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PLANTING SYSTEM AND ITS EFFECT ON SOIL PHYSICAL PROPERTIES AND SOYBEAN DEVELOPMENT: A CASE STUDY IN THE SOUTHWEST OF MATO GROSSO, BRAZIL

SISTEMA DE PLANTIO E SEU EFEITO NAS PROPRIEDADES FÍSICAS DO SOLO E NO DESENVOLVIMENTO DA SOJA: UM ESTUDO DE CASO NO SUDOESTE DE MATO GROSSO, BRASIL

SISTEMA DE SIEMBRA Y SU EFECTO EN LAS PROPIEDADES FÍSICAS DEL SUELO Y EL DESARROLLO DE LA SOJA: UN ESTUDIO DE CASO EN EL SUDESTE DE MATO GROSSO, BRASIL

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Abstract

In recent years, many producers have modified their production systems to meet the growing demand for food. However, these practices may lead to changes in the physical properties of the soil and compromise plant development. In order to evaluate the influence of production systems on soil physical properties and soybean crop yield, a study was conducted at Pitanga farm in the municipality of Tangará da Serra, Mato Grosso, Brazil. Soil physical characteristics were assessed at different depths, including penetration resistance, bulk density, and porosity, in two areas: one under conventional tillage and the other under no-tillage. Agronomic characteristics of the soybean crop were also evaluated, including plant height, height of first pod insertion, number of nodes, and yield. Significant results were observed for penetration resistance, bulensity, and plant height. The no-tillage area showed a higher level of soil compaction however, the compaction level found did not affect root system growth or soybean yield.
Keywords: Soil compaction; soil management; no-tillage; conventional tillage.

Resumo

Nos últimos anos muitos produtores têm alterado os sistemas de produção para atender o aumento na demanda de alimentos. No entanto, essas práticas podem ocasionar em alterações nas propriedades físicas do solo e comprometer o desenvolvimento das plantas. Com o objetivo de avaliar a influência dos sistemas de produção nas propriedades físicas do solo e produtividade da cultura da soja foi realizado estudo na fazenda Pitanga no município de Tangará da Serra-MT. Foram avaliadas em diferentes profundidades, as características físicas do solo: resistência a penetração, densidade e porosidade em duas áreas, uma com preparo convencional do solo e outra sob plantio direto. Também foram avaliadas as características agronômicas da cultura da soja: altura de planta, altura de inserção da 1° vagem números de nós e produtividade. Foram constatados resultado significativos para resistência a penetração, densidade e altura de plantas. Na área sob plantio direto demostrou nível de compactação mais elevado, no entanto, o nível de compactação encontrado não influenciou no crescimento do sistema radicular e nem a produtividade da soja.
Palavras-chave: Compactação; manejo de solo; plantio direto; plantio convencional.

Resumen

En los últimos años, numerosos productores han modificado sus sistemas de producción para satisfacer la creciente demanda de alimentos. Sin embargo, estas prácticas pueden generar cambios en las propiedades físicas del suelo y comprometer el desarrollo de las plantas. Con el objetivo de evaluar la influencia de los sistemas de producción sobre las propiedades físicas del suelo y la productividad del cultivo de soja, se realizó un estudio en la finca Pitanga, ubicada en el municipio de Tangará da Serra, MT. Se analizaron las características físicas del suelo a diferentes profundidades, incluyendo la resistencia a la penetración, la densidad y la porosidad, en dos áreas: una bajo labranza convencional y otra bajo labranza cero. Asimismo, se evaluaron variables agronómicas del cultivo de soja, tales como la altura de la planta, la altura de inserción de la primera vaina, el número de nudos y la productividad. Se observaron diferencias significativas en la resistencia a la penetración, la densidad del suelo y la altura de la planta. El área bajo labranza cero presentó un mayor nivel de compactación; no obstante, el grado de compactación registrado no influyó en el crecimiento del sistema radicular ni en la productividad del cultivo de soja.
Palabras clave: Compactación del suelo; manejo del suelo; labranza cero; labranza convencional.

1. Introduction

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In Brazil, the 2024/2025 soybean harvest reached approximately 170 million tons, representing a 2.7% increase in the planted area and reinforcing the country's position as the world's largest producer of this oilseed (CONAB, 2025). The crop continues to attract strong interest from producers due to its high profitability and diverse uses (Noskoski *et al.,* 2026; Saraiva *et al.,* 2026).

According to United Nations estimates (ONU, 2019), the global population could reach 9.7 billion by 2050, making it essential to advance agricultural practices to ensure sufficient production of food, feed, and fibers while preserving the environment (Hungria; Nogueira, 2021).

The need to increase production stems from population growth, which leads to a greater demand for food. Therefore, in recent decades, cultivated areas in Mato Grosso have undergone significant changes, mainly in relation to soil management practices, such as the adoption of no-till farming (Ramadhan, 2021; Hunke *et al.,* 2015; Crusciol *et al.,* 2016). However, as a consequence of these practices, soil compaction has been reported as a problem, generally attributed to years under conventional systems and to the lack of crop rotation (Behrends-Kraemer *et al.,* 2017; Sasal *et al.,* 2017; Moraes *et al.,* 2016).

Soil compaction has become a frequently observed problem in no-till farming systems in countries such as Australia (Dang *et al.,* 2015), Brazil (Peixoto *et al.,* 2019; De Moura *et al.,* 2021), the USA (Sivarajan *et al.,* 2018), and Argentina (Peralta; Alvarez; Taboada, 2021). Under no-till systems, compaction occurs mainly in clayey soils (Blanco-Canqui; Ruis, 2018). Several authors cite the absence of crop rotation, the use of shallow-rooted plants, the intensity of agricultural machinery traffic, the type of equipment, and the lack of complementary soil conservation practices as the main causes of compaction (Gao *et al.,* 2016; Bluett *et al.,* 2019; Moraes; Gusmão, 2021).

Soil compaction is the main form of soil degradation in agricultural systems (Yue *et al.,* 2021). It leads to decreased porosity, reduced water infiltration, and increased resistance to root penetration (Schjønning *et al.,* 2015; Keller *et al.,*

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2019). Therefore, compaction directly affects the absorption of water and nutrients by plants.

Compaction reduces the pore spaces in the soil responsible for aeration, as well as for the conduction and retention of water and nutrients-processes that are essential for the growth and development of plants and microorganisms and are directly linked to soil fertility and physical properties (Wu *et al.,* 2021). At a given time and location, any of these factors may restrict plant development, depending on soil type, climatic conditions, species, and the stage of plant development (Camargo; Alleoni, 1997).

Soil compaction is recognized as one of the main threats to sustainable agriculture, as it negatively affects root growth, development, and distribution, in addition to reducing crop productivity (Sivarajan *et al.,* 2018). To determine soil compaction, the physical indicators used include soil bulk density, pore size distribution, and soil penetration resistance (Moraes *et al.,* 2020).

Penetration resistance is considered the most common and effective parameter for monitoring and detecting soil compaction (Benevenute *et al.,* 2020). The most widely used instrument is the impact penetrometer, a direct mechanical device for measuring the level and depth of soil compaction (Kogelbauer *et al.,* 2013). It is influenced by soil moisture content, bulk density, and soil type (Jabro *et al.,* 2015). Penetration resistance values greater than 2 MPa may restrict water movement and limit root growth and penetration through the soil profile (Jabro *et al.,* 2021). Given the need for further information on the relationship between soil tillage systems, penetration resistance, bulk density, and plant development, a study was conducted on a soybean farm in the state of Mato Grosso, Brazil.

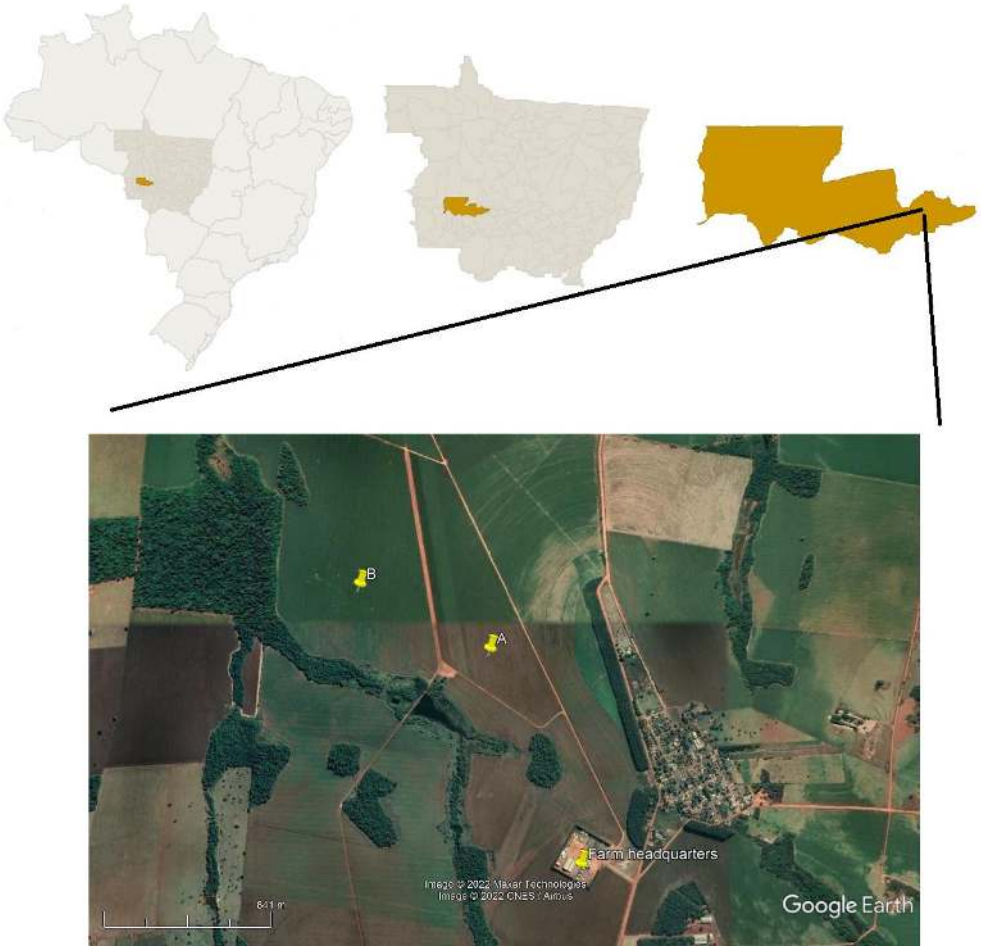
2. Materials and Methods

The case study was conducted in a 1000-ha area at Pitanga Farm (Figure 1) under a soybean production system. The farm is located in the municipality of Tangará da Serra, Mato Grosso, Brazil (14°38'57.38" S, 57°18'59.23" W).

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Figure 1. Location of Pitanga farm in the municipality of Tangará da Serra, Mato Grosso, Brazil.



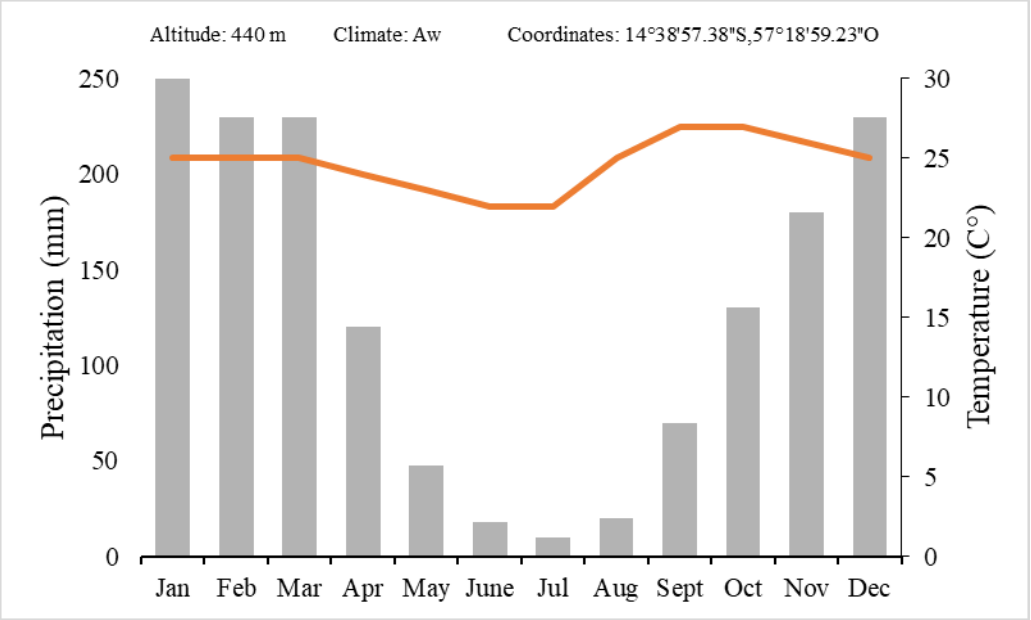
Source: IBGE (2018), Google Earth (2022).

The study area is situated at an altitude of 440 m, with a predominantly humid tropical megathermal climate (Aw) according to the Köppen classification. The average temperature is 25 °C (Figure 2), with a dry season from May to September and a rainy season from October to April. Annual rainfall ranges from 1,200 to 2,000 mm (Daniel *et al.,* 2021; Souza *et al.,* 2013).

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Figure 2. Climatological information (rainfall and temperature) at the Pitanga farm in the municipality of Tangará da Serra, Mato Grosso, Brazil.



Source: CLIMATE-DATE.ORG. (2021).

The soil was classified as a dystrophic Red Latosol, clayey, with gently undulating relief (Moreira; Vasconcelos, 2007). The sand, silt, and clay contents were 300, 150, and 550 g kg^{-1}, respectively.

Different soil tillage systems were used as criteria for selecting the study areas. Accordingly, one area under a conventional tillage system (Area A) and another under a no-till system (Area B) were evaluated. It is worth noting that the no-till system in Area B is relatively recent, having been established approximately three years ago. Within each system, four distinct sub-areas were established to account for spatial variability, serving as the basis for the sampling points and agronomic evaluations.

The soil sampling method followed the procedure proposed by Loss *et al.* (2017), consisting of a delimited area of 600 m^2 in which four trenches were opened transversely to the sowing lines for each area. Soil samples were collected, and root system depth was assessed. Samples were taken at depths of 0-10, 10-20, and 20-30 cm for the determination of soil bulk density (BD), macroporosity (MaP), and microporosity (MiP). Physical analyses were conducted following the methodology

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of Donagema et al. (2011) at the Soil Laboratory of the State University of Mato Grosso (UNEMAT), Tangará da Serra campus, Mato Grosso, Brazil.

Soil penetration resistance (PR) was determined using an impact penetrometer, following the methodology of Stolf (1991, 2014). Measurements were performed along a diagonal transect at 12 representative points per area, with data recorded to a depth of 50 cm at 5 cm intervals. To ensure standardized mechanical conditions, PR was measured when soil moisture was at approximately 70% of field capacity. This moisture level was achieved through manual irrigation to saturation at each sampling point, followed by a controlled drainage period. Soil moisture was monitored and confirmed via the thermo-gravimetric method (oven-drying at 105 °C for 24 h) prior to penetrometry.

To estimate grain yield, the three central rows (0.45 m spacing) with a length of 5 m were harvested per sampling unit, totaling an area of 6.75 m^2. This procedure was performed independently across four distinct sub-areas within each management system (A and B), with ten replicates per treatment to ensure statistical representativeness. After threshing and cleaning, grain moisture was determined and the final weight was corrected to 13% (wet basis). Yield data were then extrapolated to to Mg ha^{-1}. For the evaluation of agronomic traits, ten plants per replicate were randomly sampled to assess plant height, first pod height, and the number of nodes. Yield values were obtained separately for each area and sub-area, allowing for a precise comparative analysis between the conventional and no-till systems.

Data on soil attributes (penetration resistance, bulk density, macroporosity, and microporosity) and plant development (plant height, height of first pod insertion, number of nodes, and grain yield) were subjected to analysis of variance (ANOVA, F-value, $p < 0.05$) and correlation analysis using Pearson's correlation coefficients. ANOVA was performed separately for each soil depth. When treatment effects were significant, means were compared using Tukey's test ($p < 0.05$). All statistical analyses were carried out using the Statistical Analysis System (SAS) version 6.1 software (SAS, 2013).

The experimental data were analyzed using a completely randomized design

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(CRD). The formal statistical model is described as: $Y_{ij} = \mu + T_i + \varepsilon_{ij}$, where Y_{ij} is the observed value, μ is the overall mean, T_i is the fixed effect of the tillage system, and ε_{ij} is the experimental error. Data on soil attributes and plant traits were subjected to Analysis of Variance (ANOVA, F-test, $p < 0.05$).

For soil physical properties, ANOVA was performed separately for each depth. When significant differences were detected, treatment means were compared using Tukey's HSD test ($p < 0.05$).

Pearson's correlation analysis was conducted to assess the relationship between variables, based on a total of n = 80 observations (2 systems x 4 sub-areas x 10 replicates).

The near-perfect correlation observed between macroporosity and microporosity is justified by their mathematical interdependence, as both are components of the total porosity (TP = Macro + Micro); thus, changes in one pore class inherently result in a reciprocal shift in the other. All analyses were performed using Statistical Analysis System version 6.1 software (SAS, 2013).

3. Results and Discussion

The results presented in Figures 3 indicate a significant difference in penetration resistance between the management systems, except at a depth of 25 cm. Penetration resistance values were below the critical threshold (2 MPa) only at a depth of 5 cm. Beyond this depth, soil penetration resistance exceeded the critical limit in both management systems.

In the upper 5 cm of the soil profile, the highest penetration resistance was observed under the conventional system. This result may be attributed to the greater amount of crop residue on the soil surface in the no-till system, which promotes improved soil structure, increased porosity, and consequently lower resistance to penetration.

From a depth of 10 cm onward, the no-till system exhibited higher penetration resistance, reaching a maximum value of 3.70 MPa between 20 and 30 cm, followed by a reduction to 3.0 MPa at a depth of 50 cm.

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The conventional system exhibited lower penetration resistance than the no-till system up to a depth of 20 cm, with similar values observed at 25 cm. Beyond this depth, however, the conventional system showed greater resistance, reaching a maximum value of 4.52 MPa at 35 cm.

According to Bertol *et al.* (2000), higher levels of compaction may occur in soil layers below 10 cm under conventional tillage management. This condition is often associated with machinery traffic, as reported by Lopes *et al*. (2015), or animal trampling, as described by Parente and Maia (2011).

Working with no-till systems, Drescher et al. (2012) reported an increase in penetration resistance values up to approximately 15 cm depth. Below this layer, the results remained relatively constant, followed by a reduction after the 36 cm depth.

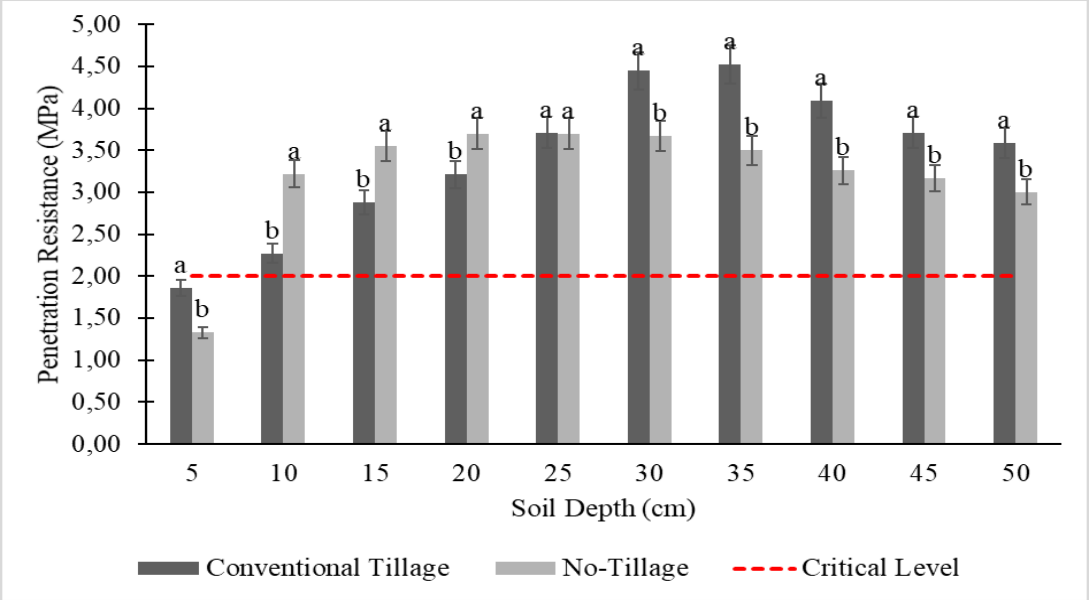
A similar pattern can be observed under no-till management (Figure 1), in which penetration resistance was 3.22 MPa at a depth of 10 cm, increasing to approximately 3.70 MPa at 20 and 30 cm, and subsequently decreasing at 40 and 50 cm. In contrast, the conventional system exhibited a different behavior: starting from 1.86 MPa, penetration resistance increased exponentially with depth, reaching a peak value of 4.52 MPa at 35 cm.

The mean penetration resistance values differed significantly between the management systems (Figure 3). In both systems, resistance values exceeded the critical threshold for plant development (2.0 MPa) from a depth of 5 cm onward. At 5 cm depth, the no-till system exhibited lower penetration resistance. Between 10 and 20 cm, the lowest values were observed under the conventional tillage system. At greater depths, however, the conventional system showed higher resistance compared to the no-till system. Overall, soil disturbance in the conventional tillage system reduces penetration resistance in the surface layers due to soil disaggregation resulting from structural breakdown. However, this practice is typically limited to a depth of approximately 20 cm. Consequently, increased penetration resistance at greater depths may restrict root system growth in deeper soil layers.

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Figure 3. Penetration resistance as a function of soil depth (0–50 cm) under no-till and conventional tillage systems. The bars represent the standard deviation.



Means followed by the same letter at each soil depth do not differ according to Tukey's test ($p < 0.05$). ns = not significant.

However, these results indicate greater soil compaction in the no-till area, likely associated with the management system and the relatively short period since its implementation (three years). The lower penetration resistance values observed in the conventional tillage area can be attributed to subsoiling performed prior to planting. Nevertheless, these reduced values may be temporary and could increase over time as soil reconsolidation occurs.

Similar results were reported by Jabro *et al.* (2015), Blanco-Canqui and Ruis (2018), Idowu *et al.* (2019), and Jabro *et al.* (2021), who observed that no-till management practices tend to increase soil penetration resistance compared to conventional tillage systems. These authors also attributed the higher resistance under no-till to wheel traffic associated with various agricultural operations, in contrast to conventional systems, where periodic soil disturbance temporarily alleviates compaction.

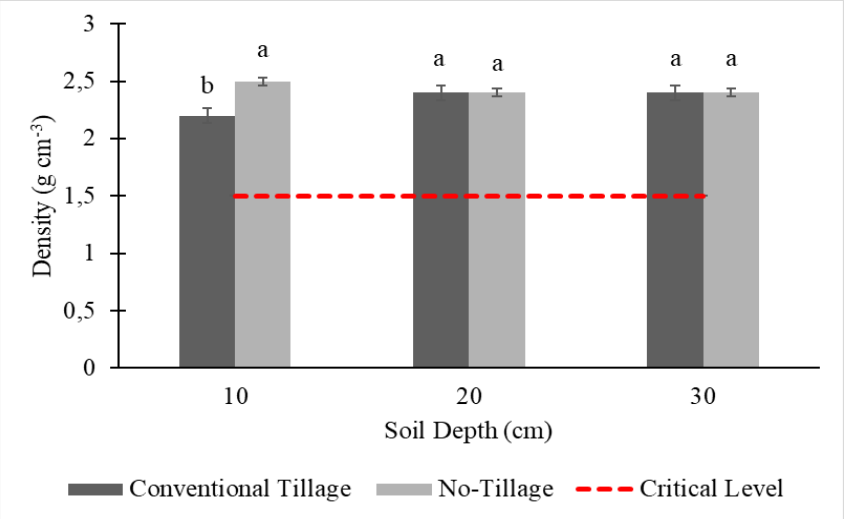
In the long term, however, the benefits of no-till in reducing compaction risks and improving soil structural quality become more evident, as reported by Blanco-Canqui and Ruis (2018) and Celik (2011).

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The results for soil bulk density at depths of 0-10, 10-20, and 20-30 cm under no-till and conventional tillage systems are presented in Figure 4. A significant difference between the systems was observed only in the 0-10 cm layer. Similarly, Jabro *et al.* (2021), when evaluating soil bulk density under no-till and conventional tillage systems, reported significant differences only in the surface soil layers.

Figure 4. Soil bulk density as a function of soil depth (10, 20, and 30 cm) under conventional and no-till planting systems. The bars represent the standard deviation.



Means followed by the same letter at each soil depth do not differ according to Tukey's test ($p < 0.05$). ns = not significant.

Soil bulk density in the no-till area was higher than that observed under conventional tillage. Similar results were reported by Moraes *et al.* (2020), who noted that soil disturbance reduces soil bulk density. An increase in soil density under no-till has also been documented by Celik (2011), who observed lower values under conventional tillage. This reduction in soil bulk density in conventional systems can be attributed to short-term tillage and the incorporation of crop residues into the soil (Celik, 2011; Moraes *et al.,* 2020).

In both areas, soil bulk density exceeded the values considered limiting for most crops. According to Klein and Câmara (2007), the critical soil bulk density threshold is approximately 1.50 g cm^{-3}. Reichert *et al.* (2009) reported that densities above 1.21 g cm^{-3} can restrict root system growth in soybean, and that values between 1.36 and 1.68 g cm^{-3} negatively affect soybean development and

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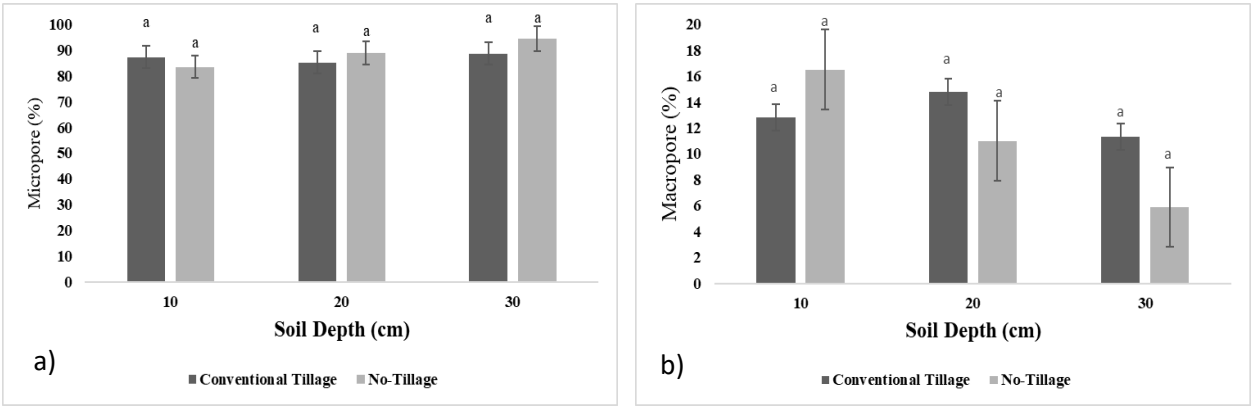
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productivity in tropical clay soils. It is important to note, however, that soil bulk density depends on particle density, which in turn is influenced by soil mineralogy. Therefore, evaluating soil bulk density alone is insufficient to assess compaction; complementary parameters such as porosity and penetration resistance should also be considered (Kiehl, 1979).

No significant differences were observed between the areas in terms of micro- and macroporosity (Figure 5). However, Mondal and Chakraborty (2022) reported a significant increase in microporosity and a decrease in macroporosity in the topsoil layer under no-till systems.

Figure 6 shows a small macropore volume in the 0–10 cm layer for both areas, approaching the critical threshold for root development, which is 10% (Andrade and Stone, 2009). Similar findings were reported by Sanchez (2012), who evaluated soybean productivity under successive winter cover crops.

Figure 5. Microporosity (a) and macroporosity (b) as a function of soil depth (10, 20, and 30 cm) under conventional and no-till planting systems. The bars represent the standard deviation.



Means followed by the same letter at each soil depth do not differ according to Tukey's test ($p < 0.05$). ns = not significant. Microporosity and macroporosity were evaluated at three different soil depths.

According to Andrade and Stone (2009), ideal soil porosity should follow a 2:1 ratio, with approximately two-thirds of the pores being micropores and one-third macropores. In contrast, Sanchez (2012) highlighted that low macroporosity combined with high microporosity can impair soil aeration, negatively affecting crop development.

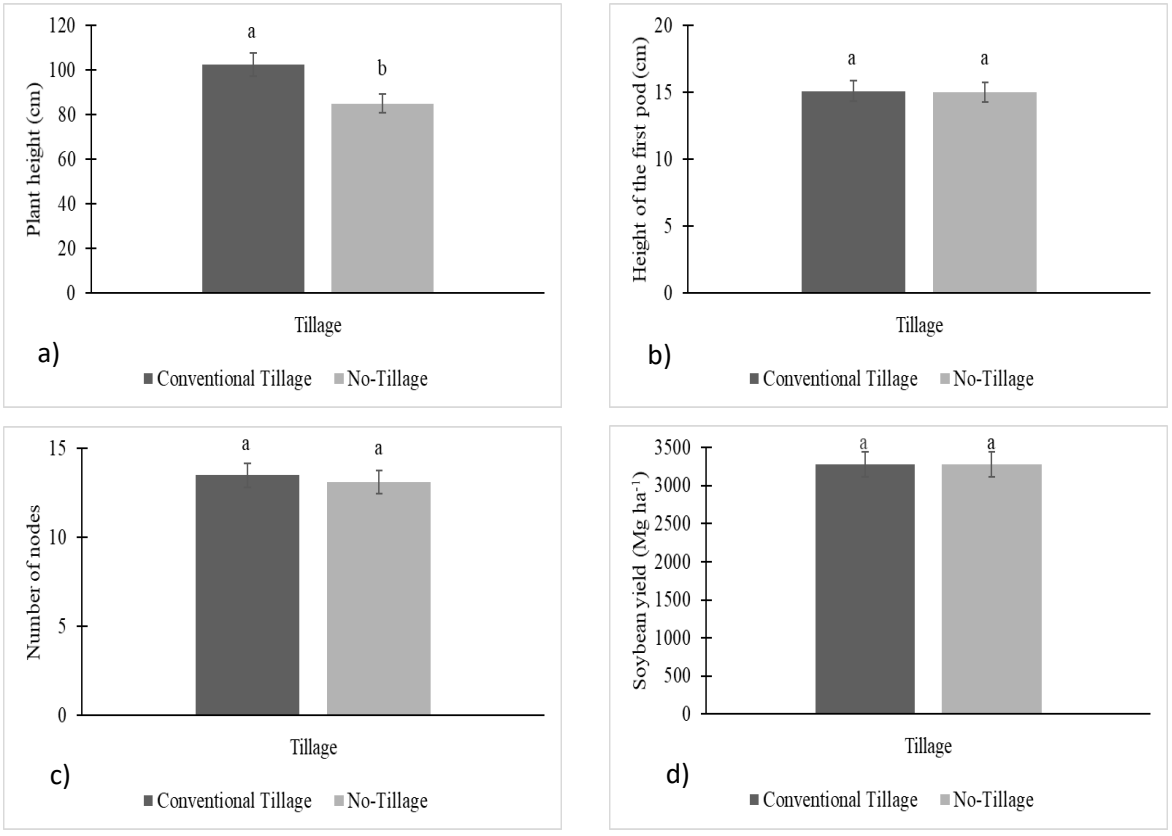
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Furthermore, Lima *et al.* (2007) emphasized that soil porosity is closely linked to the dynamics of solute storage and movement, as well as gas circulation, which are essential for plant biochemical processes, particularly those related to productivity.

The soybean growth attributes-plant height (6a), first pod insertion height (6b), number of nodes (6c), and yield (6d)-as a function of the soil management system are presented in Figure 6.

Figure 6. Plant height (a), first pod insertion height (b), number of nodes (c), and grain yield (d) as a function of conventional and no-till planting systems. The bars represent the standard deviation.



Means followed by the same letter do not differ according to Tukey's test ($p < 0.05$). ns = not significant.

Soybean growth was affected by the soil management system, showing a negative response under the no-till system (Figure 6a). However, the other growth parameters were not influenced by the planting system. Despite the observed reduction in vegetative growth, this did not translate into lower productivity. Queiroz-

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Voltan, Nogueira and Miranda (2000) similarly reported that reductions in vegetative growth did not lead to a proportional decrease in yield.

Overall, the results indicate that different soil management systems did not affect soybean productivity. In agreement with these findings, Lima et al. (2006) observed no reduction in soybean yield under no-till, even when comparing different levels of soil compaction in Latossolo and Argissolo Vermelho soils.

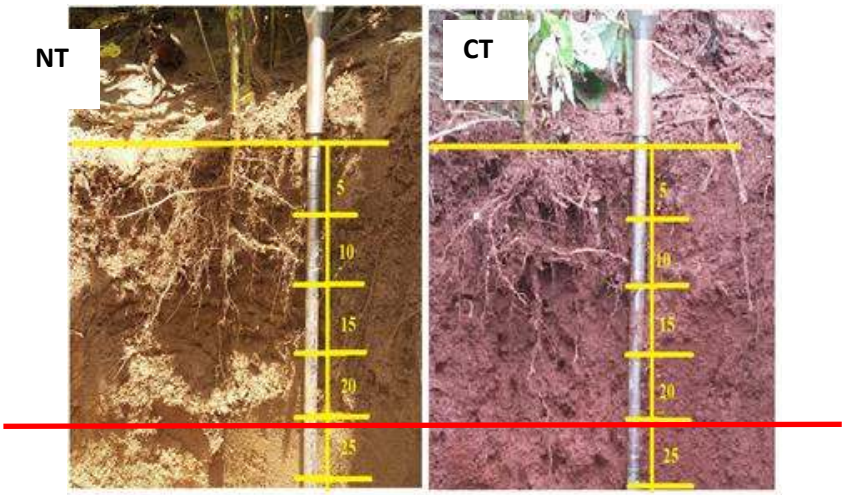
Reductions in soybean grain yield due to soil compaction have been reported in other studies and are likely associated with lower water availability, resulting from a reduced volume of exploitable soil when root growth is restricted (Calonego; Rosolem, 2010). Investigating soybean development under different planting systems, Moraes et al. (2020) observed higher productivity under the no-till system. In no-till, continuous pores formed by retained roots reduce resistance to root growth and provide effective pathways connecting the surface layer to deeper soil layers (Calonego; Rosolem, 2010), enhancing root depth and facilitating greater water and nutrient uptake (Jin *et al.,* 2013).

The effect of soil physical conditions on root growth under different planting systems is illustrated in Figure 7. Rooting depth is indicated by the lines shown. Analysis of the images depicting root system depth reveals that, in both planting systems, the majority of roots are concentrated in the top 15 cm of soil. Soil compaction can negatively influence root development, limiting the plant's ability to explore deeper soil layers.

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Figure 7. Root system depth (cm) of soybean plants observed in field trenches.



NT = no-till; CT = conventional tillage.

According to Yue *et al.* (2021), soil compaction can lead to changes in root characteristics. However, these authors did not observe significant differences in the root system growth of soybean plants, which is consistent with the results obtained in the present study. This outcome is likely related to the period of high water availability during soybean cultivation (Figure 2).

Jin *et al.* (2013) explain that if a compacted subsurface layer restricts root growth at depth, the development of the plant's aerial parts will depend primarily on the availability of water and nutrients in the upper soil layers.

Giarola *et al.* (2009) observed that, in a no-till system, compacted layers caused by traffic and the absence of soil disturbance were present in the 0-10 cm depth range, leading to a higher concentration of plant roots within this layer. Similarly, Foloni, Lima and Büll (2006) emphasized that, regardless of the compaction level in the soil, roots growing above the compacted layer accounted for 93% of the total root system, with minimal root growth occurring below 20 cm depth.

The soil physical attributes (bulk density, macroporosity, microporosity, and penetration resistance) were not significantly correlated with grain yield, number of nodes, or first pod insertion height (Table 1). Under the conditions of this study, these physical properties alone did not explain soybean growth characteristics. However, significant correlations were observed among the soil physical parameters

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themselves, specifically between bulk density and penetration resistance, as well as between macroporosity and microporosity.

Table 1. Pearson correlation coefficients between soil physical properties (penetration resistance, bulk density, macroporosity, and microporosity) and soybean growth characteristics (grain yield, plant height, number of nodes, and first pod insertion height).

	Penetration. Resistence	Bulk Density	Macropore	Micropore	Soybean yield	Plant height	Number of nodes	Height first Pod.
Penetration. Resistence	1							
Bulk Density	0.698*	1						
Macropore	-0.372^{ns}	0.163^{ns}	1					
Micropore	0.367^{ns}	-0.156^{ns}	-0.999**	1				
Soybean yield	0.060^{ns}	0.095^{ns}	0.249^{ns}	-0.258^{ns}	1			
Plant height	-0.166^{ns}	-0.557^{ns}	0.273^{ns}	-0.280^{ns}	-0.377^{ns}	1		
Number of nodes	-0.403^{ns}	-0.232^{ns}	0.410^{ns}	-0.408^{ns}	0.331^{ns}	0.1561^{ns}	1	
Height first Pod.	-0.329^{ns}	-0.278^{ns}	0.259*	-0.364^{ns}	0.304^{ns}	-0.119^{ns}	0.402^{ns}	1

* e ** indicam correlações significativas a 0,10 e 0,05 de probabilidade, respectivamente e ^{ns} não significativo.

Penetration resistance was positively and significantly correlated with soil bulk density. These results are consistent with those reported by Jabro *et al.* (2006) and Jabro *et al.* (2021), who also found significant positive correlations between penetration resistance and soil bulk density.

Regarding soil porosity, a strong negative correlation was observed, indicating that as one property increases, the other decreases. Reinert (2007) notes that in compacted soil layers, physical properties are altered compared to soils under natural conditions. During compaction, soil aggregates are broken, the clay matrix is compressed, total soil volume is reduced, and macropores collapse.

Although soil penetration resistance (PR) reached values above 3.0 Mpa exceeding the commonly cited critical threshold of 2.0 Mpa no significant reduction in soybean yield was observed. This resilience can be attributed to three synergistic factors. First, adequate nutrient supplementation through fertilization ensured high nutrient availability. Second, favorable rainfall distribution maintained soil moisture,

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reducing soil matrix suction and allowing roots to penetrate layers that would be impenetrable under drier conditions.

Finally, the presence of continuous bioporos (macropores) created by previous root systems and soil fauna likely provided low-resistance pathways for root elongation. These biological channels allow roots to bypass compacted zones, maintaining access to deeper soil layers even when the bulk soil matrix presents high mechanical resistance.

Tormena *et al.* (1999) reported that the limiting penetration resistance for root system development is 2 MPa, while Klein and Câmara (2007) suggested limiting values between 2 and 3 MPa. Additionally, Tormena, Fidalski and Rossi Junior (2008) found that in soils under long-term no-till management, the limiting value for plant development was 3.5 MPa.

Moreover, Drescher *et al.* (2012) observed that scarified areas exhibited lower penetration resistance for up to two and a half years. However, Batey (2009) notes that the duration of the effects of soil scarification remains uncertain.

The presence of compaction can also be inferred from visual symptoms in both plants and soil (Viana; Cruz; Alvarenga, 2009). As shown in Figure 6, no differences were observed in the rooting depth between the systems.

4. Conclusion

The area under no-till management exhibited a higher level of soil compaction compared to the conventionally cultivated area. However, the degree of compaction observed did not affect root system development or soybean productivity.

References

ANDRADE, R. S.; STONE, L. F. Índice S como indicador da qualidade física de solos. **Revista Brasileira de Engenharia Agrícola e Ambiental,** v. 13, n. 4, p. 382-388, 2009.

REMUNOM
ISSN 2178-6925

Received: 01/02/2026 - **Accepted:** 23/02/2026
Vol: 02.03
DOI: 10.66104/tnpbk659
Pages: 1-23

BEHRENDS KRAEMER, F. *et al.* Morpho-structural evaluation of various soils subjected to different use intensity under no-tillage. **Soil and Tillage Research**, v. 169, p. 124-137, 2017. https://doi.org/10.1016/j.still.2017.01.013

BENEVENUTE, P. A. N. *et al.* Penetration resistance: An effective indicator for monitoring soil compaction in pastures. **Ecological Indicators.** v. 117, p. 106647, 2020. https://doi.org/10.1016/j.ecolind.2020.106647.

BERTOL, I. *et al.* Propriedades físicas de um Cambissolo Húmico álico afetadas pelo tipo de manejo do solo. **Ciência Rural,** v. 30, p. 91- 95, 2000.

BLANCO-CANQUI, H.; RUIS, S. J. No-tillage and soil physical environment. **Geoderma,** v. 326, p. 164-200, 2018. https://doi.org/10.1016/j.geoderma.2018.03.011

BLUETT, C. *et al.* Soil research and soil preparation: why still focus on soil compaction. **Soil and Tillage Research,** v. 194, p. 104282, 2019. https://doi.org/10.1016/j.still.2019.05.028

CALONEGO, J. C.; ROSOLEM, C. A. Crescimento radicular e produtividade da soja em rotação com plantas de cobertura sob escarificação e plantio direto. **European Journal of Agronomy,** v. 33, n. 3, p. 242-249, 2010.

CAMARGO, O. A.; ALLEONI, L. R. F. Compactação do solo e o desenvolvimento das plantas. 1° ed. Piracicaba: Esalq. 1997. 132p.

CELIK, I. Effects of tillage methods on penetration resistance, bulk density and saturated hydraulic conductivity in a clayey soil conditions. **Journal of Agricultural Science,** v. 17. 143-156, 2011.

COMPANHIA NACIONAL DE ABASTECIMENTO (CONAB). **Portal de Informações Agropecuárias**: Produtos 360. Brasília, DF, 2025. Disponível em: https://portaldeinformacoes.conab.gov.br/produtos-360.html. Acesso em: 16 jan. 2026

CRUSCIOL, C. A. C. *et al*. Annual crop rotation of tropical pastures with no-till soil as affected by lime surface application. **European Journal of Agronomy,** v. 80, p. 88-104, 2016.

REMUNOM
ISSN 2178-6925

Received: 01/02/2026 - **Accepted:** 23/02/2026
Vol: 02.03
DOI: 10.66104/tnpbk659
Pages: 1-23

DANG, Y. P. *et al.* Strategic tillage in no-till farming systems in Australia's northern grains-growing regions: I. Drivers and implementation. **Soil and Tillage Research**, v. 152, p. 104-114, 2015. https://doi.org/10.1016/j.still.2015.03.009

DANIEL, D. F. *et al.* Agroclimatic Aptitude for Maize Crop In Regions of Mato Grosso State, Brazil. **Tropical and Subtropical Agroecosystems,** v. 24, n. 3, p. 1-15, 2021.

DE MOURA, M. S. *et al.* Soil management and diverse crop rotation can mitigate early-stage no-till compaction and improve least limiting water range in a Ferralsol. **Agricultural Water Manage,** v. 243, p. 106523, 2021. https://doi.org/10.1016/j.agwat.2020.106523

DONAGEMA, G. K. *et al.* **Manual de métodos de análise do solo**. Embrapa. 2011. 2. 29-54

DRESCHER, M. S. *et al.* Penetration resistance and soybean yield after mechanical intervention on an oxisol under tillage. **Revista Brasileira de Ciência do Solo,** v. 36, p. 1836-1844, 2012. https://doi.org/10.1590/S0100-06832012000600018.

ELTZ, F. L. F. *et al.* Resistência à penetração e rendimento da soja após intervenção mecânica em latossolo vermelho sob plantio direto. **Revista Brasileira de Ciência do Solo,** v. 36, p. 1836-1844, 2012. https://doi.org/10.1590/S0100-06832012000600018.

FOLONI, J. S. S., LIMA, S. L., BÜLL, L. T. Crescimento aéreo e radicular da soja e de plantas de cobertura em camadas compactadas de solo. **Revista Brasileira de Ciência do Solo,** v. 30. 49-57, 2006.

FREITAS, D. A. F. *et al*. Índices de qualidade do solo sob diferentes sistemas de uso e manejo florestal e cerrado nativo adjacente. **Revista Ciência Agronômica,** v. 43, n. 3, p. 417-428, 2012. https://doi.org/10.1590/S1806-66902012000300002

GAO, W. *et al*. Deep roots and soil structure. **Plant Cell Environment,** v. 39, p. 1662-1668, 2016. https://doi.org/10.1111/pce.12684

GIAROLA, N. F. B. *et al.* Cultivares de soja sob plantio direto em Latossolo Vermelho compactado. **Acta Scientiarum. Agronomy,** v. 31, n. 4, p. 2009. https://dx.doi.org/10.4025/actasciagron.v31i4.851.

REMUNOM
ISSN 2178-6925

Received: 01/02/2026 - **Accepted:** 23/02/2026
Vol: 02.03
DOI: 10.66104/tnpbk659
Pages: 1-23

HÚNGRIA, M.; NOGUEIRA, M. A. **Inoculação da cultura da soja: fatores que influenciam a eficiência da fixação biológica do nitrogênio**. Embrapa Soja, Documentos 406. Londrina: Embrapa Soja, 2021. Disponível em: https://www.embrapa.br/soja/busca-de-publicacoes/-/publicacao/1133639. Acesso em: 16 jan. 2026.

HUNKE, P. *et al.* Soil changes under different land-uses in the Cerrado of Mato Grosso, Brazil. **Geoderma Regional,** v. 4, p. 31-43, 2015.

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA (IBGE). **Regiões de Influência das Cidades 2018**. Rio de Janeiro: IBGE, 2020. Disponível em: <https://www.ibge.gov.br/geociencias/organizacao-do-territorio/redes-e-fluxos-geograficos/15798-regioes-de-influencia-das-cidades.html?=&t=acesso-ao-produto> Acesso em: 10 fev. 2026.

IDOWU, O. J. *et al.* Short-term conservation tillage effects on corn silage yield and soil quality in an irrigated, arid agroecosystem. **Agronomy,** v. 9, p. 455, 2019. https://doi.org/10.3390/agronomia9080455.

JABRO, J. D. *et al*. Soil cone index and bulk density of a sandy loam under no-till and conventional tillage in a corn-soybean rotation. **Soil and Tillage Research,** v. 206, p. 104842, 2021. https://doi.org/10.1016/j.still.2020.104842.

JABRO, J. D. *et al.* Effect of three tillage depths on sugarbeet response and soil penetrability resistance. **Agronomy Journal,** v. 107, n. 4, p. 1481-1488, 2015. https://doi.org/10.2134/agronj14.0561

JIN, K. *et al*. How do roots elongate in a structured soil? **Journal Experimental Botany,** v. 64, n. 15, p. 4761-4777, 2013. https://doi.org/10.1093/jxb/ert286

KELLER, T. *et al.* Historical increase in agricultural machinery weights enhanced soil stress levels and adversely affected soil functioning. **Soil and Tillage Research,** v. 194, p. 104293, 2019.

KIEHL, E. J. **Manual de Adafologia:** relações solo planta. Piracicaba - SP: Editora Agronômica Ceres LTDA,. 1979. 262p.

KLEIN, V. A.; CAMARA R. K. Rendimento da soja e intervalo hídrico ótimo em latossolo vermelho sob plantio direto escarificado. **Revista Brasileira de Ciência do Solo,** v. 31, p. 221-227, 2007.

REMUNOM
ISSN 2178-6925

Received: 01/02/2026 - **Accepted:** 23/02/2026
Vol: 02.03
DOI: 10.66104/tnpbk659
Pages: 1-23

KOGELBAUER, I. *et al*. Adaptation of soil physical measurement techniques for the delineation of mud and lakebed sediments at neusiedler see. **Sensors**, v. 13, p. 17067-17083, 2013. https://doi.org/10.3390/s131217067

LIMA, C. G. R. *et al.* Correlação linear e espacial entre a produtividade de forragem, a porosidade total e a densidade do solo de Pereira Barreto (SP). **Revista Brasileira de Ciência do solo,** v. 31, p. 1233-1244, 2007.

LIMA, C. L. R. *et al.* Qualidade físicohídrica e rendimento de soja (*Glycine max* L.) e feijão (*Phaseolus vulgaris* L.) de um Argissolo Vermelho distrófico sob diferentes sistemas de manejo. **Ciência Rural,** v. 36, n. 4, p. 1172-1178, 2006.

LOPES, E. S. *et al.* Compactação de um Solo Submetido ao Tráfego do Harvester e do Forwarder na Colheita de Madeira. **Revista Floresta e Ambiente,** v. 22, n. 2, p. 223-230, 2015.

LOSS, A. *et al.* Carbon, nitrogen and natural abundance of 13C and 15N in biogenic and physicogenic aggregates in a soil with 10 years of pig manure application. **Soil & Tillage Research,** v. 166, p. 52-58, 2017. https://doi.org/10.1016/j.still.2016.10.007

MONDAL, S.; CHAKRABORTY, D. Global meta-analysis suggests that no-tillage favourably changes soil structure and porosity. **Geoderma,** v. 405, p. 115443, 2022. https://doi.org/10.1016/j.geoderma.2021.115443.

MORAES, M. T. *et al.* Soil compaction impacts soybean root growth in an Oxisol from subtropical Brazil. **Soil and Tillage Research,** v. 200, p. 104611, 2020. 104611. https://doi.org/10.1016/j.still.2020.104611.

MORAES, M. T.; GUSMÃO, A. G. How do water, compaction and heat stresses affect soybean root elongation? A review. **Rhizosphere,** v. 19, p. 10040, 2021. https://doi.org/10.1016/j.rhisph.2021.100403.

MOREIRA, M. L. C.; VASCONCELOS, T. N. N. **Mato Grosso Solos e Paisagens**. Cuiabá. Entrelinhas, 2007. 238p.

NOSKOSKI, L. E. C. *et al.* Biocombustíveis no Brasil: uma revisão narrativa sobre a produção de etanol de cereais no Rio Grande do Sul. **Remunom,** v. 02, n. 1, p. 1-25, 2026. https://DOI:10.61164/5555zn48

REMUNOM
ISSN 2178-6925

Received: 01/02/2026 - **Accepted:** 23/02/2026
Vol: 02.03
DOI: 10.66104/tnpbk659
Pages: 1-23

PARENTE, H. N.; MAIA, M. O. Impacto do pastejo sobre a compactação dos solos com ênfase no Semiárido. **Revista Trópica**. v. 5, n. 3, p. 3-15, 2011. https://dx.doi.org/10.0000/rtcab.v5i3.272.

PEIXOTO, D. S. et al. Diagnosing, ameliorating, and monitoring soil compaction in no-till Brazilian soils. **Agrosystems, Geosciences & Environment**. v. 2, p. 1-14, 2019. https://doi.org/10.2134/age2018.09.0035

PERALTA, G.; ALVAREZ, C. R.; TABOADA, M. A. Soil compaction alleviation by deep non-inversion tillage and crop yield responses in no tilled soils of the Pampas region of Argentina. **Soil and Tillage Research,** v. 211, p. 105022, 2021. https://doi.org/10.1016/j.still.2021.105022.

QUEIROZ-VOLTAN, R. G.; NOGUEIRA, S. S. S.; MIRANDA, M. A. C. Aspectos da estrutura da raiz e do desenvolvimento de plantas de soja em solos compactados. **Pesquisa Agropecuária Brasileira,** v. 35, n. 5, p. 929-938, 2000.

RAMADHAN, M. N. Yield and yield components of maize and soil physical properties as affected by tillage practices and organic mulching. **Saudi Journal of Biological Sciences.** v. 28, n. 12, p. 7152-7159, 2021.

REICHERT, J. M. *et al*. Reference bulk density and critical degreeof-compactness for no-till crop production in subtropical highly weathered soils. **Soil and Tillage Research,** v. 102, n. 2, p. 242-254, 2009. https://doi.org/10.1016/j.still.2008.07.002.

SANCHEZ, E., **Propriedades físicas do solo e produtividade de soja em sucessão a plantas de cobertura de inverno**. 2012. Dissertação (Mestrado em Agronomia) - Universidade Estadual do Centro-Oeste, Guarapuava. 2012.

SAS, II. **Guia Empresarial SAS**. 2013

SARAIVA, C. R. C. et al. Considerações no Uso de Reguladores de Crescimento para Aumento da Produtividade e Qualidade de Sementes de Soja. **Revista de Gestão e Secretariado,** v. 17, n. 2, p. 01-21, 2026.

SASAL, M. C. Platy structure development under no-tillage in the northern humid Pampas of Argentina and its impact on runoff. **Soil and Tillage Research,** v. 173, p. 33-41, 2017. https://doi.org/10.1016/j.still.2016.08.014

SCHJØNNING, P. *et al.* Driver-Pressure-State-Impact-Response (DPSIR) Analysis and Risk Assessment for Soil Compaction-A European Perspective. **Advances in Agronomy,** v. 133, 183-237, 2015.

REMUNOM
ISSN 2178-6925

Received: 01/02/2026 - **Accepted:** 23/02/2026
Vol: 02.03
DOI: 10.66104/tnpbk659
Pages: 1-23

SIVARAJAN, S. *et al*. Impact of soil compaction due to wheel traffic on corn and soybean growth, development and yield. **Soil and Tillage Research,** v. 175, p. 234-243, 2018. https://doi.org/10.1016/j.still.2017.09.001.

SOUZA, A. P. *et al.* Climate classification and climatic water balance in Mato Grosso State, Brazil. **Nativa,** v. 1, n. 1, p. 34-43, 2013. https://dx.doi.org/10.14583/2318-7670.v01n01a07.

STOLF, R. *et al.* Penetrômetro de impacto Stolf - programa computacional de dados em EXCEL-VBA. **Revista Brasileira de Ciência do Solo,** v. 38, n. 3, p. 774-782, 2014. https://doi.org/10.1590/S0100-06832014000300009

TORMENA, C. A.; FIDALSKI, J.; ROSSI JUNIOR, W. Resistência tênsil e friabilidade de um latossolo sob diferentes sistemas de uso. **Revista Brasileira de Ciência do Solo.** v. 32, n. 1, p. 33-42, 2008.

UNITED STATES DEPARTMENT OF AGRICULTURE (USDA). **Grain**: World Markets and Trade, 2021. Disponível em: https://www.fas.usda.gov/data/oilseeds-world-markets-and-trade. Acesso em: 07 fev. 2026.

VIANA, J. H. M.; CRUZ, J. C.; ALVARENGA, R. C. **Cultivo do Milho.** Embrapa - 5 ª ed. 2009. Disponível em <http://www.cnpms.embrapa.br/publicacoes/milho_5_ed/manpreparo.htm>.

WU, G. Effects of long-term no-tillage with different residue application rates on soil nitrogen cycling. **Soil and Tillage Research,** v. 212, p. 105044, 2021. https://doi.org/10.1016/j.still.2021.105044.

YUE, L. *et al.* Impacts of soil compaction and historical soybean variety growth on soil macropore structure. **Soil and Tillage Research,** v. 214, p. 105166, 2021. https://doi.org/10.1016/j.still.2021.105166.