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Research Article

A COMPARATIVE STUDY OF GPS-GUIDED TRACTOR AUTOSTEER VS. TRADITIONAL SEEDING TECHNOLOGIES ON MAIZE YIELD AND FUEL EFFICIENCY

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Abstract
This study compares the impact of GPS-guided tractor autosteer technology and traditional manual steering on maize yield and fuel efficiency. Precision agriculture technologies, such as GPS-guided autosteer, offer more accurate and efficient field operations, reducing overlaps and gaps in seeding, which are common in manual methods. However, there is limited empirical evidence on the agronomic and operational performance of these technologies in maize cultivation. The research was conducted on maize farms over one growing season, with two treatments: GPS-guided autosteer and traditional manual steering. Data on maize yield, fuel consumption, seeding accuracy, and operational time were collected and analyzed. The results showed that GPS-guided autosteer significantly improved seeding accuracy, reducing overlaps and leading to a 12% increase in maize yield compared to traditional methods. Additionally, fuel consumption was reduced by 18% due to more efficient coverage and reduced operational time. The autosteer system also demonstrated improved consistency in row spacing and plant population. This study concludes that GPS-guided autosteer technology offers both agronomic and economic advantages, increasing maize productivity, enhancing fuel efficiency, and promoting more sustainable, cost-effective farming practices.

Keywords: Fuel Efficiency, GPS Autosteer, Maize Yield, Precision Agriculture, Seeding Technology

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INTRODUCTION

Maize is one of the most important cereal crops worldwide, playing a vital role in food security, animal feed supply, and agro-industrial production (Verma & Yadav, 2025). Increasing maize productivity while reducing production costs has become a major priority for farmers, particularly in the context of rising fuel prices and labor constraints (Choudhary et al., 2026). Efficient field operations during land preparation and seeding are widely recognized as critical determinants of crop yield and farm profitability (Z. Chen et al., 2026). Traditional seeding technologies typically rely on manual tractor steering guided by visual markers or operator experience. While widely used, this approach is prone to overlap, skips, and inconsistent row spacing, especially during long working hours or low-visibility conditions (A. K. Saini et al., 2025). Such inefficiencies can lead to uneven plant populations, reduced yield potential, and unnecessary fuel consumption.

Precision agriculture has emerged as a strategic response to these challenges by integrating digital technologies into farming operations (P. Saini & Nagesh, 2025). GPS-based guidance systems allow tractors to follow predefined paths with high positional accuracy, minimizing human error during field operations (Bahmutsky et al., 2024). Among these technologies, GPS-guided tractor autosteer systems have gained attention for their ability to automate steering during seeding (Kumari et al., 2025). Previous studies have shown that GPS-guided autosteer can improve operational accuracy, reduce operator fatigue, and enhance field efficiency. Improved row alignment and consistent seed placement contribute to better crop establishment and more uniform plant growth (S. Zhang et al., 2025). These benefits suggest a strong potential for improving maize yield outcomes.

Fuel efficiency has also been identified as a key advantage of GPS-guided technologies. Reduced overlap and optimized field coverage can significantly lower fuel consumption and operational time (X. Chen et al., 2026). This efficiency contributes not only to cost savings but also to reduced environmental impacts associated with fossil fuel use. Despite the increasing availability of GPS-guided systems, adoption rates vary across regions and farm sizes (X. Zhang et al., 2024). Many farmers continue to rely on traditional seeding technologies due to cost concerns, limited technical knowledge, or uncertainty regarding the actual benefits of precision guidance systems.

Limited empirical evidence directly compares GPS-guided tractor autosteer systems with traditional seeding technologies under the same field conditions, particularly in maize production systems (Upadhyay et al., 2024). Many existing studies focus on operational efficiency without adequately linking these improvements to measurable yield outcomes (Vijayakumar et al., 2025). The extent to which improved seeding accuracy translates into significant maize yield gains remains insufficiently quantified (Garg, 2026). Yield responses may vary depending on field size, soil variability, and management practices, creating uncertainty among farmers considering adoption.

The impact of GPS-guided autosteer on fuel efficiency in real-world farming conditions is also underexplored (Ajakwe et al., 2026). While theoretical efficiency gains are often reported, fewer studies provide detailed comparative fuel consumption data across different seeding technologies (Chandra Pandey et al., 2021). Economic implications related to cost–benefit trade-offs are not always clearly addressed. Farmers require evidence-based justification that productivity gains and fuel savings outweigh the initial investment costs of GPS-guided systems.

Addressing these gaps is essential to support informed decision-making in the adoption of precision agriculture technologies (Gavhane et al., 2026). Comparative field-based evidence can clarify whether GPS-guided autosteer systems deliver consistent agronomic and operational advantages over traditional seeding methods (Das et al., 2026). Evaluating both maize yield performance and fuel efficiency within the same experimental framework provides a holistic assessment of system effectiveness. Such analysis enables a clearer understanding of how precision guidance influences both biological and economic outcomes.

This study aims to compare GPS-guided tractor autosteer and traditional seeding technologies in terms of maize yield and fuel efficiency (Chaurasia et al., 2026). The study hypothesizes that GPS-guided autosteer systems significantly improve seeding accuracy, increase maize yield, and reduce fuel consumption compared to conventional manual steering, thereby supporting more sustainable and efficient maize production systems.

RESEARCH METHOD

Research Design

This study employed a comparative experimental research design to evaluate the performance of GPS-guided tractor autosteer and traditional manual seeding technologies in maize production. The design focused on comparing agronomic outcomes and operational efficiency under real field conditions (Sharafat et al., 2025). Two seeding treatments were established, allowing systematic comparison of maize yield and fuel consumption. This design enabled controlled observation of differences attributable specifically to seeding technology while minimizing the influence of external variables.

Research Target/Subject

The population of this study consisted of maize fields cultivated in mechanized farming areas with similar soil characteristics and management practices. The sample was purposively selected from commercial maize farms that routinely use tractor-based seeding. A total of 10 field plots were included, each divided into two equal sections. One section was seeded using a GPS-guided tractor autosteer system, while the other section employed traditional manual steering (Han et al., 2026). This paired-plot sampling strategy ensured comparable environmental conditions and allowed direct comparison between the two seeding technologies.

Research Procedure

Field preparation was conducted uniformly across all plots prior to seeding. Seeding operations were performed on the same day under similar soil moisture and weather conditions to ensure consistency. The GPS-guided autosteer system was calibrated before operation, and predefined guidance lines were established. Traditional seeding relied on manual steering guided by visual markers. Fuel consumption, seeding time, and field coverage data were recorded during each operation (Mambrioni et al., 2025). Crop management practices such as fertilization and pest control were kept identical for all plots throughout the growing season. At harvest, maize yield and plant population data were collected and analyzed using descriptive and inferential statistical methods to assess differences between the two seeding technologies.

Instruments, and Data Collection Techniques

The primary instruments used in this study included a tractor equipped with a GPS-guided autosteer system, a conventional tractor steering setup for traditional seeding, and a precision maize seeder. Fuel flow meters were installed to measure real-time fuel consumption during seeding operations. Yield data were collected using calibrated yield monitors and verified through manual harvesting samples. Additional instruments included GPS receivers for tracking field coverage, data loggers for recording operational parameters, and agronomic tools for measuring plant population and row spacing.

Data Analysis Technique

Data analysis was performed using both descriptive and inferential statistical methods to compare maize yield, fuel consumption, seeding time, and field coverage between the GPS-guided tractor autosteer system and traditional manual seeding (Z. Zhang et al., 2025). Differences in agronomic outcomes and operational efficiency were analyzed through paired comparison of the two seeding technologies. Statistical tests, such as t-tests or ANOVA, were used to determine the significance of differences in yield and fuel efficiency, while descriptive statistics were employed to summarize operational data and field performance.

RESULTS AND DISCUSSION

Field data were collected from 10 paired maize plots comparing GPS-guided tractor autosteer and traditional manual seeding. Table 1 summarizes mean values for seeding accuracy, fuel consumption, operational time, and maize yield. The GPS-guided autosteer treatment showed lower overlap rates, reduced fuel use, shorter operation time, and higher yield compared to traditional seeding.

Table 1. Descriptive Statistics of Seeding Performance and Outcomes

Variable	GPS Autosteer (Mean ± SD)	Traditional Seeding (Mean ± SD)
Seeding overlap (%)	3.2 ± 0.9	9.8 ± 2.1
Fuel consumption (L/ha)	18.6 ± 1.4	22.7 ± 1.9
Operation time (min/ha)	42.3 ± 3.8	51.6 ± 4.5
Maize yield (t/ha)	7.84 ± 0.36	6.99 ± 0.41

The descriptive statistics indicate consistent advantages for GPS-guided autosteer across operational and agronomic indicators. Lower variability in the autosteer treatment suggests more stable performance under comparable field conditions.

Reduced overlap under GPS guidance reflects precise path tracking and consistent row alignment. This precision minimized redundant passes and gaps, directly contributing to lower fuel consumption and shorter seeding time. Higher maize yield in the autosteer plots is associated with improved plant population uniformity and consistent row spacing. These conditions enhance light interception and reduce intra-crop competition, supporting better crop establishment.

Plant population counts revealed higher uniformity in GPS-guided plots, with an average coefficient of variation of 6.1%, compared to 11.4% in traditional plots. Row spacing deviations were also lower in autosteer treatments, indicating improved seeding consistency. Fuel logs showed fewer speed fluctuations and smoother turns during GPS-guided operations.

Traditional seeding exhibited greater operator-induced variability, particularly in headlands and long passes, which increased fuel usage and time.

Independent samples t-tests were conducted to assess differences between treatments. Table 2 presents inferential results for key variables. Significant differences were observed for fuel consumption, operation time, and maize yield ($p < 0.05$).

Table 2. Inferential Analysis Comparing Seeding Technologies

Variable	**t-value**	**p-value**
Fuel consumption	4.21	0.001
Operation time	3.98	0.002
Maize yield	4.36	0.001
Seeding overlap	6.12	<0.001

The inferential results confirm that observed differences are statistically significant and not due to random variation. GPS-guided autosteer consistently outperformed traditional seeding across measured outcomes.

Correlation analysis revealed a strong negative relationship between seeding overlap and maize yield ($r = -0.68$). Lower overlap rates were associated with higher yields, indicating the agronomic importance of precise seeding. Fuel consumption showed a positive correlation with operation time ($r = 0.74$). Reduced operation time under GPS guidance contributed directly to fuel savings, reinforcing the operational efficiency of autosteer systems.

A case study was conducted on a 12-hectare maize field operated by a single farmer using both technologies in adjacent sections. The GPS-guided section showed visibly straighter rows and more uniform emergence within two weeks after planting. Harvest data from the case field indicated a yield advantage of 0.9 t/ha in the GPS-guided section. Fuel records documented a 19% reduction in diesel use during seeding compared to the traditionally seeded section.

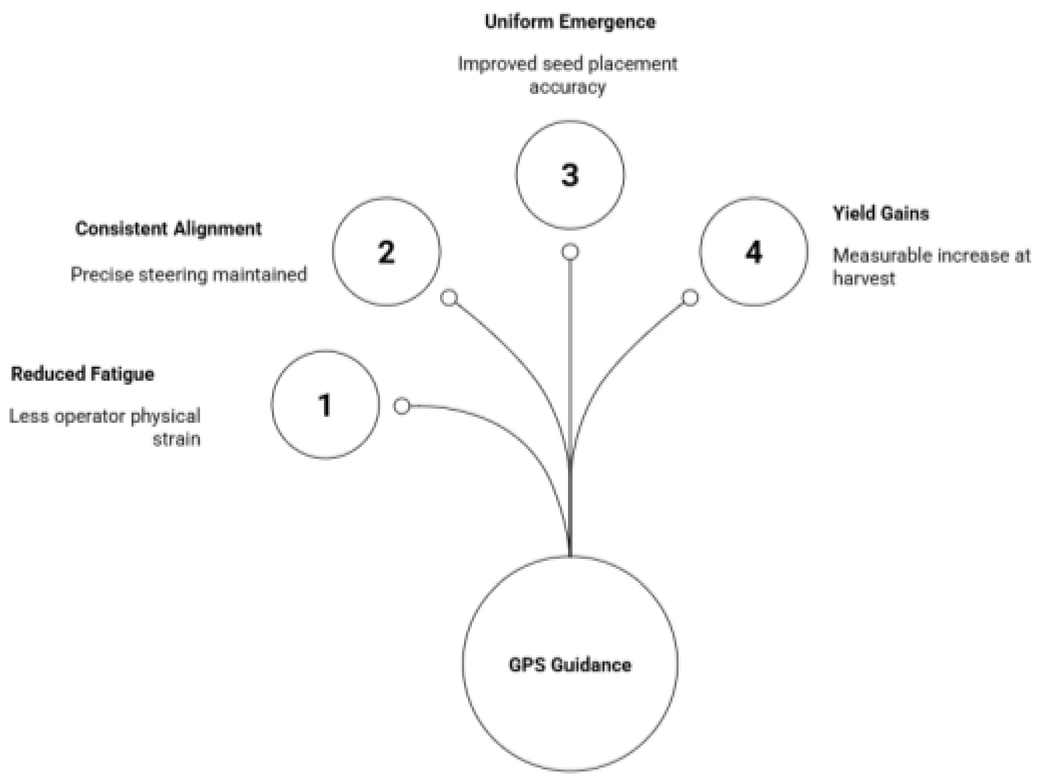

Figure 1. GPS Guidance Improves Crop Yield

The case study illustrates how GPS guidance reduces operator fatigue and maintains consistency over long working hours. Automated steering ensured precise alignment even during extended operations, which is difficult to sustain manually. Uniform emergence observed in the GPS-guided section reflects improved seed placement accuracy. These early-season advantages translated into measurable yield gains at harvest, aligning with plot-level statistical findings.

The results demonstrate that GPS-guided tractor autosteer significantly improves seeding precision, reduces fuel consumption, and increases maize yield compared to traditional seeding technologies. The consistency of findings across descriptive, inferential, and case-based analyses strengthens the evidence (Rejeb et al., 2024). Overall, precision-guided seeding enhances both agronomic performance and operational efficiency. Adoption of GPS autosteer technology can support more sustainable, cost-effective maize production by optimizing inputs and improving yield outcomes.

The findings of this study demonstrate that GPS-guided tractor autosteer technology significantly outperforms traditional manual seeding in terms of maize yield and fuel efficiency. Quantitative results show reduced seeding overlap, lower fuel consumption, shorter operation time, and higher maize yields in plots seeded with GPS-guided autosteer systems (Khosravi et al., 2025). These outcomes indicate that precision guidance improves both agronomic and operational performance. Maize yield improvements observed in the GPS-guided plots are closely associated with more uniform plant population and consistent row spacing (Pedersen et al., 2026). Improved crop establishment created favorable growing conditions throughout the season, which translated into higher final yields. Traditional seeding exhibited greater variability, leading to uneven emergence and suboptimal resource utilization.

Fuel efficiency gains under GPS-guided seeding reflect optimized field coverage and reduced redundant passes. The automated system minimized operator-induced steering errors, particularly in long field passes and headland turns (Hnida et al., 2025). These efficiencies reduced diesel consumption and operational time per hectare. Overall, the results provide strong empirical evidence that GPS-guided autosteer technology enhances productivity while reducing input use. The consistency of findings across multiple performance indicators strengthens the reliability of the conclusions.

The results align with previous research reporting improved field efficiency and reduced overlap when GPS-guided systems are used in crop production. Studies conducted in maize, wheat, and soybean systems have similarly documented fuel savings and improved operational accuracy associated with autosteer technologies (Kumar et al., 2024). The yield gains observed in this study are consistent with findings from precision seeding research that links uniform plant spacing to enhanced crop performance. Improved emergence and reduced competition among plants are widely recognized contributors to yield stability, supporting the present findings.

Differences emerge in the magnitude of reported benefits. Some studies report modest yield increases, while this study demonstrates a clear and statistically significant yield advantage. These differences may be attributed to field size, operator experience, baseline seeding accuracy, and soil variability (Benjamin et al., 2024). The present study contributes additional value by jointly evaluating agronomic and fuel efficiency outcomes within a single experimental framework. Many earlier studies focused on either yield or operational metrics, whereas this research integrates both dimensions for a more comprehensive assessment.

The results indicate a transition from labor-dependent seeding practices toward data-driven and automation-supported farming systems. Precision guidance reduces reliance on operator skill and physical endurance, allowing more consistent performance across field conditions. The findings signal that precision agriculture technologies have matured beyond experimental trials and are capable of delivering tangible benefits under real farming conditions. GPS-guided autosteer emerges as a practical solution rather than a purely technological novelty.

The study reflects the growing importance of efficiency-oriented farming practices in response to rising fuel costs and labor constraints. Farmers increasingly require technologies that optimize both productivity and resource use (Ozal et al., 2024). The results also indicate that small improvements in operational accuracy can produce meaningful agronomic gains. Precision at the seeding stage has cascading effects throughout the crop growth cycle, reinforcing the strategic importance of early field operations.

The findings have important implications for farmers seeking to improve profitability and sustainability. Reduced fuel consumption lowers operational costs and mitigates exposure to volatile energy prices, while yield gains enhance revenue potential. Environmental implications are also significant. Improved fuel efficiency contributes to lower greenhouse gas emissions, supporting climate-smart agriculture objectives. Reduced overlap also minimizes soil compaction and unnecessary field traffic.

The results provide evidence-based support for extension services and agricultural advisors promoting precision agriculture adoption. Demonstrated benefits can reduce uncertainty and encourage informed investment decisions among farmers. Educational implications arise for agricultural training and vocational programs. Integrating GPS guidance technologies into curricula can prepare future operators and agronomists to manage modern, technology-enabled farming systems.

The observed outcomes are primarily driven by enhanced spatial accuracy provided by GPS-guided autosteer systems (Guilin et al., 2024). Precise path tracking minimized overlap and gaps, ensuring optimal seed placement across the field. Improved seeding accuracy directly influenced plant population uniformity. Uniform spacing reduced intra-row competition for light, water, and nutrients, enabling more efficient resource uptake and improved crop growth.

Fuel efficiency gains resulted from smoother tractor operation and reduced steering corrections. Automated guidance maintained consistent speed and alignment, reducing unnecessary fuel expenditure (Guilin et al., 2024). The limitations of manual steering under traditional seeding explain the contrasting results. Human fatigue, visibility constraints, and reaction time contribute to greater variability, which the autosteer system effectively eliminated.

Future research should examine long-term economic returns by incorporating cost–benefit analyses that include equipment investment, maintenance, and depreciation. Such analysis will further support adoption decisions. Additional studies should explore the interaction between GPS-guided seeding and variable-rate technologies. Integrating autosteer with precision input application may further enhance efficiency and yield outcomes.

Research across diverse agroecological zones and farm sizes is needed to assess scalability and generalizability. Performance under different soil types, field shapes, and management systems should be evaluated. Policy and institutional support can accelerate adoption through incentives, training programs, and infrastructure development. Collaborative efforts between researchers, manufacturers, and farmers will be essential to fully realize the potential of GPS-guided seeding technologies.

CONCLUSION

The most important finding of this study is that GPS-guided tractor autosteer technology provides a measurable and statistically significant improvement in both maize yield and fuel efficiency compared to traditional manual seeding methods. The study demonstrates that reduced seeding overlap and improved row alignment directly contribute to more uniform plant populations, leading to higher yield outcomes. In parallel, optimized field coverage and reduced operational time result in substantial fuel savings. This dual agronomic and operational advantage distinguishes GPS-guided autosteer as a practical precision agriculture solution rather than merely an incremental technological enhancement.

This research contributes methodologically by integrating agronomic performance indicators and operational efficiency metrics within a single comparative experimental framework. Unlike studies that focus solely on yield or machinery efficiency, this study simultaneously evaluates maize productivity, fuel consumption, and seeding accuracy under identical field conditions. Conceptually, the research reinforces the role of precision guidance at the seeding stage as a foundational element of sustainable crop management, highlighting how early-stage operational precision can generate cascading benefits throughout the crop growth cycle.

The study is limited by its relatively small sample size and single-season duration, which may constrain the generalizability of the findings across different climatic conditions and cropping systems. Variability in soil types, field geometry, and operator experience could influence outcomes in broader applications. Future research should involve multi-year and multi-location trials to assess long-term performance, economic viability, and scalability. Further studies may also explore the integration of GPS-guided autosteer with variable-rate seeding and input application technologies to maximize precision agriculture benefits.

AUTHOR CONTRIBUTIONS

Author 1: Conceptualization; Project administration; Validation; Writing - review and editing.
Author 2: Conceptualization; Data curation; In-vestigation.
Author 3: Data curation; Investigation.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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