THE ROLE OF GPS TECHNOLOGY IN ENHANCING SOIL PREPARATION EFFICIENCY AND SUSTAINABILITY

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Abstract

This research investigates the impact of GPS guidance on the operational efficiency of the Horsch Tiger 3 MT across a 10-hectare field, with a specific focus on fuel consumption and time management. The study reveals that GPS technology significantly enhances efficiency, reducing operational time by 23.5% (5.2 hours with GPS versus 6.8 hours without GPS) and fuel consumption by 20.8% (14.5 liters per hectare with GPS versus 18.3 liters per hectare without GPS). Moreover, GPS eliminated field overlaps entirely (0%), in contrast to an 8% overlap observed during non-GPS operations, thereby ensuring precise and uniform field coverage. These improvements translate into measurable cost savings, with a reduction in fuel expenses, alongside environmental benefits from decreased fuel usage. The findings underscore the critical role of GPS technology in optimizing agricultural operations, promoting sustainable resource utilization, enhancing productivity, and supporting the economic viability of modern farming practices. This study underscores the importance of adopting precision agriculture practices to enhance farm profitability and sustainability.

Key words: GPS, precision agriculture, soil cultivation

Enhancing soil preparation efficiency and sustainability through the integration of GPS technology represents a transformative shift in modern agriculture. This approach, known as precision agriculture, leverages advanced technological tools to optimize farming practices, promoting soil health while minimizing environmental impacts. As global agricultural demands grow, the significance of adopting efficient and sustainable methods becomes increasingly critical in addressing food security and ecological challenges (Smith J., Robinson L., 2021).

Notably, precision agriculture enhances soil health and fertility by employing variable rate technology (VRT) that enables farmers to apply fertilizers and nutrients with precision. This targeted application, supported by extensive data from soil sensors and satellite imagery, not only boosts productivity but also prevents erosion and promotes carbon sequestration essential in mitigating climate change effects (Bora G.C. *et al,* 2012).

The importance of healthy soils is further underscored by their role in increasing organic matter, which contributes to greater agricultural resilience and sustainability.

In addition to promoting soil health, precision agriculture significantly reduces chemical usage, thereby fostering environmentally sustainable practices. By accurately analyzing soil moisture and crop needs, farmers can optimize irrigation and minimize chemical runoff into water bodies, protecting aquatic ecosystems.

These technologies enable more precise delivery of water and nutrients, thereby maintaining biodiversity and supporting beneficial species while effectively managing pests and weeds through targeted application of pesticides and herbicides.

The incorporation of GPS technology has also revolutionized resource management and machinery efficiency in agriculture. GPS-guided equipment streamlines field operations, reducing fuel consumption and lowering the overall environmental foot- print of farming practices (D'Antonio P. *et al,* 2023). Predictive modeling enhances planning, which leads to better crop management and minimizes risks associated with crop loss. Ultimately, by optimizing crop production, precision agriculture not only preserves surrounding biodiversity but also reduces the need for deforestation, thereby promoting a sustainable farming ecosystem (D'Antonio P. *et al,* 2023).

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Efficient soil preparation is critical in modern agriculture, as it directly impacts crop yield and farm sustainability (Grisso R.D. *et al,* 2022).

The Horsch Tiger 3 MT, a heavy-duty cultivator, is widely used for tillage on large fields. Integrating GPS guidance with such equipment is a hallmark of precision agriculture, offering potential benefits in reducing overlap, optimizing coverage, and minimizing resource wastage. This study aims to compare the performance of the Horsch Tiger 3 MT over 10 hectares with and without GPS guidance. The results provide actionable insights for farmers considering investments in GPS technology.

This paper presents the advantages of using GPS technology, even for soil-related works. This technology ensures that tractors and other machinery follow precise paths, minimizing overlap and missed areas, reduces the time required for soil preparation by guiding machinery efficiently, more efficient operations that lead to less wear on machinery and reduces over-tilling, which can lead to soil erosion and degradation.

This study evaluates the operational efficiency of the Horsch Tiger 3 MT over a 10-hectare field with and without GPS guidance. The analysis focuses on fuel consumption and time requirements as performance indicators. Results demonstrate that GPS significantly improves resource efficiency, reducing both fuel consumption and operational time. These findings underscore the utility of precision agriculture tools in modern farming practices.

MATERIAL AND METHOD

The study was conducted in two phases. In Phase 1, the Horsch Tiger 3 MT was operated over a 10-hectare plot equipped with a GPS guidance system. The operator was trained to ensure effective use of the GPS for optimal coverage and minimal overlap.Time and fuel consumption data were meticulously recorded during this phase. In Phase 2, the same equipment was used on another 10-hectare plot, but without GPS assistance. Manual guidance relied on the operator’s skill and experience to ensure the field was covered adequately.

Data on time and fuel consumption were collected under the same conditions as in Phase 1, with variables such as soil type, equipment settings, and ambient conditions held constant to ensure comparability.

The research was conducted using a 930 Fendt vario tractor with 300 hp and an implement for soil preparation, Horsch Tiger 3 MT with a work width of 3 m (*figure 1*).

The work depth of the implement was 25 cm and the average speed was 11 km/h. The research was conducted on a 20 ha field from which 10 ha were done without GPS and 10 ha using GPS with RTK signal and 2.5 cm precision.

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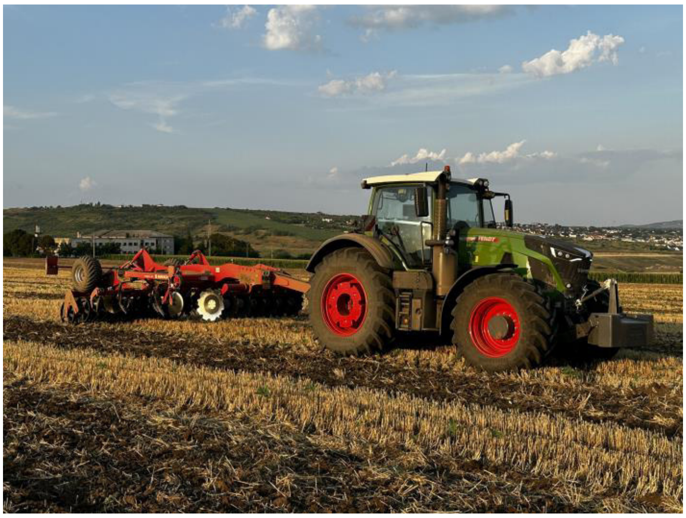


Figure 1 **Fendt vario 930 working with Horsch Tiger 3 MT**

The Fendt 930 Vario is powered by a robust MAN 6-cylinder, turbocharged, intercooled diesel engine with a displacement of 9.037 liters, delivering a rated power of 296 hp (220.7 kW) and a maximum power of 305 hp (227.4 kW) at 1,700 rpm, with a peak torque of 1,550 Nm. It features a fuel tank capacity of 625 liters and a DEF (AdBlue) tank capacity of 70 liters. The tractor is equipped with a Continuously Variable Transmission (CVT) that offers a forward speed range from 0.02 to 60 km/h and a reverse speed range of 0.02 to 33 km/h. Its advanced load-sensing hydraulic system provides a standard pump flow of 165 liters per minute, with an optional upgrade to 430 liters per minute using dual pumps, supporting rear and front hitch lift capacities of 12,410 daN and 5,584 daN, respectively. Dimensionally, the tractor has a wheelbase of 3,150 mm, an overall width of 2,710 mm, a cab height of 3,335 mm (without VarioGuide), and a ground clearance of 553 mm. It weighs 11,300 kg unladen and has a maximum permissible weight of 17,000 kg. The PTO system offers rear speeds of 540E/1000 rpm as standard, with an optional 1000/1000E rpm, and a front PTO speed of 1000 rpm. Fitted with 650/65R34 front tires and 710/70R42 rear tires, the Fendt 930 Vario is a high-performing, versatile tractor designed to meet the demands of modern agricultural operations.

The HORSCH Tiger 3 MT is a versatile cultivator designed for intensive soil preparation, particularly effective in incorporating substantial crop residues and performing deep loosening up to 35 cm. It features a combination of a two-row disc system with 68 cm diameter discs and a two-row tine system equipped with TerraGrip tines, each providing a release force of 770 kg. The machine's working width is 3.00 meters, with a transport width of 3.00 meters and a transport height of 2.40 meters. Its overall length varies between 8.30 to 9.00 meters, depending on the packer configuration.

The Tiger 3 MT weighs approximately 4,215 kg and requires a power input ranging from 110 to 220 kW (150 to 300 hp). It offers various packer options, including a tyre packer with a diameter of 78 cm or 100 cm, and an optional double RollPack packer with a diameter of 62 cm. The frame height stands at 850 mm, and the implement is compatible with lower linkages of categories III to IV.

These specifications make the HORSCH Tiger 3 MT a robust and efficient tool for modern agricultural practices, ensuring thorough mixing of organic material and effective soil consolidation.

Tests were conducted on a field with documented GPS coordinates, uniform soil conditions (texture, moisture, and compaction), and adequate area for consistent data collection. Fuel consumption was measured using a flowmeter or weighing system, while energy output and power delivery were assessed using a dynamometer and torque sensors. GPS systems tracked tractor movement and operational parameters like overlap and efficiency, while environmental sensors recorded soil resistance and ambient conditions. Baseline measurements under no-load conditions were taken before performing standardized tasks such as plowing or planting, with consistent engine speed, throttle settings, and working depth. Data such as fuel consumption, engine load, speed, and working depth were logged in real time. Energy efficiency was calculated as the ratio of useful work done (e.g., tilled area) to energy input, with specific fuel consumption (SFC) expressed as fuel consumed per kilowatt-hour of engine output. Field efficiency was determined as the ratio of effective working time to total time, and work rate was measured in hectares per hour.

RESULTS AND DISCUSSIONS

The comparison between GPS-guided and non-GPS operations on a 10-hectare field using the Horsch Tiger 3 MT reveals significant differences in time efficiency, fuel consumption, operational accuracy, and cost implications.

The results demonstrate that using GPS guidance significantly reduces the time required to complete soil preparation tasks. With GPS, the operation took 5.2 hours, compared to 6.8 hours without GPS. This translates to a 23.5% reduction in time, allowing the operator to cover more ground in a shorter period (*table 1*). The time savings are attributed to the optimized route planning provided by GPS, which minimizes redundant passes and ensures thorough coverage. By eliminating unnecessary overlaps, GPS reduces inefficiencies inherent in manual operations.

Table 1

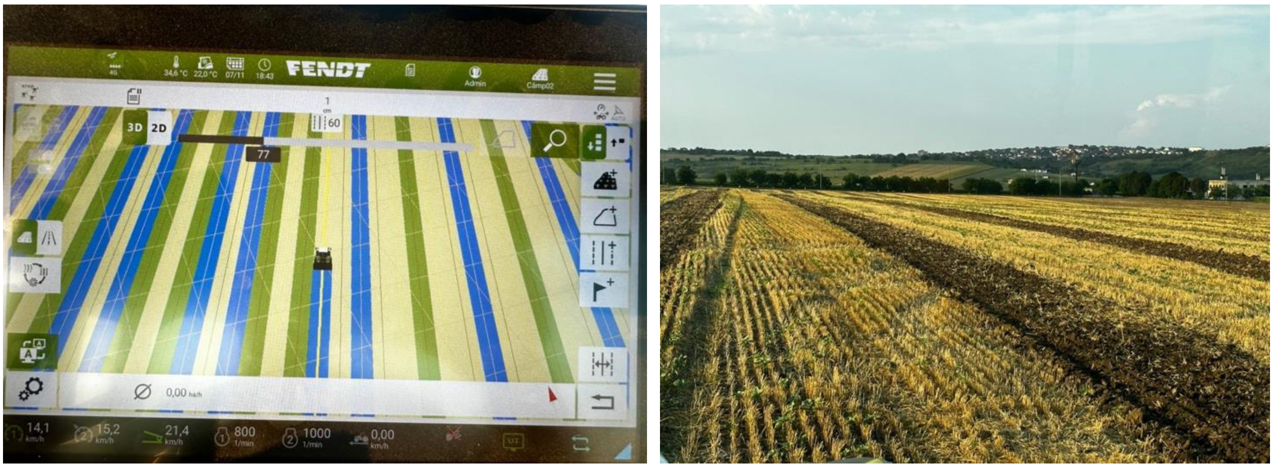
Results regarding the performance comparison of GPS and Non-GPS operations on Fendt vario 930 with Horsch Tiger 3 MT

Metric	With GPS	Without GPS	Improvement with GPS (%)
Time Taken (hours)	5.2	6.8	23.5
Fuel Consumption (liters/ha)	14.5	18.3	20.8
Overlap (%)	0	8	100

Fuel efficiency is another critical metric where GPS proves advantageous. The operation with GPS consumed 14.5 liters per hectare, while the non-GPS operation used 18.3 liters per hectare, representing a 20.8% reduction in fuel consumption. This improvement can be directly linked to the elimination of overlaps and the precise alignment of field passes, ensuring that no area is covered more than necessary. Reduced fuel consumption not only lowers operational costs but also contributes to environmental sustainability by reducing carbon emissions.

The operational accuracy of the equipment was significantly enhanced by GPS. With GPS guidance, the overlap percentage was effectively reduced to 0%, meaning no area of the field was unnecessarily covered more than once (*figure 2a, figure 2b*). In contrast, the non-GPS operation resulted in an 8% overlap, reflecting the limitations of manual navigation.

Overlap leads to wasted time, fuel, and wear on equipment, all of which are mitigated by GPS technology.



a. b.

Figure 2 **Furrow arrangement in shuttle pattern**
a. on tractor display;
b. on the field.

The reduction in fuel consumption directly impacts operational costs. These savings accumulate over multiple fields, making GPS a cost-effective solution for large-scale farming operations. Additionally, the time saved translates into opportunities for increased productivity, allowing farmers to prepare more land within the same timeframe.

Economic implications of these findings are significant. Reduced fuel consumption translates into direct cost savings. Additionally, the time saved allows for more fields to be prepared in the same timeframe, increasing overall productivity. Beyond economic benefits, GPS improves operational accuracy by ensuring no untreated areas or excessive overlap, thereby enhancing the effectiveness of soil preparation.

CONCLUSIONS

The findings of this study reveal clear advantages of integrating GPS technology with the Horsch Tiger 3 MT for soil preparation. Time savings of 23.5% highlight the productivity boost offered by GPS, while the 20.8% reduction in fuel consumption underscores its economic and environmental benefits. Enhanced operational accuracy further supports the case for GPS adoption, as it ensures optimal resource utilization. Although GPS technology requires an initial investment, the long-term savings in fuel and time, coupled with improved efficiency, justify its implementation. This study underscores the importance of adopting precision agriculture practices to enhance farm profitability and sustainability.

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