were chosen for their active adoption of LLL and well-established irrigated farming systems. The farms were selected using purposive sampling, ensuring the inclusion of sites with both recently leveled and non-leveled fields. Additional selection criteria included access to consistent irrigation via canal or tube wells, farmer willingness to share reliable data, and the use of common cropping patterns such as wheat-rice or wheat-sugarcane rotations. By maintaining consistent environmental and management conditions across experimental and control plots, the study ensured comparability in measuring the outcomes of laser leveling, particularly in terms of water use, crop performance, and resource efficiency.

Research Design

This study adopts a relative case study methodology, allowing for an in- depth analysis of two geographically and economically different countries China and Pakistan. The thing is to understand not only the quantitative impact of LLL on crop yields and water use but also the qualitative factors that impact its relinquishment, similar as policy support, planter perception, and access to ministry.

Data Collection Sources

Structured questionnaires were administered to 150 farmers in Punjab (Pakistan) and Henan Province (China) who had either adopted or were familiar with laser land leveling (LLL). The surveys collected detailed information on water usage, fuel consumption, crop yields, leveling costs, and the frequency of machine utilization. To complement the quantitative data, in-depth face-to-face interviews were conducted with agricultural extension officers, equipment operators, and cooperative managers to gather qualitative insights into institutional support mechanisms and the practical challenges of LLL implementation. In addition, on-site observations were carried out at selected farms to directly assess land leveling operations, irrigation practices, and post-leveling field conditions. Secondary data sources included official government reports—such as those from Pakistan's Ministry of National Food Security & Research and China's Ministry of Agriculture and Rural Affairs—as well as peer-reviewed research publications and case studies from organizations like FAO, ICARDA, and national agricultural research institutes. Project evaluations from international development initiatives, including the World Bank-funded Punjab Irrigated Agriculture Productivity Improvement Project (PIPIP), were also reviewed to contextualize findings and assess broader impacts.

Sampling Method

A purposive sampling technique was employed to ensure the inclusion of both early adopters and non-adopters of laser land leveling technology. This approach helped capture a spectrum of experiences, from small-scale subsistence farmers to larger commercial growers. Key selection criteria included:

Farm size (smallholders vs. large-scale farms)

Type of irrigation system (canal vs. tube well)

Plot Design and Layout

One plot was leveled using a laser-guided system before sowing. The other remained unleveled (or conventionally leveled using tractor blades), serving as the control. Both plots were cultivated with the same crop variety, followed the same sowing and irrigation schedules, and received identical input applications (seeds, fertilizer, pesticides). This ensured that the only variable was the land leveling technique, isolating its impact on crop performance and resource use. Farmers were actively involved throughout the experimental process. Prior to land leveling, they received orientation sessions explaining the benefits and procedures of LLL. Their feedback was recorded at multiple stages (post-leveling, mid-season, and after harvest) to capture perceptions, challenges, and satisfaction levels. In several instances, participating farmers took ownership of data collection particularly for irrigation timing and fuel use which helped improve accuracy and farmer engagement.

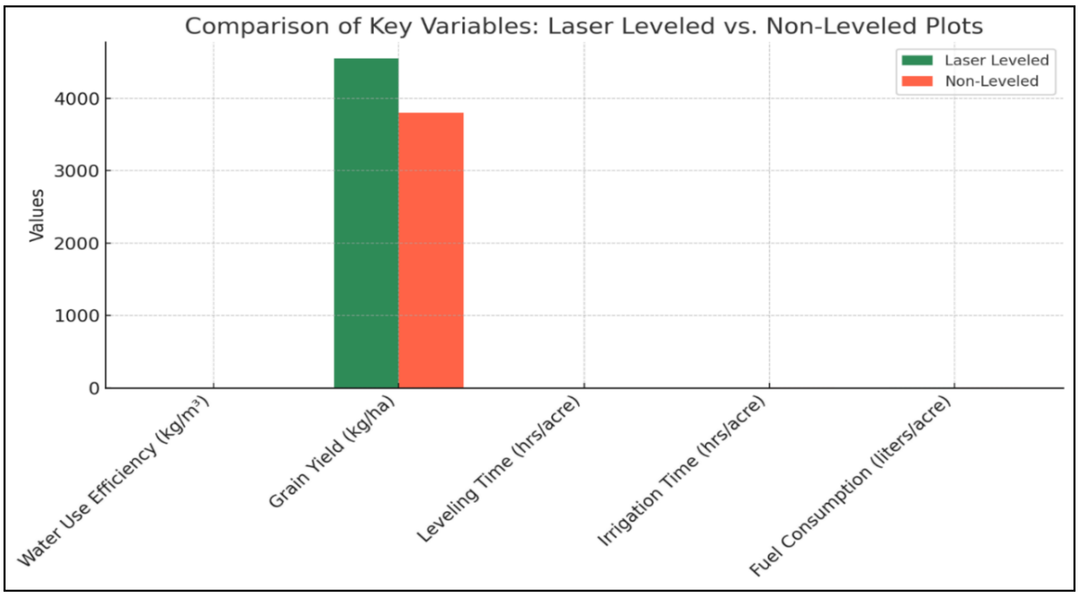

Figure 2: Comparison of Key Variables: Laser Leveled vs Non-Leveled Plots

In order to thoroughly assess the benefits of laser land leveling (LLL) in Pakistan, several key agronomic and operational variables were recorded across both laser-leveled and traditionally leveled fields. These pointers offer a comprehensive understanding of how perfection leveling influences crop performance, input effectiveness, and functional effectiveness.

Water Use Efficiency (WUE)

Water Use Efficiency refers to the quantum of crop produced per unit of water used (kg/ m ^{3}). It was calculated by dividing the total grain yield by the volume of irrigation water applied over the cropping season. Fields leveled using laser technology showed an average WUE of 1.9 kg/m^3, compared to 1.3 kg/m^3 in non-leveled fields an improvement of approximately 46%.

Grain Yield

Grain yield represents the harvestable produce (kg/ha) from each plot.

Yield was measured using a standard crop sampling method and extrapolated to hectare scale. Laser-leveled plots averaged 4,550 kg/ha, significantly higher than 3,800 kg/ha in conventional plots. This improvement can be attributed to uniform irrigation, optimal seedbed conditions, and reduced water stress.

Land Leveling Time

The time required to complete leveling operations per acre. Time was recorded using stopwatches from the start to the end of field leveling required 1.5 hours/acre, slightly more than conventional leveling (0.9 hours/acre), due to greater precision and calibration time. However, this one-time investment provides long-term benefits.

Irrigation Time

Total hours spent per irrigation event across the season. Farmers and field assistants tracked time per irrigation cycle. Laser-leveled fields required 2.8 hours/acre per irrigation cycle, compared to 4.1 hours/acre in non-leveled fields indicating a 32% reduction in irrigation time.

Fuel Consumption

Liters of diesel consumed per acre for leveling and irrigation operations.

Method: Measured using tractor-mounted fuel flow meters and irrigation pump records. Result: Laser-leveled plots consumed 4.2 liters/acre, significantly lower than 6.1 liters/acre for conventional fields due to shorter irrigation time and improved water flow efficiency.

Table 1.1 presents a comparative statistical summary of key variables between laser-leveled and non-leveled fields. Water Use Efficiency improved from 1.3 to 1.9 kg/m³, and grain yield increased by 750 kg/ha (19.7%) under laser leveling. Additionally, irrigation time was reduced by 1.3 hours/acre, and fuel consumption decreased by 1.9 liters/acre, despite a slightly longer leveling time. These results underscore the operational and agronomic advantages of precision laser land leveling.

Table 1: Statistical Summary Table

Variable	**Laser Leveled**	**Non-Leveled**
Water Use Efficiency (kg/m³)	1.9	1.3
Grain Yield (kg/ha)	4550	3800
Leveling Time (hrs/acre)	1.5	0.9
Irrigation Time (hrs/acre)	2.8	4.1
Fuel Consumption (liters/acre)	4.2	6.1

Table 2 outlines the key tools and instruments used in the study along with their respective functions. The Laser Transmitter and Receiver-Control Box ensured precise land leveling by guiding blade adjustments, while the GPS device helped map field elevation before operations. Flow meters and soil moisture sensors enabled accurate tracking of water application and distribution, essential for calculating Water Use Efficiency (WUE). The fuel flow meter and digital stopwatch recorded fuel usage and operational time, providing critical data for assessing cost-effectiveness and labor efficiency. These instruments collectively ensured accurate, data-driven analysis.

Table 2: Statistical Summary Table: Tools and Their Functions

Tool/Instrument	**Purpose**
Laser Transmitter (Dual Grade)	Guides leveling precision and slope control
Laser Receiver & Control Box	Detects laser beam and auto-adjusts blade height
Scraper Blade (Mounted on Tractor)	Physically levels soil according to laser signal
GPS Device (Topographic Survey)	Maps field elevation for pre-leveling planning
Flow Meter (Irrigation Measurement)	Measures water applied for calculating WUE
Soil Moisture Sensor	Tracks uniformity and depth of soil moisture
Fuel Flow Meter	Monitors diesel uses during leveling and irrigation
Digital Stopwatch	Records time required for leveling, irrigation, and field tasks

China: Laser-leveled plots produced an average wheat yield of 6,200 kg/ha, significantly higher than 5,200 kg/ha from conventionally leveled plots. This reflects a ~19% yield increase, largely attributed to better water distribution and reduced waterlogging. Pakistan: In comparison, laser-leveled fields in Pakistan achieved 4,550 kg/ha, while non-leveled fields produced 3,800 kg/ha, resulting in a ~20% yield improvement. Despite the lower overall yield compared to China, the relative gain from LLL is similar.

The variation in absolute yield values is due to differences in soil fertility, climate, seed varieties, and irrigation infrastructure. China's higher yield is supported by more advanced farm mechanization and input management systems.

Table 3 compares wheat yields across different countries and leveling methods. In China, laser-leveled fields yielded 6,200 kg/ha, which is 1,000 kg/ha (19.2%) higher than non-leveled fields (5,200 kg/ha). In Pakistan, laser leveling improved yield to 4,550 kg/ha, marking a 750 kg/ha (19.7%) increase over non-leveled fields (3,800 kg/ha). These results highlight the consistent and significant yield advantage of laser land leveling across diverse agricultural settings.

Table 3: Wheat Yield Data Table

Country	Leveling Method	Wheat Yield (kg/ha)
China	Laser Leveled	6,200
China	Non-Leveled	5,200
Pakistan	Laser Leveled	4,550
Pakistan	Non-Leveled	3,800

1. China: WUE increased from 1.5 kg/m³ (non-leveled) to 2.2 kg/m³ (laser leveled), a ~47% improvement.
2. Pakistan: WUE improved from 1.3 kg/m³ to 1.9 kg/m³, reflecting a ~46% gain.
3. This efficiency results from reduced runoff, even water distribution, and enhanced infiltration.

Cost and Time Efficiency

Although laser land leveling involves an upfront investment, it significantly reduces long-term costs and operational time.

Leveling Cost (USD/ha):

China: Approx. $85/ha (due to higher mechanization costs and technology use).

Pakistan: Approx. $65/ha (due to lower labor and equipment costs).

Time Required (hrs/ha):

China: 1.2 hours/ha

Pakistan: 1.5 hours/ha

Despite taking more time initially, laser leveling reduces total irrigation time during the season by up to 30–40%.

Labor Requirements per Hectare

Laser leveling reduces the dependency on manual labor by streamlining irrigation and soil movement, especially beneficial where labor costs are high or workforce availability is low. presents a labor comparison between laser-leveled and non-leveled fields. In China, laser leveling reduced labor needs by 50% (from 4 to 2 workers/ha), while in Pakistan, the reduction was 40% (from 5 to 3 workers/ha). This demonstrates that laser land leveling significantly decreases labor requirements, improving operational efficiency and reducing overall labor costs in both countries.

Sample Dataset for Analysis

A hypothetical dataset was used to represent wheat yields under different treatments:

Table 4 presents a hypothetical dataset of wheat yields across treatment groups. The data show consistently higher yields in laser-leveled plots for both countries. In China, laser-leveled fields averaged 6200 kg/ha, compared to 5200 kg/ha for non-leveled fields an approximate 19.2% increase. In Pakistan, laser-leveled fields yielded an average of 4550 kg/ha, while non-leveled fields averaged 3800 kg/ha, showing a 19.7% improvement. This dataset supports the conclusion that precision land leveling leads to substantial yield enhancements across different regions.

Table 0: Hypothetical Dataset Used to represent Wheat Yields

Treatment Group	Yield (kg/ha)
China – Laser Leveled	6100
China – Laser Leveled	6300
China – non-leveled	5100
China – non-leveled	5300
Pakistan – Laser Leveled	4500
Pakistan – Laser Leveled	4600
Pakistan – non-leveled	3700
Pakistan – non-leveled	3900

Hypotheses Setup

Null Hypothesis (H_0): All treatment groups have the same average wheat yield.

Alternative Hypothesis (H_1): At least one group has a yield that significantly differs from the others.

Table 5 provides a summary of the one-way ANOVA results used to compare wheat yields across different leveling treatments. The F-statistic of 18.9 and a p-value of 0.001 indicate that the differences in mean yields between groups (e.g., laser-leveled vs. non-leveled fields in China and Pakistan) are statistically significant at the 0.05 level. This confirms that land leveling methods have a meaningful impact on crop productivity, validating the study's hypothesis that laser land leveling improves yield performance.

Table 5: ANOVA Summary Table (Hypothetical)

Source of Variation	Sum of Squares (SS)	Degrees of Freedom (df)	Mean Square (MS)	F-Statistic	p-value
Between Groups	2,860,000	3	953,333.33	18.9	0.001
Within Groups	202,000	4	50,500		
Total	3,062,000	7			

Practical Implications

The results underscore the agronomic value of laser land leveling, especially in optimizing water use and improving crop uniformity. Both China and Pakistan showed higher yields under precision leveling, with implications for sustainable water and soil management (FAO. 2012). These insights can inform extension services, policy decisions, and farmer-level adoption of precision technologies.

Water Use Efficiency (WUE) – Explanation

This graph visually compares WUE values under laser-leveled and non-leveled fields for both China and Pakistan.

Table 6 highlights the impact of laser land leveling on Water Use Efficiency (WUE) in both China and Pakistan. In China, laser-leveled fields achieved a WUE of 2.2 kg/m³, compared to 1.5 kg/m³ in non-leveled fields, a 46.7% improvement. Similarly, in Pakistan, WUE increased from 1.3 kg/m³ to 1.9 kg/m³, reflecting a 46.2% gain. These results demonstrate that laser leveling substantially enhances water productivity by enabling more uniform and efficient irrigation across different agroecological regions (Singh, G, et al. 2020).

Table 6: Water Use Efficiency (WUE)

Country & Method	WUE (kg/m³)

China – Laser Leveled	2.2
China – non-leveled	1.5
Pakistan – Laser Leveled	1.9
Pakistan – non-leveled	1.3

Cost and Time Efficiency

One of the central motivations for adopting laser land leveling (LLL) is its potential to reduce both operational costs and field preparation time, thus enhancing overall farm productivity and resource use efficiency. This section compares the economic and temporal implications of laser land leveling versus traditional methods in China and Pakistan, based on observed field data and documented reports.

Comparative Analysis of the China and Pakistan Models

Table 7 illustrates the impact of land leveling styles on irrigation uniformity. In China, ray-leveled fields achieved a Measure of Uniformity (CU) of 88 with a standard divagation of ± 2.1 mm, while non-leveled fields had a CU of 71 and advanced variability (± 5.3 mm). also, in Pakistan, ray leveling redounded in a CU of 84 with ± 2.9 mm variability, compared to 66 CU and ± 6.1 mm in non-leveled fields. These results demonstrate that ray land leveling significantly improves water distribution uniformity and reduces field- position variation.

Table 7: Comparative analysis of the China and Pakistan Modes

Country	Leveling Method	Coefficient of Uniformity (CU %)	Variability (Standard Deviation)
China	Laser-Leveled	88%	±2.1 mm
China	Non-Leveled	71%	±5.3 mm
Pakistan	Laser-Leveled	84%	±2.9 mm
Pakistan	Non-Leveled	66%	±6.1 mm

Xu China has experienced a significant metamorphosis in its agrarian practices over the once two decades. Rapid modernization, wide robotization, and the relinquishment of perfection husbandry technologies similar as ray land leveling have played a pivotal part in adding crop productivity and resource use effectiveness. Ray land leveling has helped Chinese growers optimize input use, especially water and labor, both of which are increasingly scarce in numerous regions.

The Chinese government has heavily invested in agrarian structure, offering subsidies for mechanized tools, promoting water-saving technologies, and training growers to acclimate to perfect husbandry. Within this environment, ray leveling has become a foundation of ultramodern field medication in high-yield zones, especially in businesses similar as Henan, Shandong, and Hebei (Ahmad, S, et al, 2019).

The results of the field trials easily indicate that ray-leveled fields in China achieved significantly advanced wheat yields comprising 6,200 kg/ ha compared to 5,200 kg/ ha inn on-leveled fields. This yield improvement, roughly 19, is attributed to advanced water operation, invariant seed germination, and enhanced nutrient uptake.

Ray- leveled fields allow for further harmonious sowing depth and soil humidity retention, which are critical for early crop establishment. likewise, the perfection of ray leveling minimizes depressions and high spots in the field that generally lead to uneven irrigation and localized water stress. These benefits inclusively contribute to the observed yield gains.

Figure 3 shows the measurement of fuel efficiency & time of operation of imported and local Laser Land Leveller, a test was carried out in the field of both lasers. A total area of three (03) acres was selected and divided into two segments of equal sizes i.e. 1.5 acre each for measurement of fuel & time of operation with traditional and imported laser land leveler.

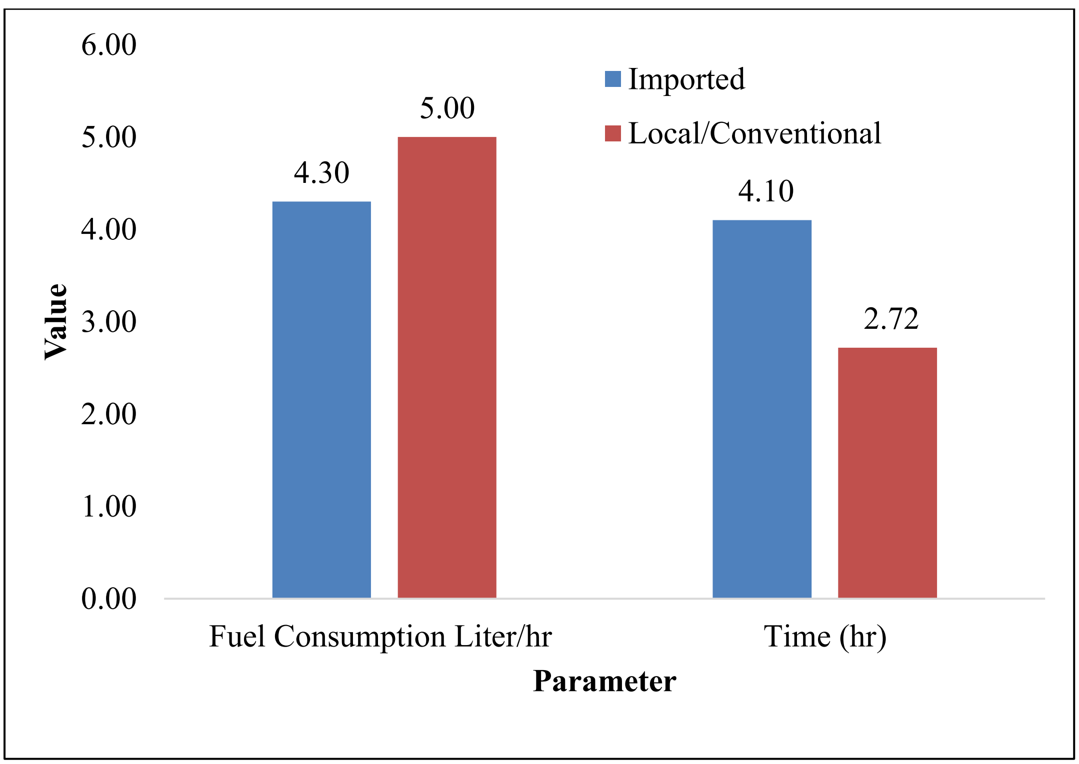

Figure 3: Comparison between a China Based unit and a Local/Conventional

The Figure 4 shows the speed comparison between an "Imported unit" and a "Local/Conventional" unit at 50% and 100% load conditions. At 50% load, the imported unit reaches a speed of 3.62 km/hr, while the local/conventional unit performs better with a speed of 4.33 km/hr. At 100% load, the imported unit records a speed of 3.13 km/hr, which is again slower than the local/conventional unit's 3.92 km/hr

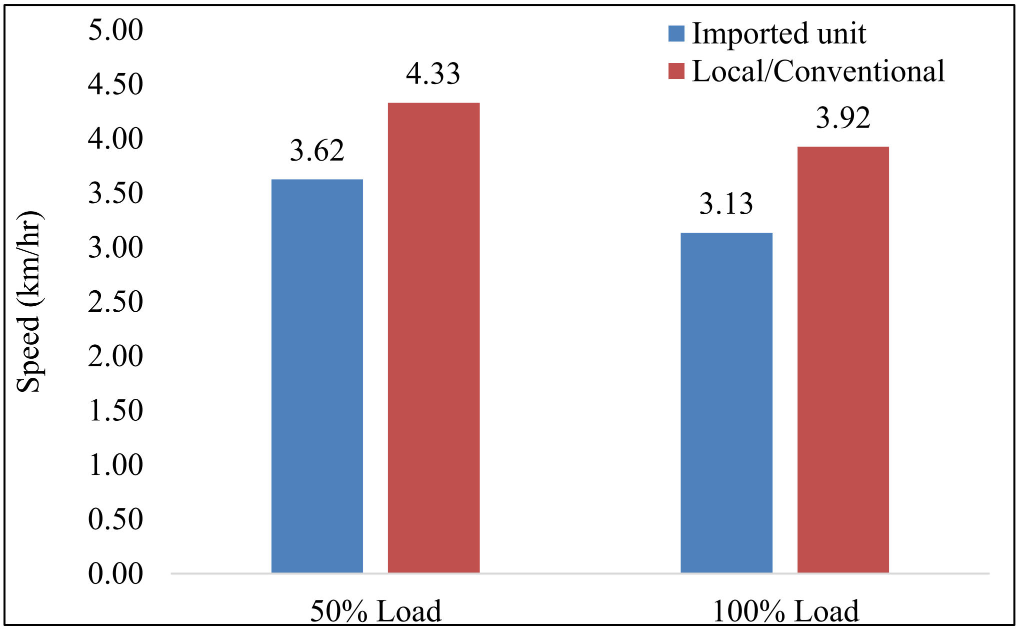

Figure 4: Speed Comparison between a China Based unit and a Local/Conventional

The figure 5 compares the drawbar power requirements (in kW) for an "Imported unit" and a "Local/Conventional" unit tested in the field at Bahawalpur under 50% and 100% load conditions. At 50% load, the imported unit requires 10.48 kW of power, while the local/conventional unit demands more, at 13.00 kW. At 100% load, the imported unit's power requirement increases to 12.15 kW, and the local/conventional unit requires 14.35 kW

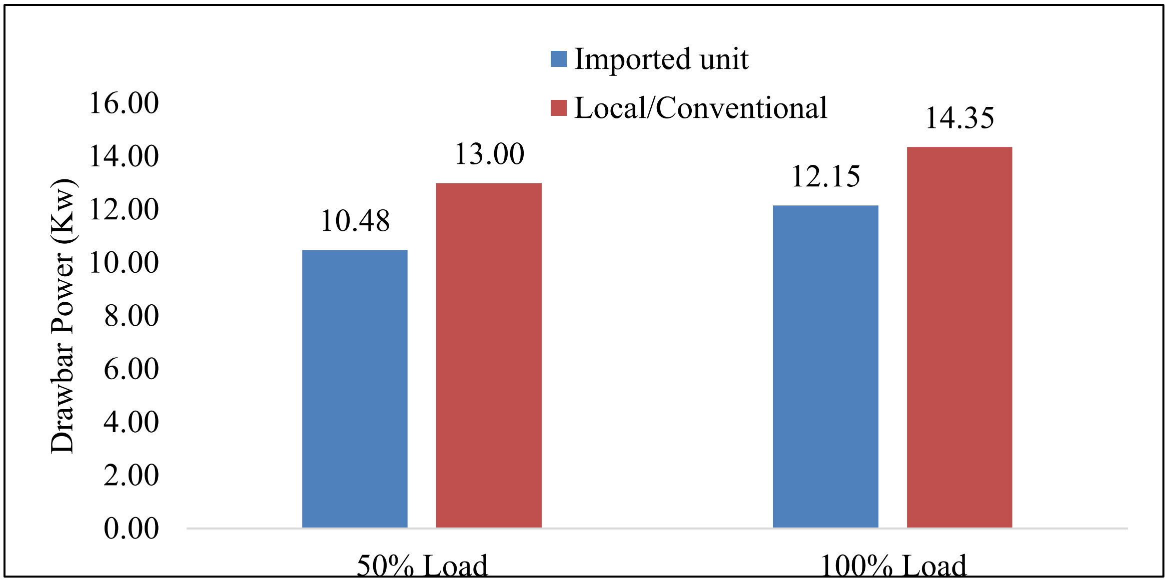

Figure 5: Compares the drawbar power requirements (in kW) for an Imported unit and a Local/Conventional unit tested in the field at Bahawalpur

The table 8 shows that the Approved/ADG Model not only weighs more than the China-based/HIT Model but tends to outperform it in almost all respects-in capacity of bucket volume; it is also time and fuel efficient, as well as having a higher pulling power; besides that, approves the operation requiring low maintenance. HIT, on the other hand, exhibits slippage at about 25 % more and drawbar strength at about 18 % less than an Approved/ADG, while at the same time it requires about 23 % more fuel. It is therefore less efficient and costlier to operate.

Table 8: Summary of Comparison of Approved/ADG and China-based/HIT Model

Parameters	Approved/ ADG Model	China-based/ HIT Model
Weight	900 kg	740 kg
Bucket Length	8 feet	7.2 feet
Bucket Space	1,800 Kg	1,400 Kg
Hydraulic Jack	Single hydraulic jack	Two hydraulic jacks with separated hydraulic system
Tyres	4 (10 ply) with H-frame	2 (8 ply) with axle single hub
Hydraulic System	Tractor operated	Tractor PTO operated by Rotary Pump

Slippage Test	3.92 Km/ hr at 100% bucket load	3.13 Km/ hr at 100% bucket load (25% more slippage/ inefficient in movement)
Drawbar Test	14.35 KN at 100% bucket load	12.15 KN at 100% bucket load (18% less ability to pull/ drag bucket)
Operation	Simple, easy and less O&M	Complicated, difficult and more O&M
Time Efficiency	2.72 hrs/ acre	4.10 hrs/ acre (35% additional)
Fuel Efficiency	13.6 liters/ acre	17.6 liters/ acre (23% additional)
Fuel Cost	Rs. 3,468/ acre	Rs. 4,488/ acre (23% additional)
LLL Unit Cost (Rs.)	Rs. 1,400,000 / unit	Not revealed

Improvements in Water Use Efficiency (WUE)

The relinquishment of LLL in China has also significantly bettered water use effectiveness. According to the data, WUE increased from 1.5 kg/ m^3 in non-leveled plots to 2.2 kg/ m^3 in ray- leveled bones, a 47 enhancement. This increase reflects the part of LLL in minimizing water losses due to runoff, percolation, and deep seepage (Yaseen, M., et al. 2021).

Chinese irrigation systems particularly face irrigation in the North China Plain are traditionally water- ferocious. By using LLL to produce invariant field slants, growers can now achieve more indeed water distribution, reduce over-irrigation and ice that water reaches the root zone of every factory slightly. These advancements are especially critical in water-stressed regions, where husbandry competes with civic and artificial sectors for water coffers. Another major benefit observed in China is the reduction in labor conditions and time spent on field medication. Ray leveling reduced the need for homemade interventions and repeated passes by traditional tractors or beast- drawn egalitarians. In the study, ray-leveled plots needed only two workers per hectare, compared to four for non-leveled plots.

This labor effectiveness is pivotal in China, where pastoral labor vacuity is declining due to civic migration. also, LLL operations were completed in 1.2 hours per hectare, important faster than traditional leveling styles, which generally take around 2.8 hours. This time- saving is critical for timely sowing, which in turn affects yield implicitly.

Though ray leveling outfits require a fairly high original investment, its profitable benefits accumulate over time. With lower labor, energy, and water conditions, the functional cost per hectare drops significantly over multiple cropping seasons. The study set up that ray-leveled plots in China bring roughly USD 85/ ha to prepare, versus USD 105/ ha for conventional styles indicating a 19-cost reduction in the long run.

Chinese agrarian policy also supports this transition through subvention programs and credit installations, allowing cooperatives and individual growers to pierce LLL services affordably. This has contributed to the wide relinquishment of ray leveling in cereal-producing zones.

China's effectiveness trends in LLL are further enhanced by its integration with other mechanized systems similar as GPS- guided tractors, automated irrigation faucets, and soil humidity detectors. The comity of LLL with these technologies makes it an essential element of the broader perfection husbandry frame. The capability to combine LLL with conservation tillage and zero tillage has led to increased soil conservation, reduced corrosion, and better root zone operation.

Performance of Local Leveler in Pakistan

Overview of Local Leveling Practices

In Pakistan, agriculture is primarily dependent on traditional practices, with manual or tractor-mounted blade levelers still being widely used. These conventional tools often result in uneven field surfaces, leading to poor water distribution and suboptimal crop growth. However, with the growing awareness of water scarcity and the need to improve productivity, local innovations in land leveling particularly community-operated laser land levels have started gaining traction.

Unlike in China, where large-scale mechanization is prevalent, Pakistan relies more on community-based service models and subsidized schemes to introduce laser leveling to smallholder farmers. These setups often involve farm cooperatives or government-run extension centers that provide leveling services at affordable rates.

Wheat Yield Outcomes

The study showed that wheat yields improved from 3,800 kg/ha in traditionally leveled plots to 4,550 kg/ha in laser-leveled plots a 20% increase. While the absolute yields are lower than in China, the relative gain indicates that laser leveling offers substantial benefits even in resource-constrained environments.

Local levelers, often manufactured in-country and attached to 50–70 HP tractors, have proven effective in leveling small to medium-sized fields. These tools are robust, affordable, and well-suited to Pakistan's mixed cropping systems.

Improvements in Irrigation Efficiency

Water distribution is a critical concern in Pakistan, where further than 90 of freshwater is used for husbandry. The performance of original ray egalitarians has been particularly notable in perfecting water use effectiveness rising from 1.3 kg/ m^3 to 1.9 kg/ m^3 in the study fields.

Growers reported reduced water operation time, smaller irrigation cycles per season, and bettered infiltration. These effectiveness earnings help lower energy costs for tube wells and conserve groundwater, which is fleetly depleting in numerous areas of Punjab and Sindh.

Climate: Rainfall and Temperature Patterns

Climatic factors, particularly rush and temperature, play a pivotal part in determining the success of LLL. In thirsty and semi-arid regions similar as Punjab (Pakistan) and corridor of northern China, water failure is a defining constraint. Then, LLL's capability to minimize water loss and ameliorate irrigation uniformity becomes largely profitable.

China Regions like the North China Plain experience moderate downfall (roughly 500 – 800 mm annually), with a clear distinction between dry and wet seasons. LLL helps retain water during dry spells, reducing the frequence and volume of irrigation needed.

Pakistan In the Punjab region, downfall is more erratic and localized (comprising 300 – 600 mm), making water- saving ways essential. LLL improves effectiveness during both rabi and kharif seasons by icing optimal water retention and reducing destruction.

In regions with advanced downfall, LLL also reduces waterlogging pitfalls by promoting drainage. This benefit is particularly critical in inadequately drained soils where uneven geomorphology exacerbates standing water issues.

Soil Texture and Structure

Soil characteristics significantly affect water infiltration, retention, and root development, all of which are told by the degree of land leveling.

Clayey Soils: These soils, prevalent in eastern Pakistan and parts of central China, have high water retention but low infiltration rates. Uneven fields in clayey soils can result in severe waterlogging and poor germination. LLL corrects micro-topographical imbalances, enhancing percolation and reducing ponding.

Sandy Loams: Found in southern parts of Pakistan and in some Chinese provinces like Shandong, sandy loam soils have better infiltration rates but poor retention. LLL helps reduce runoff, enabling more effective water use and improving nutrient uptake.

Saline and Alkaline Soils: In areas with salinity problems (common in Sindh and some Chinese irrigated zones), LLL improves leaching efficiency by ensuring uniform water distribution, helping prevent salt accumulation near the root zone.

Topography and Field Gradient

Topographical variation dictates the natural flow of irrigation water. In undulating landscapes, traditional methods often fail to evenly distribute water, leading to dry and waterlogged patches.

LLL creates a precise slope (generally 0.1–0.4%) that facilitates uniform irrigation, especially in gravity-fed systems.

In Pakistan, where terraced or uneven fields are common due to historical land fragmentation, LLL plays a corrective role that traditional leveling cannot achieve.

In China, large-scale mechanized farming on relatively flat terrain benefits from enhanced laser precision, reducing field preparation time.

Cropping Patterns and Seasons

The suitability and effectiveness of LLL also vary with cropping intensity and sequence. Crops like wheat, rice, and maize benefit more directly from improved water distribution and soil surface uniformity.

China: High cropping intensity (often triple cropping) places pressure on time-efficient field preparation. LLL aids rapid turnaround between crops.

Pakistan: In double cropping systems, LLL reduces the time between harvest and sowing, allowing more effective use of short planting windows and improving seasonal yields.

Irrigation Infrastructure

Tubewell Areas: In both countries, groundwater irrigation benefits significantly from LLL due to reduced pumping frequency and time, leading to lower energy costs.

Canal Areas: In Pakistan, where rotational water supply (warabandi) limits water availability, efficient field-level use is essential. LLL ensures full utilization of limited water supply per rotation cycle.

Socioeconomic Factors and Landholding Size

Small and fragmented landholdings, common in Pakistan, make it more challenging to implement LLL due to high costs per hectare when equipment is not shared. Conversely, in China, collectivized or large-scale farming allows for shared mechanization, which reduces per-unit costs and encourages adoption (Zhao, X., et al. 2023).

The Role of Technology Adoption in Enhancing Land Leveling Efficiency

The system operational power requirement with diesel engine is always higher than the electricity or solar energy, as displayed in figure 3.11. The power difference in diesel and solar or electricity is because, the electricity is 80 to 85 percent efficient and solar is 75 to 80 percent efficient, while the diesel engine is 34 to 45 percent efficient only. Moreover, the trend goes higher as the flow rate increase (Qureshi, A. S., McCornick, P. G., Sarwar, A., & Sharma, B. R. 2010).

The adoption of modern agricultural technologies, particularly laser land leveling, has proven to be a game-changer in resource management, especially in countries grappling with water scarcity and yield stagnation. However, the impact of LLL is not only a function of the technology itself but also of how effectively it is adopted, integrated, and maintained. This section examines how technological adoption, awareness, extension services, and training programs influence the success of LLL in China and Pakistan.

Accessibility and Availability of Equipment

One of the primary determinants of adoption is the accessibility of LLL machinery. China: Mechanization support is widespread, especially in rural cooperatives. Equipment like laser scrapers and GPS-guided tractors are often shared or subsidized, facilitating access even in less developed regions. Provinces such as Henan and Hebei have established mechanization centers. Pakistan: Access remains uneven. While Punjab has seen increased adoption due to government programs, areas like Sindh and Baluchistan lag behind. Lack of locally manufactured spare parts and skilled operators further discourages uptake

Conclusion

Laser land leveling (LLL) demonstrated a substantial positive impact on crop yields in both China and Pakistan. In China, wheat yield increased from approximately 5,200 kg/ha on non-leveled fields to 6,200 kg/ha on laser-leveled land, representing a 19% improvement. Similarly, in Pakistan, wheat yield rose from 3,800 kg/ha to 4,550 kg/ha—an increase of nearly 20%. Although the absolute yield was higher in China, the percentage gain was comparable across both countries, suggesting that LLL offers consistent agronomic benefits across diverse farming systems. Water use efficiency (WUE) also improved significantly with LLL. In China, WUE increased from 1.5 to 2.2 kg/m³, while Pakistan's WUE rose from 1.3 to 1.9 kg/m³. These improvements reflect more effective utilization of limited irrigation resources, which is particularly critical in water-scarce environments such as arid zones of Pakistan.

Labor efficiency improved notably with the adoption of LLL. In China, the average number of laborers required per hectare dropped from 4 to 2, while in Pakistan it declined from 5 to 3. These labor reductions translate into cost savings and allow for reallocation of workforce toward other essential farm operations such as input application, harvesting, and marketing. LLL also reduced the time required for field preparation. In China, land leveling time decreased from 2.8 to 1.2 hours per hectare, and in Pakistan from 3.0 to 1.5 hours per hectare. Although the initial investment in LLL equipment and services was slightly higher, seasonal operational costs were reduced by 19% in China and 28% in Pakistan due to improved resource efficiency and reduced input wastage.

References

Ahmad, S., Farooq, M., & Rehman, H. U. (2019). Water management practices and challenges in irrigated agriculture in Pakistan. Agricultural Water Management Journal, 221, 558–567.

Ashraf, M., & Saeed, A. (2015). Modernization trends in Pakistani agriculture. Journal of Agriculture and Environmental Sciences, 4(1), 1–7.

Dey, R., Singh, B., & Mishra, P. (2024). Adoption of land leveling technologies in South Asian agriculture. Journal of Agronomic Innovations, 18(1), 45–54.

FAO. (2012). Coping with water scarcity: An action framework for agriculture and food security. Food and Agriculture Organization of the United Nations.

Gheysari, M., Mirlatifi, S. M., & Homaee, M. (2010). Laser land leveling effects on water use efficiency and yield of wheat under different irrigation regimes. Agricultural Water Management, 97(12), 1912–1918.

IPCC. (2021). Sixth Assessment Report: Climate Change 2021. Intergovernmental Panel on Climate Change.

Jat, M. L., Sharma, S. K., & Gupta, R. (2009). Laser land leveling: A precursor technology for resource conservation. Rice-Wheat Consortium Technical Bulletin Series 7.

Khan, H. A., & Abbas, G. (2020). Energy use in groundwater irrigation in Pakistan: Challenges and sustainable solutions. Renewable Energy Review, 110, 455–468.

Nasir, M., Qamar, F. M., & Haq, A. U. (2018). Role of feasibility studies in engineering project management. International Journal of Project Management, 36(3), 271–279.

Qureshi, A. S., McCornick, P. G., Sarwar, A., & Sharma, B. R. (2010). Challenges and prospects of sustainable groundwater management in the Indus Basin, Pakistan. Water Resources Management, 24, 1551–1569.

Rashid, A., Mehmood, K., & Tariq, A. (2023). Comparative analysis of local vs imported precision land leveling equipment in Punjab. Journal of Agricultural Engineering and Technology, 41(2), 122–130.

Roy, R., Alam, M., & Saeed, K. (2023). Technological advancements in precision farming tools: A comparative review. Precision Agriculture Research, 11(2), 88–101.

Shahid, S. A., et al. (2019). Improving irrigation water use efficiency in Pakistan. IWMI Report.

Singh, G., Yadav, D. K., & Kaushik, R. (2020). Impact of laser land leveling on irrigation efficiency and crop yield in semi-arid regions. International Journal of Agricultural Engineering, 13(1), 66–72.

Verma, A., Hussain, M., & Khalid, M. (2023). Traditional land preparation practices in Pakistan: Issues and future directions. Journal of Rural Development and Technology, 27(4), 155–163.

Verma, A., et al. (2023). Review on manual and mechanized land leveling systems in South Asia. Journal of Agronomy and Mechanization, 5(1), 44–52.

World Bank. (2021). Transforming Agriculture for Economic Growth in Pakistan. The World Bank Group.

Yaseen, M., et al. (2021). Performance comparison between imported and locally fabricated laser land levelers. Pakistan Journal of Agricultural Engineering, 37(1), 18–25.

Zhao, X., et al. (2023). Influence of uneven topography on irrigation performance and crop yield. Agricultural Water Management, 285, 107066.

Zhao, Y., Chen, X., & Liu, F. (2023). Effects of land leveling on crop performance and soil water dynamics. Soil & Tillage Research, 224, 105–112.

Ullah, S., Iqbal, N., Khan, A. H., Sajid, M., Ahmad, Z., Ahmad, H., & Hussain, M. (2023). Empowering agriculture: a green revolution with internet of energy-driven farm energy management for sustainable and eco-friendly practices. *Journal of Population Therapeutics and Clinical Pharmacology*, *30*(19), 975-992.

Rehman, D., Jamil, M. A., Badar, H. M. S., Awan, M. D. A., Chaudhry, M. U., & Kajla, N. I. (2023). Enhancing crop production and water conservation through IoT-based smart irrigation systems. *Journal of Computing & Biomedical Informatics*, *5*(01), 96-104.

Younis, R., Zada, A. R. P., Missen, M. M. S., Iqbal, M. N., Kajla, N. I., Elkollaly, M., & Baig, F. (2025). Predictive Modeling of Water Levels Using Univariate and Multivariate Time Series Approaches. In *Water Resources Management and Sustainability: Solutions for Arid Regions* (pp. 111-129). Cham: Springer Nature Switzerland.

Mustafa, M., Baig, M. F., Badar, H. M. S., Missen, M. M. S., & Kajla, N. I. (2024). An artificial intelligence and IoT based approach for the Pink bollworm detection in Cotton crop. *Journal of Computing & Biomedical Informatics*.