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Influence of liquid swine slurry on soil quality and water infiltration

Influência dos dejetos líquidos suínos na qualidade do solo e na infiltração de água

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ABSTRACT

Liquid swine slurry (LSS) can improve soil quality when applied to agricultural areas. However, when applied indiscriminately, it can cause contamination of soil and water resources. In this context, this study aimed to evaluate the effects on chemical, physical, and water attributes of the soil, resulting from the application of LSS, as well as on water infiltration. In this research, two areas were evaluated, namely: area 1 (treatment 1), where LSS is not applied; and area 2 (treatment 2), with LSS applied to the soil for a period of three years, twice a year. For the physical characterization of the soil, data on moisture, particle density, soil density, and total porosity were analyzed. For the chemical characterization of the soil, analyses were performed for potential hydrogen (pH), organic matter, aluminum hydride (H+Al), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sodium (Na), sum of bases (SB), cation exchange capacity (CEC), and base saturation (V%). A double-ring infiltrometer was employed in order to determine water infiltration into the soil. Treatment 2 showed a higher average water infiltration velocity, in addition to higher levels of organic matter, moisture, and K. However, this treatment resulted in a more acidic soil, with a lower pH and a higher value of H+Al when compared to treatment 1. Significant statistical differences were found between the two treatments for pH, H+Al, K, SB, V, Mg, and organic matter. It can be concluded that the application of LSS in the soil contributes to improving soil quality.

Keywords: chemical attributes; organic matter; water resources; agriculture.

RESUMO

Os dejetos líquidos suínos (DLS) podem melhorar a qualidade do solo quando aplicados em áreas de agricultura. No entanto, quando aplicados indiscriminadamente, podem causar contaminação do solo e dos recursos hídricos. Neste contexto, o presente estudo teve como objetivo avaliar os efeitos nos atributos químicos, físicos e hídricos do solo, decorrentes da aplicação de DLS, assim como na infiltração de água. Nesta pesquisa, foram avaliadas duas áreas, nomeadamente: área 1 (tratamento 1), onde não ocorre a aplicação de DLS; e área 2 (tratamento 2), com aplicação de DLS no solo no período de três anos, duas vezes por ano. Para a caracterização física do solo, foram analisados os dados de umidade, densidade de partículas, densidade do solo e porosidade total. Para a caracterização química do solo, foram efetuadas análises de potencial de hidrogênio (pH), matéria orgânica, hidreto de alumínio (H+Al), fósforo (P), potássio (K), cálcio (Ca), magnésio (Mg), sódio (Na), soma das bases (SB), capacidade de troca catiônica (CTC) e saturação de base (V%). Um infiltrômetro de duplo anel foi utilizado para determinar a infiltração de água no solo. O tratamento 2 apresentou maior média de velocidade de infiltração de água, além de maiores teores de matéria orgânica, umidade e K. No entanto, esse tratamento resultou em um solo mais ácido, com um pH mais baixo e um valor maior de H+Al quando comparado ao tratamento 1. Foram encontradas diferenças estatísticas significativas entre os dois tratamentos para pH, H+Al, K, SB, V, Mg e matéria orgânica. Pode-se concluir que a aplicação de DLS no solo contribui na melhoria da qualidade do solo.

Palavras-chave: atributos químicos; matéria orgânica; recursos hídricos; agricultura.

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Introduction

Pork is one of the most widely consumed sources of protein in Brazil and globally, with a significant increase in pig slaughter observed in recent years (ABCS, 2023). This growing demand has led to an expansion in pig farming, consequently increasing the generation of swine slurry. When improperly managed or disposed of without adequate treatment, it can pose serious environmental risks, including water pollution, soil contamination, and the proliferation of disease vectors.

In this context, the application of liquid swine slurry (LSS) to the soil can be an effective strategy for the disposal of this residue, allowing its use as a substitute for, or in combination with, chemical fertilizers. When applied to agricultural areas, LSS can improve soil structure, increase organic matter content, and enhance nutrient availability, thereby promoting plant development. As a result, it helps prevent the improper disposal of this residue and mitigates several environmental problems.

In addition to the increasing generation of swine slurry, another challenge faced in Brazil relates to fertilizers. The country is the fourth largest consumer of fertilizers in the world, with 70% of its supply being imported, which makes it dependent on producing countries (Barros et al., 2019). Beginning in 2020, with the onset of the COVID-19 pandemic, and again in 2022 due to the war between Ukraine and Russia, the production and transportation of agricultural fertilizers faced significant disruptions, highlighting the need to seek alternative nutrient sources for crop cultivation (Chojnacka et al., 2023).

Swine slurry provides organic matter that improves the physical properties of the soil, contributing to increased water infiltration and enhanced soil quality (Almeida Júnior et al., 2020; Wang et al., 2023).

Assessing soil attributes in areas where LSS is applied is essential to prevent issues such as nutrient accumulation and erosion processes, since soils with a high degree of compaction tend to exhibit increased surface water runoff, contributing to soil and nutrient losses in agricultural areas. According to Martínez-Mena et al. (2020), understanding the mechanisms of soil degradation is crucial for maintaining soil quality, especially in soils with low organic matter content and high susceptibility to deterioration.

Infiltration is one key process of the water cycle, directly influencing soil water retention, groundwater recharge, and surface runoff. For this reason, evaluating water infiltration into the soil is crucial for implementing mitigation strategies related to surface runoff (Tang et al., 2022). It is important to note that areas with low infiltration rates can lead to issues such as erosion, river siltation due to sediment deposition, flood-related damages, reduced agricultural productivity, and decreased groundwater availability (Ilha et al., 2019; Pachepsky and Karahan, 2022).

Infiltration can be affected by various soil attributes, including bulk density, moisture content, texture, and total porosity. Therefore, assessing these parameters in conjunction with the infiltration rate is essential for a more comprehensive understanding of the process.

Based on this, the present study aimed to evaluate the effects of LSS application on the chemical and physical attributes of the soil, as well as on water infiltration.

Materials and method

Study area and experimental conditions

The study area is located in the rural region of the municipality of Prudentópolis (Figure 1), district of Jesuíno Marcondes, Paraná state, Brazil, approximately 19 km from the urban area, under the geographic coordinates 25°18’50” South latitude and 51º00’54” West longitude.

In order to evaluate the influence of liquid swine waste on the physical, chemical, and hydrological properties of the soil, agricultural areas with the same management practices in terms of crop cultivation and soil preparation were identified, differing only by the incorporation of swine waste into the environment.

According to the Köppen climate classification, the study area is characterized as Cfb, corresponding to a humid subtropical climate with mild summers and up to five nighttime frosts annually, and no distinct dry season. Mean temperatures during the warmest months average 22°C, while those in the cooler months remain below 18°C. The mean annual precipitation over the last thirty years is 1,772 mm (Maack, 1981; IAT, 2024).

The soil in the study area is classified as alumic brown Nitisol, characterized as a shrink-swell soil with a humic A horizon. The upper portion of the B horizon exhibits a brownish to yellowish coloration and displays significant aluminic properties within the first 100 cm (Embrapa, 2018; Geoinfo, 2024).

The study was conducted on a single property comprising two distinct areas. Area 1 covers 12,500 m^2, where no waste was applied and no irrigation was employed. Area 2 encompasses 40,300 m^2, where LSS was applied via sprinklers every six months, from 2021 to 2024. The sprinklers were used exclusively for the application of LSS.

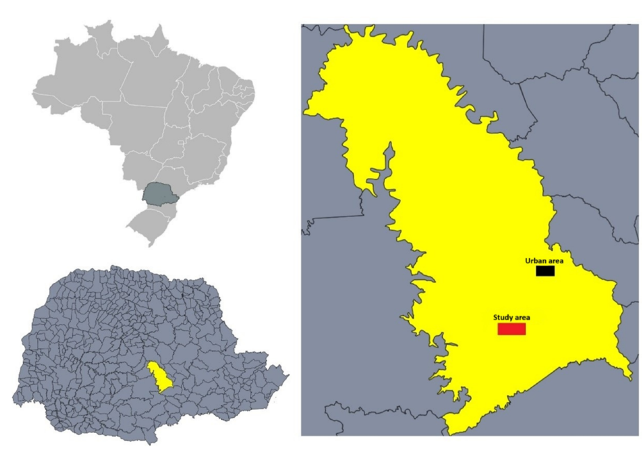

Figure 1 – Location of the municipality of Prudentópolis, Paraná, Brazil.

In each experimental area, plots measuring 100 m^2 (10 × 10 m) were delineated for soil sampling aimed at physicochemical characterization and water infiltration testing. Sampling and tests were conducted in the midslope position of the experimental areas in March 2024.

Determination of soil physical attributes

Soil samples were collected at three distinct points and depths of 0–10 cm, 10–20 cm, and 20–30 cm. Sampling was performed manually and after soil removal; samples were immediately placed in plastic bags to preserve their original moisture conditions. The samples were then transported to the laboratories of the Department of Environmental Engineering and the Department of Geography at Unicentro – Irati-PR Campus. Analyses were conducted to determine moisture content, bulk density, particle density, and total porosity. All procedures followed the protocols outlined in the Manual of Methods for Soil Analysis by Embrapa (Embrapa, 2017).

Determination of soil chemical attributes

Soil samples from the surface layer (0–10 cm) were collected at three different points within each study area. The analyses were performed by the Department of Forestry Science, Soils, and Environment at São Paulo State University (UNESP) – Botucatu-SP Campus. The following soil parameters were analyzed: potential hydrogen (pH), aluminum hydride (H^{+}+Al^{3+}), phosphorus (P), potassium (K^{+}), calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), sum of bases (SB), cation exchange capacity (CEC), and base saturation (V%). These analyses followed the methodology proposed by Raij et al. (2001).

Soil organic matter was determined in the laboratories of the Department of Environmental Engineering and the Department of Geography at Unicentro – Irati-PR Campus, using the methodology described in the Manual of Methods for Soil Analysis by Embrapa (Embrapa, 2017). For this parameter, samples were collected at three different points in each experimental area, at depths of 0–10 cm, 10–20 cm, and 20–30 cm.

Determination of water infiltration in the soil

The double-ring infiltrometer technique was used to analyze the behavior of water infiltration into the soil, employing the flooding methodology adapted from Bernardo et al. (2006) and Garcez and Alvarez (1988).

Three double-ring infiltrometer sets were used, each placed at three distinct points within the study areas. To avoid interference from prior soil moisture conditions, infiltration tests were conducted on the same day for each experimental area.

Each set consisted of two concentric metal rings: an outer ring with a diameter of 20 cm and an inner ring with a diameter of 10 cm, both 25 cm in height, driven into the soil to a depth of 15 cm. Above the rings, a water reservoir composed of a 51 cm-high PVC pipe with a 10 cm diameter, supported by a metal frame, was installed to maintain a constant water supply during the test.

The infiltration tests began by simultaneously filling both rings with water, maintaining a 7 cm water depth above the soil surface. A tolerance of up to 2 cm for water level decrease was allowed, with water replenished as needed to maintain the layer.

Statistical analysis

For the analyses, area 1 was designated as treatment 1 (T1) and area 2 as treatment 2 (T2). Statistical analyses were performed using R software and Statistica version 7 (R Core Team, 2023).

The comparison of soil attributes, determined from samples collected at different depths, was carried out using a heat map, highlighting the differences between treatments. The heat map included data from all soil layers. For the comparative analysis of soil chemical attributes between treatments, a t-test was performed at a 5% significance level.

Principal component analysis was performed to evaluate the influence of soil attributes on water infiltration rate, using data from both treatments.

Results and discussion

Soil physicochemical attributes

The results of the analyses of soil organic matter, moisture, density, and total porosity in the 0–10 cm, 10–20 cm, and 20–30 cm layers under T1 and T2 are presented in Figure 2.

The soil with LSS application (T2) exhibited higher organic matter content at all three depths compared to the area without LSS application (T1). T2 showed an organic matter content of 112 $g \cdot kg^{-1}$ in the topsoil layer, whereas T1 showed 78 $g \cdot kg^{-1}$. Barilli (2005) evaluated areas with pig manure applications over 3, 7, and 26 years in red Latosol and reported that LSS application increased soil organic matter. Similarly, Antoneli et al. (2019) assessed LSS application periods of 1, 3, 5, 7, 10, and 15 years in Cambisol and observed an increase in organic matter.

Li et al. (2024) investigated the impact of swine manure application on soil properties and reported that this residue also contributed to an improvement in soil organic matter content.

Lourenzi et al. (2014), studying the application of different rates of LSS in Argisol, found that LSS increased soil organic matter levels, with the highest application rate (80 m^3 ha^{-1}) resulting in a 98% growth in organic matter. Similar results were reported by Stalbert et al. (2023), who found an increase in organic matter across eight treatments involving different LSS application rates.

On the other hand, according to Bettiol et al. (2023), soils with lower organic matter content may exhibit reduced total porosity, water infiltration, pH, and CEC, along with decreased nutrient availability.

Regarding soil moisture, T2 showed higher levels than T1, with a gradual improvement presented as soil depth increased. This behavior may be associated with organic matter introduced through LSS, as organic matter has a high-water retention capacity and can enhance water availability during drought periods (Bettiol et al., 2023).

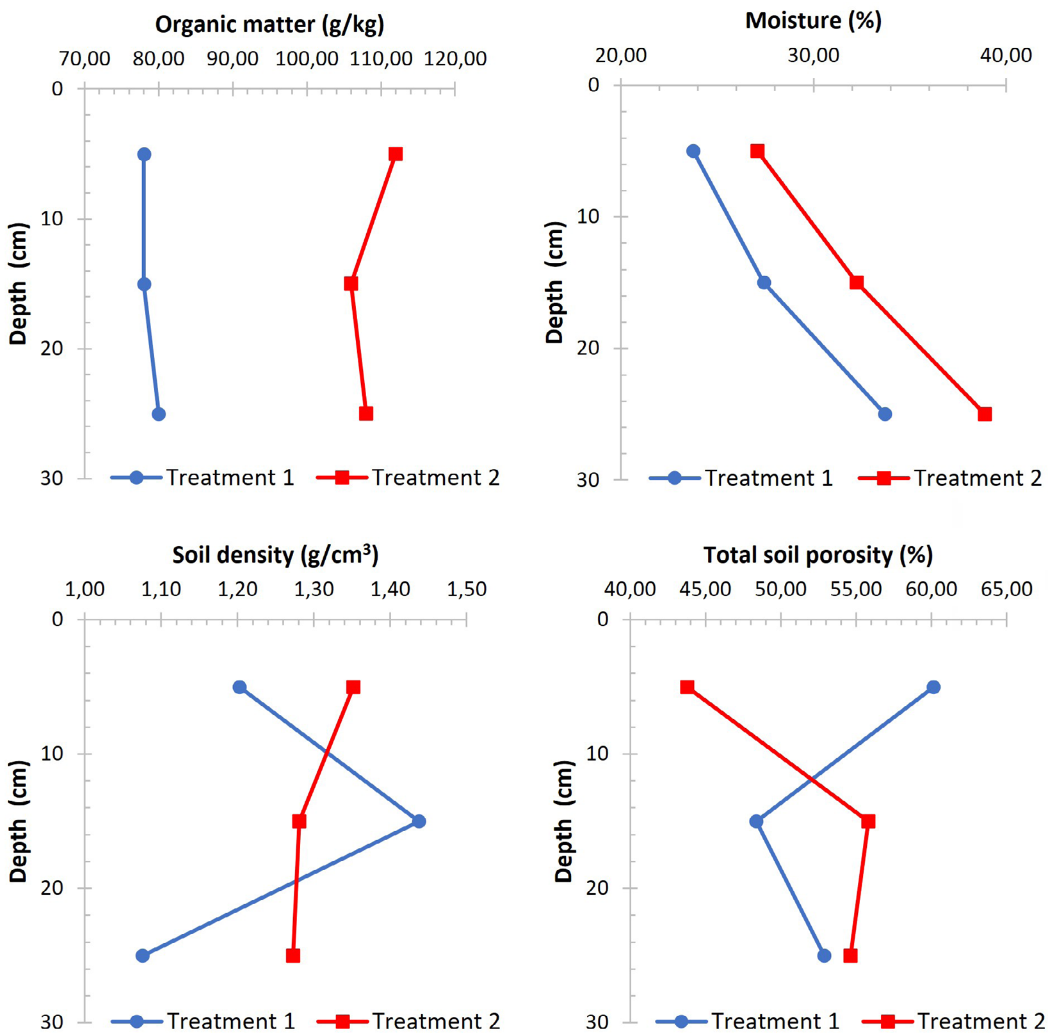

Figure 2 – Mean values of soil organic matter content, moisture, bulk density, and total porosity.

Krajeski and Povaluk (2014) stated that organic fertilizers promote soil moisture. In contrast, Matsuoka et al. (2019) evaluated soil characteristics in areas subjected to LSS applications for 3 and 7 years in Nitisol, and found that LSS had no significant effect on soil moisture.

Regarding soil bulk density, T2 exhibited higher values at 0–10 cm and 20–30 cm depths (Figure 2). Additionally, for this treatment, a decreasing trend in bulk density was identified with increasing soil depth, with values of 1.35, 1.28, and 1.27 g cm^{-3} for the 0–10 cm, 10–20 cm, and 20–30 cm layers, respectively. Similar results were reported by Yu et al. (2020) in ferralic Cambisol, where the soil that had received pig slurry applications for 23 years showed higher bulk density compared to soils under other treatments, such as control, pig slurry+NPK, and nitrogen-phosphorus-potassium (NPK) alone.

On the contrary, Barilli (2005) demonstrated that areas receiving LSS over a longer period (26 years) exhibited lower soil bulk density. Corrêa et al. (2011) reported that this reduction in density can be attributed to the high levels of soil organic matter, as organic matter has a lower density than mineral particles. This difference influences aggregate stability, indicating that soils with higher organic matter content tend to exhibit lower bulk density.

Suzuki et al. (2022) related that soils with lower bulk density are more susceptible to compaction caused by the pressure of agricultural machinery or animals. In contrast, soils with moderate compaction levels tend to exhibit improved structure, which benefits plant development and overall ecosystem function. Conversely, highly compacted soils hinder water infiltration, resulting in surface runoff and, consequently, increasing the risk of erosion.

When analyzing the results for total soil porosity, an inverse behavior compared to bulk density was observed, which was expected, as soil porosity is inversely proportional to density (Gondim et al., 2015). In the first layer, T1 exhibited the highest value (60.16%), with a decrease as depth increased. In contrast, in the area where LSS was applied, the opposite trend was noted: the 0–10 cm layer showed the lowest total porosity value, at 43.79%.

In the other two layers of T2, total soil porosity increased, reaching values of 55.80% (10–20 cm) and 54.64% (20–30 cm). According to Kumar et al. (2020), soils with high organic matter content promote soil fauna, where organisms such as earthworms increase pore space. Additionally, root decay also contributes to the enhancement of total soil porosity.

Pagliai et al. (1983) reported an increase in total porosity following the application of 300 m^3 ha^{-1} of pig manure in silty clay soil. Conversely, Matsuoka et al. (2019) evaluated the application of LSS in Nitisol and found that LSS did not affect total soil porosity. Similar results were reported by Arruda et al. (2010), who assessed three doses of pig LSS applied to Oxisol and identified no significant differences in total soil porosity among treatments and soil layers.

A more refined comparative assessment was carried out using a heat map based on field-collected data. The heat map is a statistical tool that enables the evaluation of a dataset through variations in color intensity, indicating differences between the treatments analyzed. The legend reflects the color gradient based on the values, with red representing higher values and blue indicating lower values.

Figure 3 presents the heat map results for soil organic matter, bulk density, total porosity, and moisture under T1 and T2.

The analysis shows that soil organic matter stood out as the variable with the most significant difference between treatments, with the area receiving LSS application (T2) presenting the highest value. Regarding soil bulk density, no significant differences were observed. However, slight differences were noted for total soil porosity and moisture.

Regarding the soil's chemical attributes, Table 1 presents the t-test results for the mean values of pH, P, Ca, Mg, K, Na, H+Al, CEC, SB, and V%.

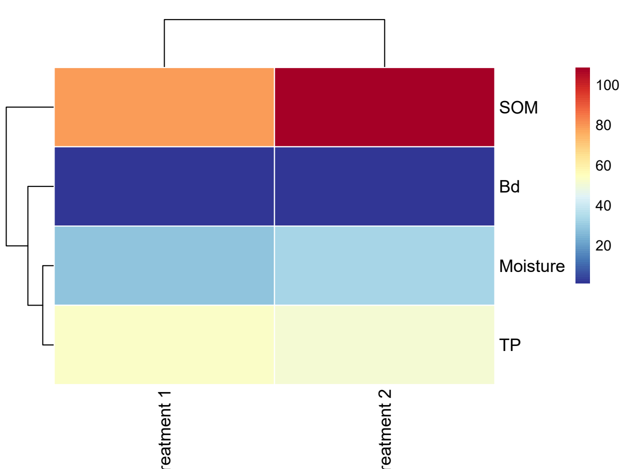

Figure 3 – Heat map of soil physical attributes.
SOM: soil organic matter; Bd: bulk density; Tp: total porosity.

The comparison between T1 and T2 (Table 1) reveals significant differences in the mean values of pH, Mg, K, H^++Al^{3+}, SB, and V% ($p<0.05$), with K showing the highest mean in T2. Although no significant difference was found for P between the treatments, it is noteworthy that the use of LSS nearly doubled the soil P content compared to the area without residue application.

Silva et al. (2024) also observed higher P and K levels as LSS doses increased when applying different amounts. Similarly, a study conducted by Rebonatti et al. (2023) showed that the increase in soil P and K contributed to improved soybean productivity.

According to Silva et al. (2024), the frequent application of LSS to the soil can lead to increased P levels. Therefore, it is essential to maintain adequate concentrations of this nutrient, as excessive amounts can result in runoff, carrying large quantities of P into water bodies. Johnston et al. (2014) stated that although P is vital for life on Earth, when presented in excessive amounts, it can lead to the eutrophication of water resources, thereby harming aquatic ecosystems.

Grando et al. (2021) analyzed P losses through surface runoff in Nitisol soils with LSS and found that while LSS application reduced sediment losses, it continuously increased P losses. This may be explained by the solubilization of P in water, allowing it to be transported, especially considering that LSS had no significant influence on water loss.

Regarding the values of pH, SB, and V%, T1 exhibited higher average values, whereas T2 showed increased CEC and H+Al (Table 1). The area receiving LSS application had more acidic soil compared to T1, characterized by a lower pH (5.0) and higher H+Al content. Similarly, Matsuoka et al. (2019) reported that treatments involving LSS application resulted in lower soil pH and increased aluminum (Al) presence.

Table 1 – T-test results for the mean values of soil chemical attributes under both treatments.

Parameters	Units	Treatment 1	Treatment 2
pH ($CaCl_2$)	----	5.5a	5.0b
P	mg dm^{-3}	40.3a	86.9a
H+Al	$mmol_c$ dm^{-3}	31.9b	62.8a
K	$mmol_c$ dm^{-3}	2.3b	7.9a
SB	$mmol_c$ dm^{-3}	104.8a	79.5b
CEC	$mmol_c$ dm^{-3}	136.7a	142.3a
V	(%)	76.6a	55.9b
Na	$mmol_c$ dm^{-3}	0.5a	0.7a
Ca	$mmol_c$ dm^{-3}	68.3a	51.8a
Mg	$mmol_c$ dm^{-3}	34.3a	19.8b

*Means followed by the same letter in the row do not differ significantly by the t-test at the 5% probability level ($p<0.05$); pH: potential hydrogen; $CaCl_2$: calcium chloride; P: phosphorus; H+Al: aluminum hydride; K: potassium; SB: sum of bases; CEC: cation exchange capacity; V: base saturation; Na: sodium; Ca: calcium; Mg: magnesium.

According to Smanhotto et al. (2013), soil acidity (indicated by H+Al), may rise due to microbial mineralization of organic matter. Furthermore, Dornelles et al. (2017) demonstrated that different doses of LSS contribute to enhanced microbial activity in the soil.

Scherer et al. (2007) applied LSS for four years in an area in Chapecó city and for three years in Guatambu city, state of Santa Catarina, with application rates of 460 m^3 ha^{-1} and 345 m^3 ha^{-1}, respectively. Their results showed a decrease in soil pH and an increase in potential acidity in Guatambu, whereas in Chapecó, there was an increase in pH and a decrease in potential acidity up to the 20 cm soil layer.

Barilli (2005) reported that areas receiving LSS application exhibited increases in CEC, organic matter, and P, consistent with the findings of this study. However, Barilli also identified increases in SB, V%, pH, Mg, and Ca, which differ from the results found for T2 in the present study.

Antoneli et al. (2019) conducted a research in areas with LSS application over different time periods (0, 1, 3, 5, 7, 10, and 15 years). The authors found, over the years, increases in K, Ca, Mg, and soil porosity, along with decreases in soil bulk density at depths of 0–10 cm, 10–20 cm, and 20–30 cm.

As shown in Table 1, T2 exhibited higher Na content, whereas Ca and Mg levels were lower in the area without LSS application. These findings contrast with those reported by Cui et al. (2023), who evaluated five different treatments, including one with pig manure application and two others combining manure with varying N doses. The authors concluded that the three manure treatments resulted in higher Ca concentrations and lower Na levels compared to both the unfertilized control and the mineral fertilizer (NPK) treatments.

Almeida Júnior et al. (2020) reported that, in the 0–20 cm soil layer of an area without pig manure application, the concentrations of Na, Ca, and Mg were 8.00, 2.34, and 0.22 cmolc dm^{-3}, respectively. In contrast, in the area with pig manure application, the Na content remained similar to that of the area without residue application, while Ca content increased to 3.38 cmolc dm^{-3} and Mg showed a comparable increase, reaching 0.33 cmolc dm^{-3}. Silva et al. (2024) noticed an increase in soil Na concentration following the application of different doses of LSS.

Infiltration rate assessment

Figure 4 shows the infiltration rate (mm h^{-1}) measured in the field using the double-ring infiltrometer method for both treatments.

In T1, the initial infiltration rate was 300 mm h^{-1}, which can be attributed to high porosity and low bulk density in the topsoil layer (0–10 cm). As bulk density increased and porosity decreased in the 0–20 cm layer, the infiltration rate also declined, reaching 160 mm h^{-1}. In contrast, in T2, the infiltration rate increased after the first two time intervals, likely due to reduced bulk density and increased porosity in the 0–20 cm soil layer. Porosity plays a key role in both water infiltration and retention. Compacted soils exhibit high bulk density, which alters both the volume and spatial arrangement of soil pores (Bittelli et al., 2021). As outlined by Basset et al. (2023), soils with high porosity tend to enhance water infiltration.

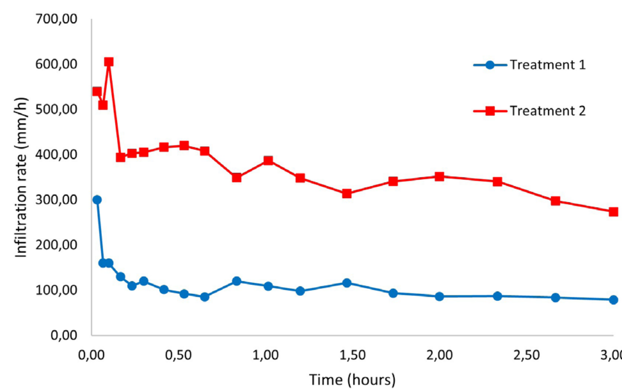

Figure 4 – Mean water infiltration rates in the evaluated areas.

Another factor that may have contributed to the higher infiltration rate observed in T2 is the greater sand content compared to T1. As reported by Mellek et al. (2014), soils with higher sand content facilitate water movement, thereby enhancing infiltration. Bettiol et al. (2023) also reported that soils with higher organic matter content promote increased water infiltration. Thus, while the application of LSS may positively influence soil water infiltration rates, other factors also play a significant role.

Wang et al. (2023), in correlating infiltration measured using the double-ring infiltrometer with soil properties, encountered that soil texture has a direct effect on infiltration. In addition to influencing plant root development, other parameters such as porosity and organic matter content were also found to significantly impact infiltration behavior.

In both treatments, as the test duration increased, the infiltration rate decreased. This behavior can be attributed to soil saturation and the rise in moisture content as depth increased in both treatments. Liu et al. (2019) also reported that soil moisture significantly affects infiltration rates, particularly during the initial stages of the infiltration process.

T2 exhibited a higher infiltration rate than T1 throughout the entire field test. Similar results were reported by Almeida Júnior et al. (2020), who evaluated soil water infiltration using a double-ring infiltrometer and found that soils receiving swine manure applications had greater infiltration rates than those without manure. As stated by the authors, long-term manure applications can enhance infiltration capacity.

In a study conducted by Mellek et al. (2010), which assessed infiltration rates in soils treated with liquid dairy manure over a two-year period, the results also indicated increased infiltration in manure-amended soils. This increase in infiltration can potentially reduce surface runoff, thereby minimizing soil and nutrient losses.

Cherobim et al. (2015) also evaluated the infiltration rate using a double-ring infiltrometer in soils treated with liquid dairy waste and verified that higher waste application rates resulted in lower infiltration rates. Furthermore, the most pronounced effects of the waste occured within the first few days following application. Therefore, the authors recommend applying the waste at least five days prior to heavy rainfall to reduce runoff and prevent potential environmental impacts.

The effects of LSS application on water infiltration into the soil can vary depending on factors such as soil type, climate conditions, and management practices. Thus, appropriate management and application strategies are essential to ensure the intended agronomic and environmental benefits.

Figure 5 presents the principal component analysis (PCA) performed for T1 and T2. The following variables were evaluated: soil density, total porosity, soil organic matter, moisture, and initial infiltration rate measured in the field. For the infiltration parameter, only data from the first ten minutes of the field infiltration test were considered.

PCA 1 explains 51.1% of the data variance. Variables that showed a positive correlation with this component included soil organic matter, actual initial infiltration rate, and soil moisture.

PCA 2 accounts for 31% of the data variability. Total porosity was positively correlated, while soil density showed a negative correlation, indicating that as density increases, porosity decreases, and vice versa.

It can be observed that soil organic matter and initial infiltration rate exhibit vectors that are close and oriented in the same direction, indicating a strong relationship between these variables. Therefore, it can be concluded that soil organic matter is the variable that most influences the initial water infiltration rate in the soil.

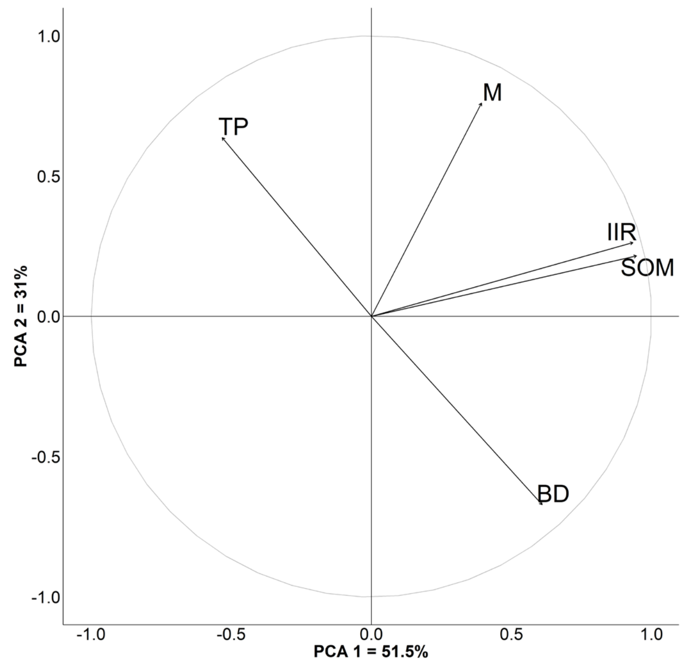

Figure 5 – Principal component analysis.
PCA: principal component analysis; BD: bulk density; TP: total porosity; M: moisture; IIR: initial infiltration rate; SOM: soil organic matter.

Conclusion

The area where LSS was applied showed a higher K content compared to the area without residue application, along with increased H+Al levels and a decrease in pH, resulting in greater soil acidity. The application of liquid swine manure may have contributed to the increase in the infiltration rate measured in the field, as well as significantly increasing the soil organic matter. Among the variables analyzed, soil organic matter had the greatest influence on the initial infiltration rate determined by using the double-ring infiltrometer.

Based on these results, we can conclude that the application of LSS to the soil can contribute to improving soil quality, making its use in agriculture a suitable destination for this residue. However, further studies are necessary to assess, over time, whether the waste continues to enhance soil quality and to investigate the potential occurrence of any negative impacts.

Authors' Contributions

Florentino, R.W.: conceptualization, data curation, formal analysis, investigation, methodology, project administration, writing – original draft, writing – review & editing. **Kummer**, A.C.B.: formal analysis, methodology, project administration, supervision, validation, visualization, writing – review & editing. **Bednarz**, J.A.: formal analysis, methodology, visualization, writing – review & editing. **Martins**, K.G.: data curation, formal analysis, methodology, writing – review & editing.

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