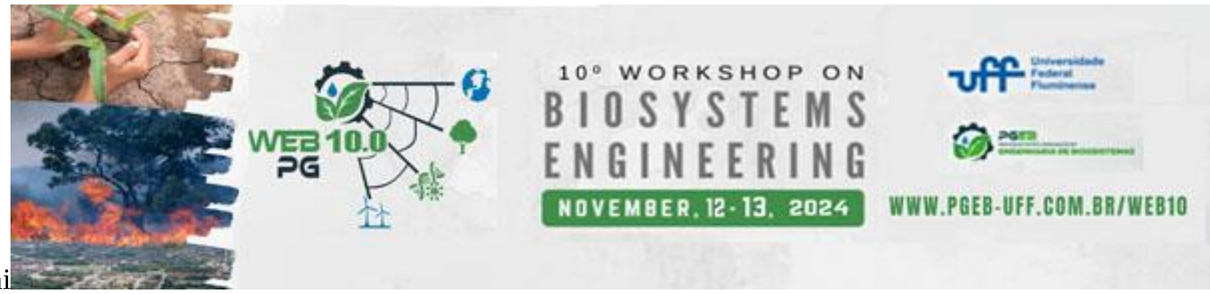

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HYDRAULIC CONDUCTIVITY IN SANDY SOILS OF THE BRAZILIAN AGRICULTURAL FRONTIER

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Abstract

This study investigated the relationship between saturated hydraulic conductivity (SSIR) and soil physical attributes in 494 samples of sandy soils (total sand > 50% and clay < 20%) from the Brazilian agricultural frontier, using data from the "KSAT-SSIR-DB-2024.xlsx" database. The samples, originating from 49 municipalities, were classified into three textural classes ("very fine sandy loam," "loamy fine sand," and "sand"). SSIR measurement methods were categorized as "Guelph permeameter," "missing" (unreported), and "other." Pearson correlations were analyzed between SSIR and clay content, total sand, bulk density, and total porosity for each combination of textural class and measurement method. Results showed inconsistent correlations when the measurement method was unreported ("missing"). For the Guelph permeameter method, only the "sand" textural class had sufficient samples, exhibiting a strong positive correlation between SSIR and total sand (0.997) and a negative correlation with clay (-0.92). Total porosity emerged as an important variable, showing positive correlations with SSIR, especially in the "loamy fine sand" class for the "missing" method and in both "loamy fine sand" and "sand" classes for the "other" methods. Bulk density showed inconsistent relationships with SSIR. The limited sample size for some method-texture combinations highlights the need for more data in future analyses.

Keywords: Saturated hydraulic conductivity, SSIR, sandy soils, agricultural frontier, PTF, erosion, soil texture, porosity, bulk density.

INTRODUCTION

Soil erosion, resulting from surface water movement, is one of the main challenges faced by farmers and land managers (Martins et al., 2019).

Saturated hydraulic conductivity (SHC) is a crucial parameter for understanding water movement in soil, influencing hydrological processes and water availability for plants (Schroeder et al., 2019). This study analyzes the relationship between SHC and soil physical attributes in sandy soils of the Brazilian agricultural frontier. Data were obtained from the compiled database "KSAT-SSIR-DB-2024.xlsx" (Ottoni et al., 2024), which gathers information from different studies conducted in Brazil. This work focuses on the analysis of sandy soils, defined as those with a total sand content greater than 50%, in agricultural frontier areas, aiming to understand how soil characteristics affect SHC and water infiltration.

Sandy soils, frequently found in agricultural frontier regions, exhibit high porosity and permeability, resulting in significantly high SHC. This characteristic can influence the efficiency of agricultural practices, such as irrigation and water management, and soil conservation, making it essential for the sustainability of production systems (González et al., 2020). Understanding the relationship between SHC, infiltration, and soil attributes like texture, bulk density, and porosity is crucial for developing and implementing appropriate management practices for these areas, aiming to minimize erosion, optimize water use, and ensure agricultural productivity (Silva et al., 2022). Pedotransfer Functions (PTFs) emerge as promising tools for estimating SHC based on more easily measurable soil attributes, optimizing time and resources (Costa & Soares, 2021).

In this study, we investigate the correlations between SHC, measured as steady-state infiltration rate (SSIR), and soil physical attributes, such as texture, bulk density, and porosity, in sandy soils of the Brazilian agricultural frontier. The analysis of these correlations will contribute to the selection of relevant variables for developing and applying PTFs to estimate SHC in sandy soils, aiming to support sustainable water and soil management practices in these regions.

MATERIALS AND METHODS

Data Collection

Data were obtained from the "KSAT-SSIR-DB-2024.xlsx" database (sheet "KSAT-SSIR-DB - Sample Data”), a comprehensive compilation of saturated hydraulic conductivity and basic infiltration rate measurements across diverse Brazilian soils. This dataset includes information on soil properties, land use, and measurement methodologies. Initially, 589 samples with total sand content greater than 50% and clay content less than 20% were selected. (FILIZOLA, et al., 2019) These samples originate from the following municipalities: Coruripe-AL, Luis Eduardo Magalhães-BA, Sapeaçu-BA, Cruz das Almas-BA, Rio Real-BA, Acaraú-CE, São Mateus-ES, Santa Teresa-ES, Conceição da Barra-ES, Trindade-GO, Paraíso das Águas-GO, São Luís-MA, São José de Ribamar-MA, Campo Verde-MT, Cáceres-MT, Campo Grande-MS, Naviraí-MS, Aquidauana-MS, Itutinga-MG, Itumirim-MG, Nepomuceno-MG, Castanhal-PA, Tailândia-PA, Redenção-PA, Alagoinha-PB, Pocinhos-PB, Cuité-PB, Areia-PB, Carpina-PE, Goiana-PE, Fernando de Noronha-PE, São Bento do Una-PE, Campos dos Goytacazes-RJ, Itaboraí-RJ, Seropédica-RJ, Martins-RN, Apodi-RN, Upanema-RN, Santa Maria-RS, Arvorezinha-RS, Rosário do Sul-RS, Eldorado do Sul-RS, Barra do Ribeiro-RS, São Gabriel-RS, Pindorama-SP, Lençóis Paulista-SP, Umbaúba-SE, Cananeia-SP, Gália-SP, Assis-SP, Choró-CE, Paranaiguara-GO, Uruçuí-PI, Barreiras-BA, São Desidério-BA, Jaborandi-BA, Deodápolis-MS, Rodrigues Alves-AC.

Saturated hydraulic conductivity (SHC) was determined from the steady-state infiltration rate (SSIR). The SSIR measurement methods present in the database were categorized as:

- Guelph permeameter: 111 samples
- Missing (method unreported): 375 samples
- Other (other methods): 8 samples

Data Processing and Consolidation:

Data were processed using the Pandas library in Python. The analyzed variables were clay content (%), total sand (%), bulk density (g/cm³), and total porosity (cm³/cm³). Missing values in the Kfs_Method and Texture_detail_en columns were filled with the string "missing". No imputation by mean or median was performed. After creating the "missing" category and defining the textural classes, samples with missing values in the SSIR (mm/h) column were removed from the analysis, resulting in 494 samples for the final correlation analysis.

Statistical Analysis:

Pearson correlations were calculated between SSIR and the variables clay content, total sand, bulk density, and total porosity. To evaluate the impact of the measurement method and textural class on the relationship between SSIR and soil attributes, the samples were divided into three textural classes according to the USDA Soil Survey Manual (2017): "very fine sandy loam" (15% ≤ clay < 20%), "loamy fine sand" (10% ≤ clay < 15%), and "sand" (clay < 10%). Correlations were calculated separately for each combination of measurement method ("missing," "Guelph permeameter," and "other") and textural class.

RESULTS AND DISCUSSION

This study analyzed the relationship between saturated hydraulic conductivity (SSIR) and soil attributes in sandy soil samples (total sand > 50% and clay < 20%) from the KSAT-SSIR-DB-2024 database. Data preprocessing included creating the "missing" category for missing values in Kfs_Method and Texture_detail_en, resulting in 589 initial samples. Table 1 shows the sample distribution among textural classes and SSIR measurement methods.

Table 1: Sample distribution by textural class and SSIR measurement method.

Metod	very fine sandy loam	loamy fine sand	sand	Total
missing	111	135	129	375
Guelph Permeameter	43	39	29	111
other	1	5	2	8
Total	**155**	**179**	**160**	**494**

Analysis of Pearson correlations (Tables 2-4) between SSIR and soil attributes (clay, total sand, bulk density, and porosity) revealed distinct patterns varying with textural class and measurement method.

"Missing" Method (Table 2): For samples where the measurement method was unreported ("missing"), inconsistent correlations were observed across textural classes. In "very fine sandy loam," a moderate positive correlation was found between SSIR and bulk density (0.33), along with a moderate negative correlation between SSIR and porosity (-0.50). "Loamy fine sand" soils showed a moderate positive correlation between SSIR and porosity (0.53). In contrast, for "sand," SSIR positively correlated with total sand (0.45) and negatively correlated with clay (-0.58). The variability in these results highlights the importance of reporting the measurement method for accurate interpretation.

Table 2: Pearson correlations for the “missing” method.

Texture	Argila	Areia Total	Densidade	Porosidade	SSIR
very fine sandy loam	0.00	-0.52	0.33	-0.50	1.00
loamy fine sand	0.17	0.11	-0.36	0.53	1.00
sand	-0.58	0.45	-0.16	-0.02	1.00

Table 3: Pearson correlations for the Guelph permeameter method.

Texture	Caly	Total Sand	Bulk Density	Porosity	SSIR
very fine sandy loam	NaN	NaN	NaN	NaN	NaN
loamy fine sand	NaN	NaN	NaN	NaN	NaN
sand	-0.92	0.997	0.72	-0.72	1.00

Guelph Permeameter (Table 3): For this method, most texture combinations had insufficient data to calculate reliable correlations (NaN values). Only the "sand" textural class had enough samples, exhibiting a strong positive correlation between SSIR and total sand (0.997) and a strong negative correlation with clay (-0.92), confirming that higher clay contents reduce infiltration in sandy soils. (Donagemma et al 2016)

"Other" Method (Table 4): Limited data also constrained analysis for this method. In the "loamy fine sand" class, a high positive correlation was observed between porosity and SSIR (0.74). For "sand," the correlation between total sand and porosity was perfect (1.0).

Table 4: Pearson correlations for the "other" method.

Texture	Caly	Total Sand	Bulk Density	Porosity	SSIR
very fine sandy loam	NaN	NaN	NaN	NaN	NaN

loamy fine sand	NaN	NaN	NaN	0.74	1.00
sand	NaN	NaN	NaN	1.00	NaN

In general, total porosity proved to be an important variable, with positive correlations with CHS, especially in the "loamy fine sand" textural class for the "missing" method and in both the "loamy fine sand" and "sand" classes for the "other" method. Clay and total sand showed negative and positive correlations, respectively, with CHS, which is consistent with soil physics, where sandier soils tend to have higher hydraulic conductivity (FILIZOLA, et al., 2019). Soil density showed inconsistent relationships with CHS, suggesting that other variables, such as soil structure, may influence this relationship.

CONSIDERATIONS

This preliminary study demonstrates the complexity of the relationships between C.H. saturated hydraulic conductivity and soil attributes in agricultural frontier areas.

The results suggest that total porosity is a promising variable to be included in Pedotransfer Functions (FPTs) to estimate C.H. Other variables, such as clay and total sand, may also be relevant, depending on the textural class and conductivity measurement method. hydraulics. Soil density, although important, may not be a good isolated predictor of C.H.

The continuation of this work will involve the selection and application of FPTs, using the suggested variables (porosity, clay, total sand), to estimate C.H and evaluate the reliability of PTFs in estimating C.H through the Pearson correlation (R^2). This study will contribute to the calculation of the ecosystem service erosion control in light-textured soils on the agricultural frontier, which could guide the sustainable management of light-textured soils in these regions

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PRESENTATION: https://youtu.be/0caPfmBJlNA