DIGITAL TERRAIN MODELING AND TOPOGRAPHIC SMOOTHING FOR LEVEE OPTIMIZATION IN IRRIGATED RICE AREAS USING AGROCAD® AND T3RRA CUTTA©

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Abstract

The systematization of lowland areas intended for irrigated rice production requires precise topographic planning to ensure efficiency in water management and operational performance of agricultural activities. Traditional land leveling methods are often based on empirical approaches, which may result in excessive soil movement and inefficient levee configurations. Advances in Precision Agriculture have enabled the integration of high-precision GNSS positioning with digital terrain modeling tools, allowing improvements in planning and optimization of irrigation structures. However, quantitative evaluations of digital terrain smoothing applied to levee optimization under real field conditions remain limited. This study aimed to evaluate the impact of digital terrain smoothing on levee configuration and operational efficiency in irrigated rice areas through the integration of AgroCAD® and T3rra Cutta© software. The research was conducted in two commercial irrigated rice production areas located in the municipalities of Alegrete and Mostardas, Rio Grande do Sul, Brazil, covering 26.2 ha and 17.8 ha, respectively. Planialtimetric surveys were carried out using John Deere RTK GNSS systems, with elevation data collected at 0.5 m intervals and mapping passes spaced 6 m apart, ensuring high spatial data density for Digital Terrain Model (DTM) generation. Topographic data were processed using AgroCAD® software for DTM generation, slope condition analysis, and initial levee line definition. Subsequently, T3rra Cutta© software was used to perform terrain smoothing and automatically recalculate levee configurations, as well as cut and fill volumes. Both areas presented predominantly flat terrain, with slopes below 1% and average soil movement close to 230 m^3 ha^{-1}. Terrain smoothing resulted in a reduction in the number of levees while maintaining similar soil movement volumes. In the Mostardas area, the number of levees decreased from 95 to 89 after smoothing. In the Alegrete area, the reduction was more significant, decreasing from 99 to 47 levees. These results indicate that digital terrain smoothing optimizes levee distribution by reducing unnecessary structures while preserving hydraulic functionality and operational feasibility. The combined use of AgroCAD® and T3rra Cutta© software proved to be complementary, integrating detailed topographic analysis with automated terrain optimization and operational simulation. The proposed workflow improves land systematization planning, increases irrigation efficiency, and supports data-driven decision-making in irrigated rice production systems. This approach demonstrates the potential of digital terrain modeling as a scalable operational framework to enhance water management and operational efficiency in lowland agricultural environments within the principles of Precision Agriculture.

Keywords
Irrigated rice; land systematization; levees.

1 INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most socioeconomically important food crops worldwide and serves as a staple food for billions of people. It is the second most cultivated cereal globally, occupying approximately 161 million hectares, with an annual production exceeding 756 million tons of paddy rice, representing about 29% of the total grain production destined for human consumption (WANDER; SILVA, 2013; FAO, 2022). In Brazil, irrigated rice cultivation is strongly concentrated in the state of Rio Grande do Sul, which accounts for approximately 70% of the national production. The cultivated area has remained stable at around one million hectares since the 2004/2005 growing season, consolidating the region as the country's main rice-producing area (SOSBAI, 2022).

In Rio Grande do Sul, irrigated rice is cultivated in 129 municipalities located in the southern half of the state, where approximately 232,000 people depend directly or indirectly on this activity. The agro-industrial sector includes 184 rice processing facilities, responsible for nearly half of the rice consumed in Brazil (SOSBAI, 2023). This productive and economic relevance highlights the need for efficient management practices capable of combining environmental sustainability and economic competitiveness.

Areas designated for irrigated rice cultivation are predominantly lowlands characterized by flat topography, hydromorphic soils, and drainage limitations. Under these conditions, land leveling is an essential practice because it enables proper water management. The process includes the construction of irrigation and drainage channels, internal roads, surface leveling, and levee construction, as well as additional structures when necessary (SILVA et al., 2008; EMBRAPA, 2023). Levees, arranged along contour lines, are used to divide the field into irrigation basins, enabling continuous flood irrigation and ensuring water-use efficiency within the production system.

Historically, land leveling was performed using empirical methods and simple instruments, such as water levels, leveling frames, and laser-guided equipment, later evolving toward greater mechanization with narrow- and wide-base levee builders (CONAB, 2015). However, in recent decades, advances in Precision Agriculture have transformed this practice. The adoption of high-accuracy GNSS receivers and real-time correction systems, such as Real-Time Kinematic (RTK), has improved topographic surveying accuracy, reducing errors and optimizing leveling projects (MOLIN; AMARAL; COLAÇO, 2015; JOHN DEERE, 2025).

Among the available digital tools, AgroCAD® and T3rra Cutta© stand out. AgroCAD® enables the generation of Digital Terrain Models (DTMs), slope analysis, and initial levee layout design, representing an important resource for agricultural planning (TECGRAF, 2020). T3rra Cutta© incorporates advanced features such as terrain smoothing, automated cut-and-fill calculations, and optimization of levee alignments with reduced soil movement (T3RRA, 2025). The integration of these tools allows the development of more realistic projects better adapted to field conditions, contributing to improved operational efficiency and reduced costs.

Therefore, the objective of this study was to evaluate the impact of digital terrain smoothing on levee configuration in lowland areas intended for irrigated rice cultivation in Rio Grande do Sul, Brazil. AgroCAD® and T3rra Cutta© software were used to generate and analyze Digital Terrain Models (DTMs), design the initial levee layout, and perform terrain smoothing. The comparison between the two tools allowed the identification of differences in the number of generated structures, soil movement volumes, and topographic planning efficiency. The study aimed to understand how the combined use of these Precision Agriculture technologies can contribute to optimizing land leveling, improving water management, and enhancing operational efficiency in irrigated rice production systems.

2 MATERIALS AND METHODS

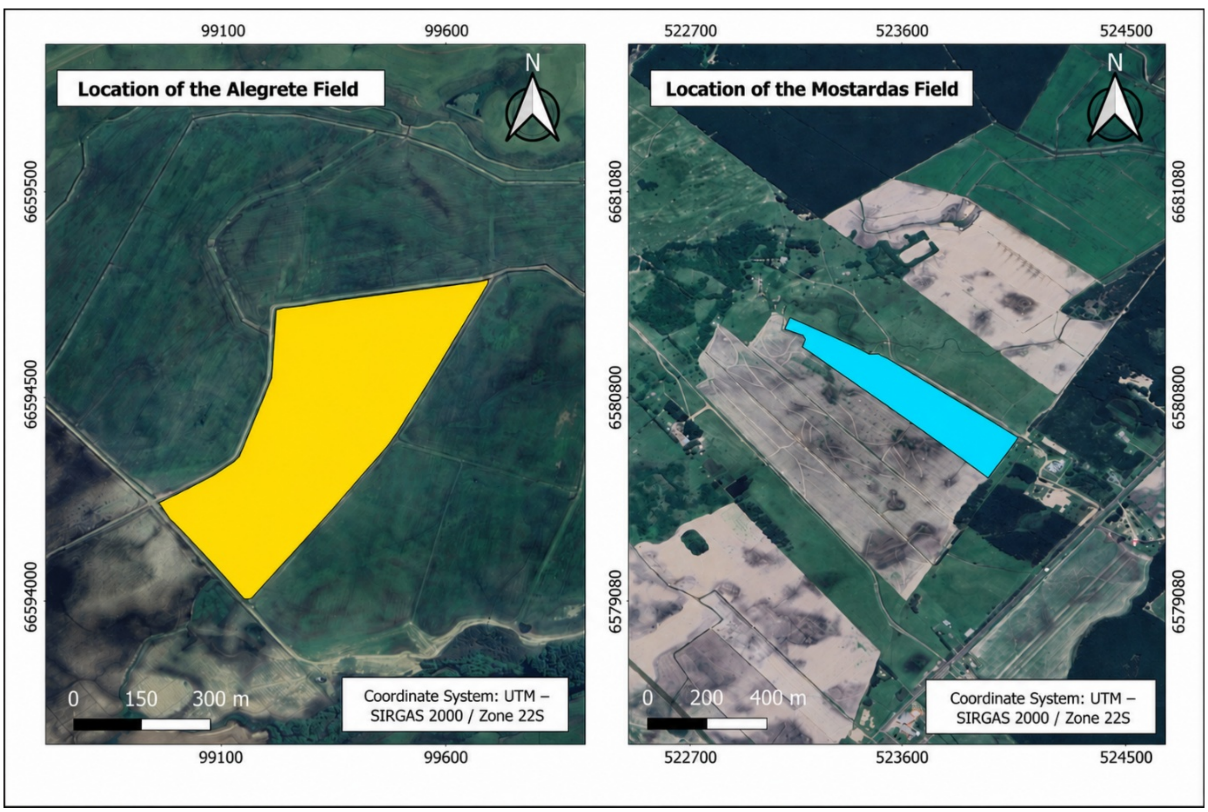
2.1 Study Area

The land leveling project, developed using AgroCAD® and T3rra Cutta© software, was conducted in two rice-producing areas in the state of Rio Grande do Sul, Brazil, selected because of their distinct topographic characteristics and slope conditions.

The first area, referred to as the Alegrete field, is located in the municipality of Alegrete, in the Campanha region, with central coordinates of 29°49'04.6" S and 55°09'14.1" W. The farm is dedicated to rice and soybean production. The terrain is gently undulating, typical of the Campanha region, and the predominant soils are Planosols, which have good water retention capacity but require land leveling to prevent excessive water accumulation in lower areas. The regional climate is humid subtropical, with rainfall well distributed throughout the year, favoring flood-irrigated rice cultivation. The evaluated field covers an area of 26.2 hectares (Figure 1).

The second area, referred to as the Mostardas field, is located in the municipality of Mostardas, in the southern coastal region of Rio Grande do Sul, with central coordinates of 30°55'10.3" S and 50°45'20.9" W. The farm is situated within the coastal plain, characterized by flat terrain and the presence of Gleysols, which are highly suitable for irrigated rice production. The region presents high water availability and low elevation variability, providing favorable conditions for flood irrigation. The evaluated field covers an area of 17.8 hectares (Figure 1).

Figure 1. Location and identification of the study fields.



Source: Authors (2025)

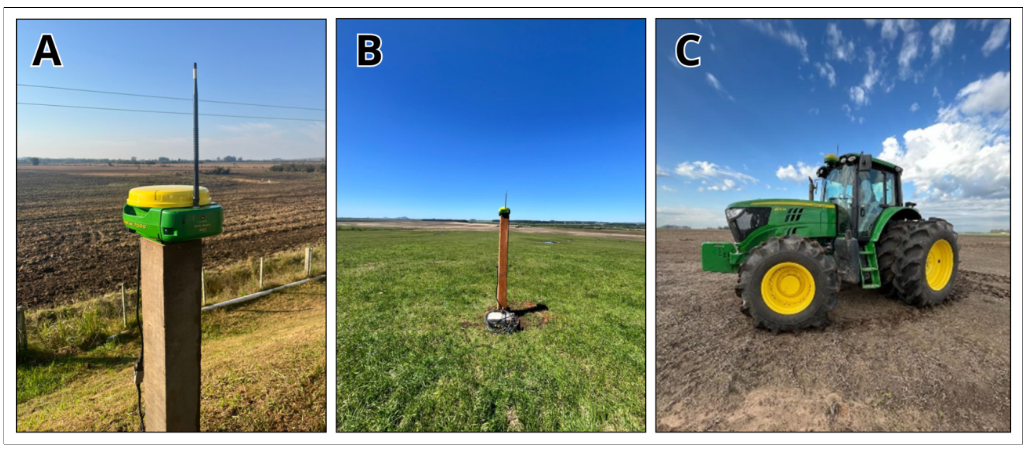
2.2 Data Collection, Processing, and Analysis

The topographic survey of the study areas was conducted using a John Deere RTK (Real-Time Kinematic) GNSS system operating in absolute base mode. To ensure high vertical accuracy, the RTK base station remained active for 24 hours, performing self-calibration and adjusting its position based on satellite data. The equipment consisted of StarFire 6000 and 7000 receivers and a 450 MHz RTK radio (Figures 2A and 2B), enabling the transmission of real-time correction signals to the rover during data collection.

The survey was performed using an agricultural tractor equipped with a GNSS receiver, also referred to as a rover (Figure 2C). This approach was chosen due to operational availability and ease of movement across cultivated fields. It is noteworthy that the John Deere differential correction system is supported by a network of five permanently referenced base stations in South America, located in Catalão (GO, Brazil), Sapezal (MT, Brazil), Horizontina (RS, Brazil), Luís Eduardo Magalhães (BA, Brazil), and Rosario (Argentina) (BRUTTI, 2014).

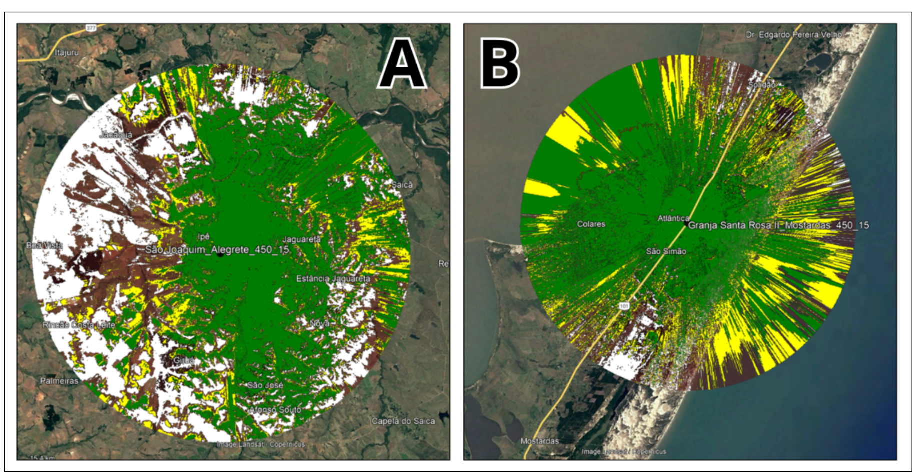
The maximum effective range of the RTK base station was approximately 19 km. Signal strength was represented using color classes: green for optimal coverage, yellow for unstable coverage, and white for areas without signal reception. This variation was primarily associated with regional terrain characteristics (Figure 3).

Figure 2. RTK base stations and agricultural tractor used for the topographic survey.



Source: Authors (2025)

Figure 3. Signal coverage of the RTK base stations installed in Alegrete (A) and Mostardas (B).

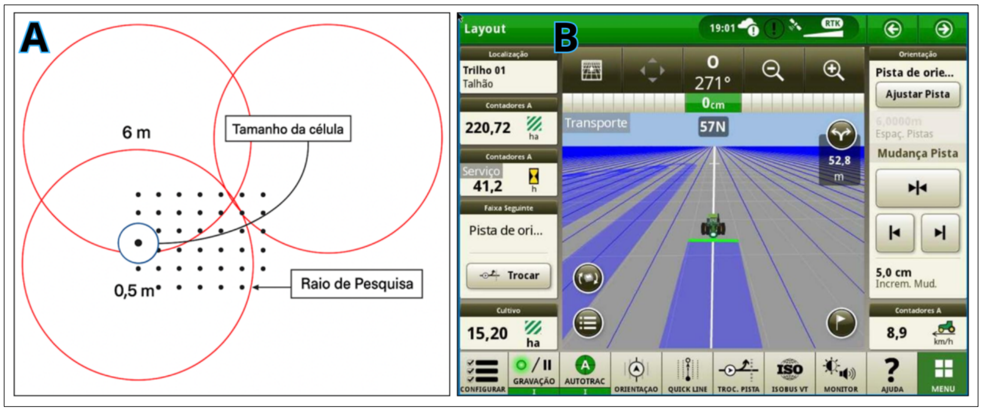


Source: Authors (2025)

Figure 4 illustrates the point sampling grid obtained during the topographic survey. Tractor (rover) passes were conducted at 6 m intervals, while elevation points were automatically recorded every 0.5 m by the John Deere Generation 4 Display. This configuration resulted in a high-density dataset, ensuring accuracy in the generation of the Digital Terrain Model (DTM).

The red circles represent the search radius adopted during data processing, whereas the highlighted cell exemplifies the interpolation area between neighboring points, which is essential for terrain smoothing and surface modeling. The tractor operating speed was maintained between 10 and 12 km h^{-1}, a range considered appropriate for ensuring measurement accuracy and signal stability.

Figure 4. Point sampling grid used during the topographic survey (A) and overview of the John Deere Generation 4 Display during field mapping operations (B).



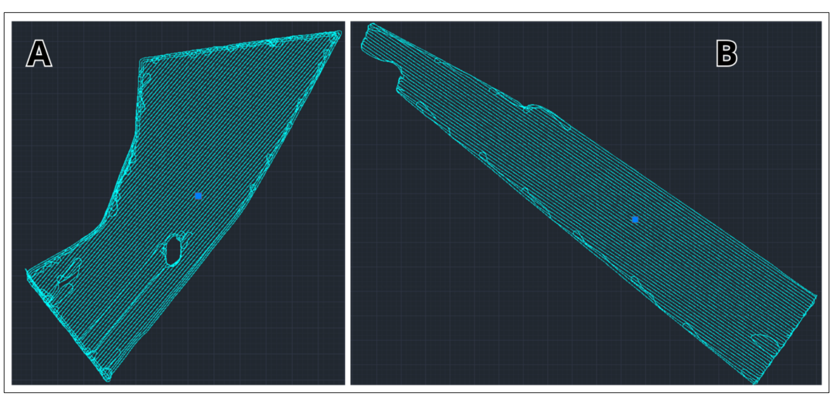
Source: Authors (2025)

In the Mostardas field, topographic data collection was performed on August 26, 2024, followed by levee construction on September 7, 2024, resulting in an interval of approximately 12 days between the survey and field operations. In the Alegrete field, the survey was conducted on October 30, 2024, and levee construction was completed on November 1, 2024, with a reduced operational interval of only two days.

At the end of the mapping process, the collected data were automatically transmitted through the onboard JDLink telematics system, enabling remote transfer to the Operations Center and eliminating the need for manual extraction using a USB device. The files, received in JD-Data format, were subsequently imported into AgroCAD® for processing.

Following data import, quality checks were performed on the raw datasets (Figure 5), including assessments of signal quality and mapping speed, ensuring that the collected information accurately represented actual field conditions.

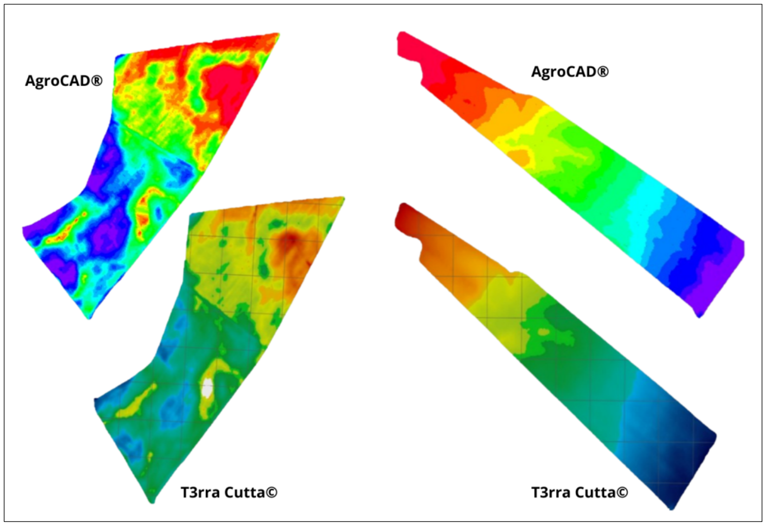
Figure 5. Topographic survey of the Alegrete field (A) and the Mostardas field (B).



Source: Authors (2025)

Subsequently, the point grid was processed to generate Digital Terrain Models (DTMs) using the AgroCAD® and T3rra Cutta© software platforms, enabling a comparative analysis of terrain topography. As shown in Figure 6, the DTM generated by AgroCAD® presented greater color-scale contrast, highlighting subtle terrain variations, whereas T3rra Cutta© produced a smoother representation while still preserving relevant elevation differences. These variations reflect the processing approach adopted by each platform and may influence visual interpretation and operational planning.

Figure 6. Digital Terrain Models (DTMs) of the study fields generated using AgroCAD® and T3rra Cutta© software.



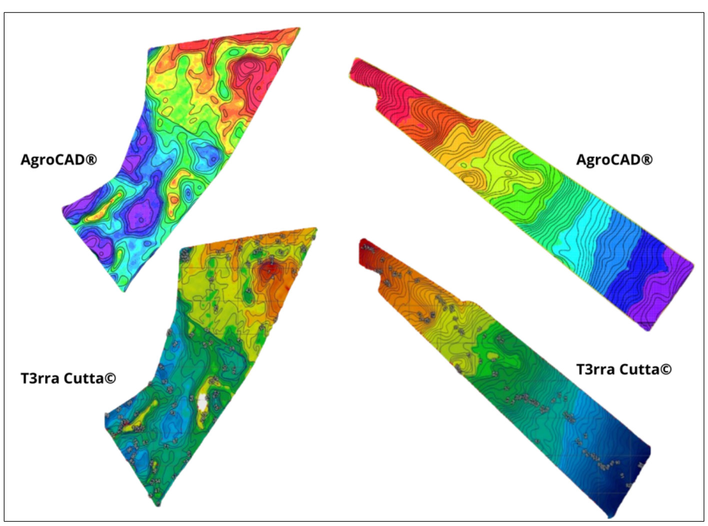
Source: Authors (2025)

Based on the DTMs and contour lines, levee layouts were designed considering an elevation difference of 6 to 7 cm between adjacent points, a value considered suitable for ensuring proper water depth management in leveled fields.

3 RESULTS AND DISCUSSION

Figure 7 presents the levee designs developed using AgroCAD® and T3rra Cutta© software. The differences observed in contour lines and delineated areas reflect the specific processing criteria and design algorithms adopted by each platform.

Figure 7. Levee designs developed using AgroCAD® and T3rra Cutta© software.

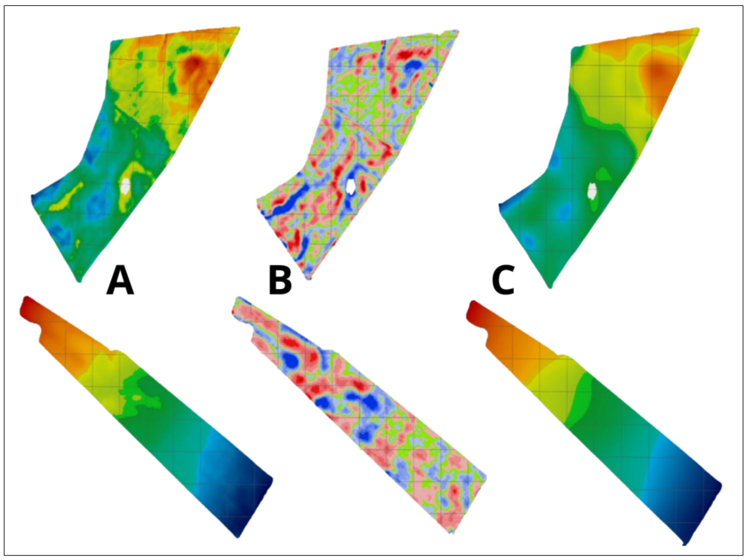


Source: Authors (2025)

When comparing the number of levees generated by each software platform, a relatively small difference was observed prior to terrain smoothing. In the Mostardas field, AgroCAD® generated 98 levees, whereas T3rra Cutta© generated 95. In the Alegrete field, AgroCAD® produced 105 levees, compared to 99 generated by T3rra Cutta©. This difference can be attributed to the smoothing algorithm employed by T3rra Cutta©, which tends to simplify terrain segments, resulting in fewer levee lines, whereas AgroCAD® generates more detailed layouts. This contrast highlights that the evaluation should consider not only the number of levees but also the quality and practical applicability of the layouts under field conditions.

Figure 8 illustrates the land leveling process in both study areas. The original DTMs (Figure 8A) show greater elevation variability, with terrain irregularities requiring significant intervention to achieve adequate leveling. The cut-and-fill maps (Figure 8B) demonstrate the need for soil movement, with areas of excavation and deposition distributed throughout the fields. Following terrain smoothing (Figure 8C), a more uniform surface can be observed, with a reduction in undulations and minor terrain irregularities.

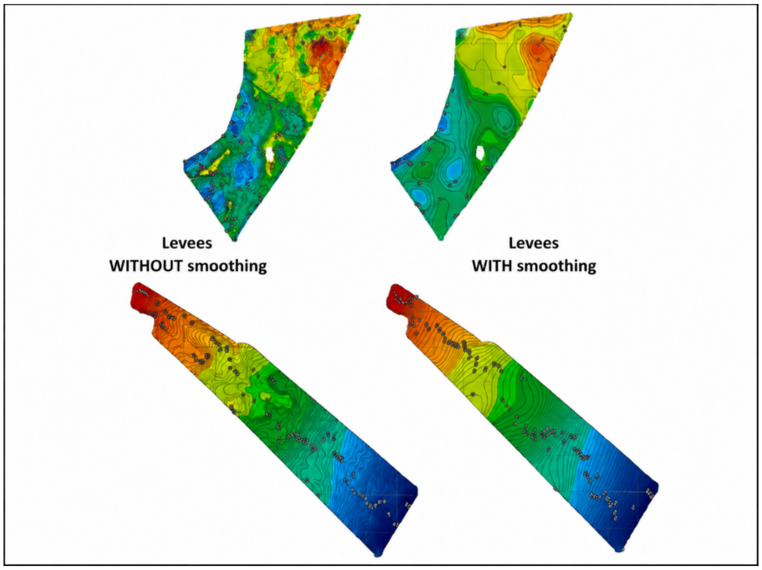
Figure 8. Land leveling process performed using T3rra Cutta© software.



Source: Authors (2025)

This process had a direct impact on the number of projected levees, as shown in Figure 9. In the Mostardas field, the number of levees decreased from 95 to 89 after terrain smoothing. In the Alegrete field, the reduction was even more pronounced, decreasing from 99 to 47 levees. These results demonstrate that digital terrain smoothing can optimize levee layout design, improve water flow distribution, and facilitate mechanized field operations, particularly in areas with lower residual terrain variability.

Figure 9. Comparison of the study fields before and after terrain smoothing and levee optimization following land leveling.



Source: Authors (2025)

The average volume of soil moved per hectare was similar between the study fields, reaching 227.8 m³ ha⁻¹ in Mostardas and 231.1 m³ ha⁻¹ in Alegrete. These results indicate that, despite the reduction in the number of levees after terrain smoothing, the intensity of cut-and-fill operations remained nearly equivalent.

Currently, there is no standardized threshold for soil movement in land-leveling projects, as this variable depends on factors such as terrain characteristics, field size, field geometry, and the specific objectives of the project. Recent studies, such as that of Parfitt et al. (2023), have discussed terrain smoothing practices in lowland areas as a strategy to reduce the number of levees and improve operational efficiency.

Table 1. Results obtained from data processed using AgroCAD® and T3rra Cutta© software.

Processing Stage	Mostardas Field	Alegrete Field
Number of levees generated by AgroCAD®	98	105
Number of levees generated by T3rra Cutta©	95	99
Number of levees after terrain smoothing in T3rra Cutta©	89	47

Source: Authors (2025)

AgroCAD® proved to be effective for DTM generation, slope analysis, and initial levee layout design, allowing basic adjustments to levee alignments. However, the software does not perform terrain smoothing or automated cut-and-fill calculations, limiting its application to the initial planning stage. In contrast, T3rra Cutta© stood out by integrating terrain smoothing, levee optimization, and cut-and-fill volume calculations within a single platform. The combined use of both tools provided a more comprehensive approach, integrating detailed topographic analysis with operational estimates applicable to agricultural field management.

4 CONCLUSIONS

The land leveling of agricultural areas using digital Precision Agriculture tools proved effective in reducing the number of levees and improving planning efficiency in lowland environments. The comparative analysis revealed distinct reductions between the evaluated fields: in the Mostardas field, the number of levees decreased from 95 to 89, whereas in the Alegrete field the reduction was more pronounced, decreasing from 99 to 47 levees. These results demonstrate the impact of digital terrain smoothing on levee layout optimization.

Slope analyses confirmed that both study areas exhibit predominantly flat terrain, with average slopes below 1%, a condition considered ideal for flood-irrigated rice production. The average soil movement volume was similar between fields (approximately 230 $m^3\ ha^{-1}$), reinforcing that terrain smoothing primarily affects levee configuration without substantially increasing cut-and-fill requirements.

The integrated use of AgroCAD® and T3rra Cutta© proved to be complementary. While AgroCAD® enables detailed topographic analysis and initial levee planning, T3rra Cutta© provides terrain smoothing functions, automated cut-and-fill calculations, and simulations related to water management. Furthermore, these software platforms enhance terrain visualization, facilitate the generation of intuitive maps, and support integration with agricultural machinery, contributing to greater operational efficiency.

In conclusion, the adoption of these technologies represents a significant advancement for irrigated rice production in Rio Grande do Sul, contributing to cost reduction, improved water management, and increased sustainability of agricultural operations in lowland areas.

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