Revista Brasileira de Ciência do Solo

Division - Soil Processes and Properties | Commission – Soil Physics

Saturated hydraulic conductivity and steady-state infiltration rate database for Brazilian soils

Marta Vasconcelos Ottoni[(1)*], Wenceslau Geraldes Teixeira[(2)], Aline Mari Huf dos Reis[(2)], Letícia Guimarães Pimentel[(2)], Luciana Rodrigues Souza[(1)], Jackson Adriano Albuquerque[(3)], Valdinar Ferreira Melo[(4)], Karina Maria Vieira Cavalieri-Polizeli[(5)], José Miguel Reichert[(6)], João Herbert Moreira Viana[(7)], Ademir Fontana[(8)], Lucas de Castro Medrado[(9)], Glenio Guimarães Santos[(9)], Luís Gustavo Henriques do Amaral[(10)], Lúcia Helena Cunha dos Anjos[(11)], José Coelho de Araújo Filho[(12)], Silvio Barge Bhering[(2)], Gabrielle Fernandes de Brito[(1)], Pedro Gomes de Campos do Valle[(1)], Pablo Nieto Campos[(1)], Adriana Monteiro da Costa[(13)], Jean Dalmo de Oliveira Marques[(14)], Alba Leonor da Silva Martins[(2)], Michele Bruna de Souza do Nascimento[(1)], Norberto Cornejo Noronha[(15)], Ricardo Duarte de Oliveira[(16)], Jeane Cruz Portela[(17)], Milson Evaldo Serafim[(18)], Marlen Barros e Silva[(19)], Sueli Rodrigues[(20)], Wilk Sampaio de Almeida[(21)], Margareth Lopes de Moraes[(22)] and Nilton Curi[(23)]

[(1)] Serviço Geológico do Brasil, Departamento de Hidrologia, Rio de Janeiro, Rio de Janeiro, Brasil.
[(2)] Empresa Brasileira de Pesquisa Agropecuária, Embrapa Solos, Rio de Janeiro, Rio de Janeiro, Brasil.
[(3)] Universidade do Estado de Santa Catarina, Departamento de Solos e Recursos Naturais, Lages, Santa Catarina, Brasil.
[(4)] Universidade Federal de Roraima, Departamento de Solos e Engenharia Agrícola, Boa Vista, Roraima, Brasil.
[(5)] Universidade Federal do Paraná, Departamento de Solos e Engenharia Agrícola, Curitiba, Paraná, Brasil.
[(6)] Universidade Federal de Santa Maria, Departamento de Solos, Santa Maria, Rio Grande do Sul, Brasil.
[(7)] Empresa Brasileira de Pesquisa Agropecuária, Embrapa Milho e Sorgo, Sete Lagoas, Minas Gerais, Brasil.
[(8)] Empresa Brasileira de Pesquisa Agropecuária, Embrapa Gado de Corte, Campo Grande, Mato Grosso do Sul, Brasil.
[(9)] Universidade Federal de Goiás, Departamento de Solos, Escola de Agronomia, Goiânia, Goiás, Brasil.
[(10)] Universidade Federal do Oeste da Bahia, Centro das Ciências Exatas e das Tecnologias, Barreiras, Bahia, Brasil.
[(11)] Universidade Federal Rural do Rio de Janeiro, Departamento Solos, Seropédica, Rio de Janeiro, Brasil.
[(12)] Empresa Brasileira de Pesquisa Agropecuária, Embrapa Solos, Recife, Pernambuco, Brasil.
[(13)] Universidade Federal de Minas Gerais, Departamento de Geografia, Belo Horizonte, Minas Gerais, Brasil.
[(14)] Instituto Federal do Amazonas, Departamento de Química, Ambiente e Alimentos, Manaus, Amazônia, Brasil.
[(15)] Universidade Federal Rural da Amazônia, Instituto de Ciências Agrárias, Belém, Pará, Brasil.
[(16)] Serviço Geológico do Brasil, Departamento de Informações Institucionais, Rio de Janeiro, Rio de Janeiro, Brasil.
[(17)] Universidade Federal Rural do Semi-Árido, Departamento de Ciências Agronômicas e Florestais, Mossoró, Rio Grande do Norte, Brasil.
[(18)] Instituto Federal de Educação Ciência e Tecnologia de Mato Grosso, Cáceres, Mato Grosso, Brasil.
[(19)] Universidade Estadual do Maranhão, Departamento de Engenharia Agrícola, São Luís, Maranhão, Brasil.
[(20)] Universidade Federal Rural da Amazônia, Instituto de Ciências Agrárias, Belém, Pará, Brasil.
[(21)] Instituto Federal de Educação, Ciência e Tecnologia de Rondônia, Departamento de Agronomia, Ariquemes, Rondônia, Brasil.
[(22)] Serviço Geológico do Brasil, Divisão de Documentação Técnica, Rio de Janeiro, Rio de Janeiro, Brasil.
[(23)] Universidade Federal de Lavras, Departamento de Ciência do Solo, Lavras, Minas Gerais, Brasil.

*** Corresponding author:**
E-mail: marta.ottoni@sgb.gov.br

Received: January 05, 2024

Approved: June 18, 2024

How to cite: Ottoni MV, Teixeira WG, Reis AMH, Pimentel LG, Souza LR, Albuquerque JA, Melo VF, Cavalieri-Polizeli KMV, Reichert JM, Viana JHM, Fontana A, Medrado LC, Santos GG, Amaral LGH, Anjos LHC, Araújo Filho JC, Bhering SB, Brito GF, Valle PGC, Campos PN, Costa AM, Marques JDO, Martins ALS, Melo VF, Nascimento MBS, Noronha NC, Oliveira RD, Portela JC, Serafim ME, Silva MB, Sueli Rodrigues S, Almeida WS, Moraes ML, Curi N. Saturated hydraulic conductivity and steady-state infiltration rate database for Brazilian soils. Rev Bras Cienc Solo. 2025;49:e0240003.
https://doi.org/10.36783/18069657rbcs20240003

Editors: Reinaldo Bertola Cantarutti and Cássio Antônio Tormena.

ABSTRACT: Soil saturated hydraulic conductivity (Ksat) and steady-state infiltration rate (SSIR) are essential and necessary soil properties for different geoscience applications. Values of these hydraulic properties for the Brazilian territory are difficult to access and are dispersed in research efforts carried out around the country. This study developed an easy-to-manipulate, freely accessible database of soil saturated hydraulic conductivity, comprising field and laboratory analyses, and steady-state infiltration rates for Brazilian soils. This database was named Ksat-SSIR-DB. One analysis of the Ksat-SSIR-DB aimed to evaluate its coverage in Brazilian territory and in different soil groups. Average values of these hydraulic properties were also presented for textural classes, with values compared to those reported in international literature, and for other groupings, such as soil class, land use class, and porosity class. The variability of Ksat data in these groupings and in their combinations were also analyzed. The Ksat-SSIR-DB showed broad national coverage, comprising a total of 2,579 records, corresponding to 409 sampling sites, with Ksat and/or SSIR data and other associated soil information. A significant difference was observed between Ksat values for the vast majority of Brazilian clayey and very clayey soils compared to soils from the same textural groups from temperate regions. The two groupings that presented the lowest variability in terms of Ksat standard deviation values were the combination of textural classes with soil classes at the second category level of SiBCS (Brazilian Soil Classification System), and porosity classes with soil classes at the second category level of SiBCS. The Ksat-SSIR-DB has enormous potential for developing and testing Ksat pedotransfer functions in Brazilian soils, serving as a reference source for different geoenvironmental applications and, in particular, for modeling land surface processes. It is open access and can be accessed at https://www.sgb.gov.br/ksat-ssir-db-base-de-dados-de-condutividade-hidraulica-saturada-e-de-taxa-de-infiltracao-basica-em-solos-brasileiros, which also includes the python script for data analysis.

Keywords: tropical soils, soil hydraulic properties, class pedotransfer functions.

INTRODUCTION

Saturated hydraulic conductivity (Ksat) is a soil property that expresses the water permeability of the saturated soil, defined by the relationship between the flux density of percolating water and total potential gradient. The Ksat has been used in hydrological (García-Gutiérrez et al., 2018; Bagarello et al., 2020), climatological (Agyare et al., 2007; Gupta et al., 2021), and geotechnical applications (Feng and Vardanega, 2019; Bilardi et al., 2020), and in agricultural, irrigation, and drainage projects (Duan et al., 2012; Gootman et al., 2020), being relevant for the modeling of the partitioning of rainfall into runoff and infiltration (Anderson, 2014).

Saturated hydraulic conductivity is strongly affected by pore geometry, particularly by pore size, where larger pores (cracks and macropores) play a very important role, through which preferential flow may occur (Iversen et al., 2012; Zhang and Schaap, 2019). Spatio-temporal variability of soils and diversity of land use classes promote varied and complex environments, making it very difficult to spatially-represent Ksat, even for small areas.

Direct Ksat determination can be done by laboratory methods, either using constant head or falling head permeameters; and by field methods, which use infiltration tests, such as the Guelph permeameter. Each method has specificities and limitations (Reynolds and Elrick, 1986; Ebrahimi and Moradi, 2015; Thomas et al., 2016).

Indirect methods, such as pedotransfer functions (PTFs) (Bouma, 1989), have also been used to estimate Ksat (Cosby et al., 1984; Ahuja et al., 1989; Ottoni et al., 2019; Gupta et al., 2021; Szabó et al., 2021; Perreault et al., 2022). One approach to these PTFs, and probably the easiest one to use, encompasses those defined for soil textural classes, also called class pedotransfer functions. They provide average Ksat values (arithmetic mean, median, or geometric mean) in tables for different soil textural classes, such as the PTFs of Rawls et al. (1982) and Carsel and Parrish (1988), the most used in soil science and vadose zone hydrology (Zhang and Schaap, 2019). Other soil groupings, rather than soil texture, have also been used for Ksat representation, such as at the study from Pachepsky and Park (2015), which applied textural class and bulk density groups for average Ksat computation. Nonetheless, no investigation has been done to evaluate which soil groups or combinations among them best represent Ksat values in terms of their average values. The estimates of Ksat considering soil groups have the advantage of utility in data-poor environments and large-scale projects, but by far have comparable accuracy from estimates obtained with detailed soil information using sophisticated machine learning techniques (Pachepsky and Park, 2015).

Saturated hydraulic conductivity is sometimes mistaken with the steady-state infiltration rate (SSIR), obtained from field infiltration analyses, when infiltration rates asymptotically approach a constant value in time. In an unstratified soil, at this infiltration stage, the soil profile is practically saturated close to soil surface. The similarity between these soil variables is justified by Darcy's law, in which water inflow through the soil surface due to rainfall is close related to the SSIR, while this scenario results in a unit gradient. Therefore, Ksat is numerically equal to SSIR, an equality which is only valid when the soil is homogeneous, isotropic, with a stable structure (Hillel, 1998), and the flux is vertical. This particularly applies to *Latossolos* (Ferralsols, according to the FAO/WRB system - IUSS Working Group WRB, 2022), the dominant soil class in Brazil. Despite the possible similarity between these soil variables, their physical nature is distinct: while Ksat represents an intrinsic property of the soil horizons, SSIR is an infiltration rate affected by soil surface features such as cracks or crusts, the Ksat of the underlying horizons, and the soil profile moisture at the beginning of infiltration (Rauber et al., 2024).

The SSIR has been used to plan irrigation systems, conservation practices, and water erosion control projects (Pruski et al., 2006). It is determined in the field, often using the single- or double-ring infiltrometer method, due to its ease of operation.

In Brazil and around the globe, there is a growing need to obtain SSIR and, mainly, Ksat data for hydrological and land surface modeling applications (Montzka et al., 2017; Rahmanti et al., 2018; Centeno et al., 2020; Gupta et al., 2021; Horta et al., 2024). HYBRAS version I (Ottoni et al., 2018) was one of the first platforms with easy access to hydraulic property data for Brazilian soils, but it contains few Ksat data and a low representation of the Brazilian territory. In the platform mentioned above, only 419 observations contain Ksat data obtained from 10 out of 26 Brazilian states. In addition, SSIR data are not available in HYBRAS version I.

Some other databases for Ksat of Brazilian soils are BDSOLOS (Brazilian Soil Information System – https://www.bdsolos.cnptia.embrapa.br/consulta_publica.html) and SoilData (https://soildata.mapbiomas.org). The BDSOLOS system has information on soil classes from soil surveys in Brazil coordinated by Embrapa (Brazilian Agricultural Research Corporation), covering 216 samples with Ksat data; however, it lacks information on the methods used for its determination. Infiltration data are also not included in this database. SoilData (https://soildata.mapbiomas.org) is a general purpose repository for publishing studies with Brazilian soil data, containing 838 publication records. In this repository, data on many soil properties can be found, but information on hydraulic properties and water infiltration data is scarce. These findings show that Brazil lacks a soil database with consistent and comprehensive information on Ksat and infiltration capacity data.

At a global level, Gupta et al. (2021) launched an international Ksat database, compiling 13,258 records from 1,908 locations, including Brazil. Pachepsky and Park (2015) compiled more than 21,000 laboratory experiments with Ksat data for North American soils. Rahmati et al. (2018) compiled 5,023 results of infiltration tests and physical hydraulic properties of soils from several countries worldwide. Hohenbrink et al. (2023) compiled combined water retention and hydraulic conductivity information from 572 soil samples, mainly, in Germany using the HYPROP method, with wide application in modeling water flow and solute transport. The European HYdropedological Data Inventory (EU-HYDI) (Weynants et al., 2013), which collects data from European soils focusing on soil physical, chemical and hydrological properties, also contains several Ksat measurements.

This scenario on availability of Ksat and infiltration test data at an international level and their lack for Brazilian conditions has stimulated the use of pedotransfer functions calibrated for temperate climate soils. However, the literature has shown that these models are not efficient in predicting the hydraulic properties of tropical soils, especially regarding soils with a highly stable granular structure and clayey and very clayey texture, with emphasis on *Latossolos* (Ferralsols), *Nitossolos* (Nitisols) and *Argissolos* (Acrisols), which are geographically predominant and significant soils in Brazil (Santos et al., 2018). This fact possibly explains the high uncertainties in modeling studies of hydrological processes for most Brazilian soils (Mello et al., 2019), with errors in estimates and decision-making involving these processes.

Therefore, organizing a database with Brazilian Ksat and SSIR measurements and making this information widely available, including details on methodology, is an urgent matter. In addition, there is also a need to expand knowledge on the variability of Brazilian soil hydraulic properties to support the development of different scientific and practical applications in which these data are required.

This study aimed to present and discuss Ksat and SSIR data measured in Brazilian soils, compiled in a single comprehensive database. Up to date, this information was fragmented in several publications or unpublished. The new database is aimed to serve as a reference source. The study also proposes an investigation of different soil groups or combinations among them that would best represent Ksat values, aiming to be used when soil information is scarce or for large-scale projects.

MATERIALS AND METHODS

Working Group of the Brazilian Soil Science Society for Data Collection

A working group (WG-Hydraulic Properties of Brazilian Soils) was created within the scope of the Brazilian Soil Science Society (SBCS) to compile Ksat and SSIR data throughout the national territory. The WG was composed of 17 members of the SBCS representing the 26 Brazilian states. Table 1A of Section A in the Supplementary Material describes the members of this WG. More details about the organization of the working group and challenges encountered are also provided in section A, that could assist other initiatives in planning and executing more effectively similar data compilation.

Throughout the text, soil saturated hydraulic conductivity determined in the field will be given the acronym Kfs and, in the laboratory, Kslab. From now on, the term Ksat will be used as a generic reference to saturated hydraulic conductivity.

Data Collection and Harmonization

Soil hydraulic property data were collected through online and library research, as well as through contact with researchers at universities and institutes. The following information was collected: SSIR, Ksat (including field measurements - Kfs and/or laboratory measurements - Kslab), geographic coordinates of evaluation sites, soil classes (Brazilian Soil Classification System), land use classes, soil horizons, depths, particle size fractions, bulk density, particle density, porosity, organic carbon content, pH, CEC (cation exchange capacity at pH 7, on a weight or volume basis), volumetric water retention at suctions of 0, 6, 10, 33, and 1500 kPa (when available), methods for determining hydraulic properties (SSIR, Ksat, and water retention), and the reference source. Data was included in a database named Ksat-SSIR-DB, acronym of Saturated Hydraulic Conductivity and Steady-State Infiltration Rate Database.

The database structure (section "Data Structure") was organized in Google Sheets® to enable simultaneous data filling and secure storage at Google cloud®. Data were filled separately per federation state. After this phase, all spreadsheets from the state databases were unified into one for harmonization and data consistency.

Data on soil classes, land use classes were harmonized according to the current national classification systems [Brazilian Soil Classification System – SiBCS (Santos et al., 2018) and MapBiomas (Project MapBiomas, 2022), respectively]. Brazilian soil classes at the first categorical level of SiBCS were also standardized to the FAO/WRB soil classification system (IUSS Working Group WRB, 2022), based on a mixing between expert knowledge and morphological and laboratory analyses data. Along the text, when necessary, the soil classes at the first category level of the SiBCS (Santos et al., 2018) were correlated to the FAO/WRB soil classification system (IUSS Working Group WRB, 2022).

Harmonization also took place for publication references using ABNT (Brazilian Association of Technical Standards), soil depth, and methods for determining soil properties, the last two according to standards described in the Supplementary Material provided in Section B. Afterwards, the data were processed and analyzed for consistency, both for geographic coordinates and other fields represented by numerical data, considering procedures detailed at Supplementary Material (Section B). Soil property data with inconsistent values were excluded from the database.

Studies presenting water retention data (on a volumetric basis) at suctions of 33 (TH33) and 1500 kPa (TH1500) had the total available water (AW) content calculated by the difference between TH33 and TH1500. Effective porosity (EP) was also calculated as the difference between saturated water content (TH0) (or total porosity - TP, when the former was not available) and TH33. These calculations were carried out to add information on soil hydraulic properties in the Ksat-SSIR-DB.

A total of 2,579 records from 143 publications were compiled in the Ksat-SSIR-DB, the majority coming from national and international journals (50 %), master's dissertations (26 %), and doctoral theses (10 %). Table 1 presents the list of publications in the database, the Brazilian states of origin of the data, and the number of corresponding records.

Data Structure

The Ksat-SSIR-DB was developed in a Microsoft Excel® spreadsheet (xlsx), containing two sheets. The first sheet, named *Metadata*, contains the metadata of this database, as detailed in table 2, with a synthetic description of its fields and the corresponding data formats (integer, decimal, or text). The second sheet, called *Sample Data*, contains records of the fields in table 2. All Ksat-SSIR-DB fields are in English and some of them have data reported in English and Portuguese, as was the case involving "Land Use" and "Texture". This was done to potentially expand the use of this database.

Statistical analysis of the data

Average values of Kslab, Kfs, and SSIR were evaluated for textural classes, according to Santos et al. (2015), land use classes, according to the MapBiomas collection (MapBiomas Project, 2022), and the soil classes, according to the Brazilian Soil Classification System (SiBCS) (Santos et al., 2018). These mean values were also recorded for groups of textural classes, called fine (clay loam, silty clay, sandy clay, silty clay loam, clay and very clay), medium (sandy loam, loam, sandy clay loam, silty loam, silt), coarse (sand, loamy sand), as proposed by Cassel et al. (1983), to facilitate discussion of the results. These groupings were chosen to represent Ksat and SSIR results because they are the most used formats in several applications in which they are required. Average values of Kslab, Kfs, and SSIR are the geometric mean, considering the frequent asymmetric distribution of Ksat (Warrick, 2001).

In Santos et al. (2015), 13 soil textural classes are proposed and they differ from the USDA soil textural classification (USDA, 2017) for the clay class. In Santos et al. (2015), the clay class from the USDA classification (USDA, 2017) is subdivided into two groups: 'very clayey' when the clay fraction is higher than 60 % and 'clay' when the clay fraction is lower than 60 %. We decided to present the results for the Santos et al. (2015) soil textural classification, since the Ksat-SSIR-DB classified many soil samples in the very clayey textural class, where soil samples from temperate climate databases are usually not found.

Average Ksat and SSIR results were also calculated for porosity classes since porosity possibly has a strong relationship with this soil hydraulic property. Porosity class values were arbitrarily separated into six intervals, namely <0.3 cm^3 cm^{-3}, 0.3-0.4 cm^3 cm^{-3}, 0.4-0.5 cm^3 cm^{-3}, 0.5-0.6 cm^3 cm^{-3}, 0.6-0.7 cm^3 cm^{-3}, and >0.7cm^3 cm^{-3}.

Groups with less than five records in any of the analyzed variables (Kfs, Kslab, and SSIR) did not have means computed. The Ksat class standards proposed by the Soil Science Division Staff (2017) were adapted to three classes in mm h^{-1}: low (<3.6), moderate (3.6 – 36), and high (>36), and were used to evaluate the classes of geometric mean Ksat and SSIR values at the different groups evaluated.

Average results recorded by textural class from the Ksat-SSIR-DB were compared to average values of the corresponding classes in the international saturated hydraulic conductivity database compiled by Gupta et al. (2021), which includes Ksat data for Brazilian soils. In both datasets, the particle-size limits for clay, silt, and sand content are the same (clay <0.002 mm; silt >0.002 and <0.05 mm; sand >0.05 and <2 mm). This comparison was only made for the Kslab variable, as it contains a greater number of records, although both compilations by Gupta et al. (2021) and Ksat-SSIR-DB contain Kfs measurements. In Gupta´s database, Ksat values were measured mostly for soils in temperate climates; those from Brazilian soils were excluded in this report to guarantee more reliable comparisons of Ksat values between both databases.

Table 1. Source of Ksat and SSIR data with the Brazilian state where the data were measured, and the number of records

References	Brazilian states	Number of records
Portugal (2009)	Acre	20
Maia and Ribeiro (2004)	Alagoas	9
Silva and Ribeiro (1997)	Alagoas	12
Borkowski and Silva (2021)	Amapá	3
Corrêa (1985)	Amazonas	12
Coelho et al. (2005)	Amazonas	20
Marques et al. (2004)	Amazonas	10
Teixeira (2001)	Amazonas	6
Teixeira et al. (2014)	Amazonas	6
Marques et al. (2008)	Amazonas	25
Marques et al. (2010)	Amazonas	25
Souza et al. (2004)	Amazonas	7
Aquino (2012)	Amazonas	3
Tomasella and Hodnett (1996)	Amazonas	3
Eger et al. (2021)	Bahia	16
Nacif et al. (2008)	Bahia	20
Souza and Souza (2001)	Bahia	36
Paiva et al. (2000)	Bahia	11
Fontana et al. (2016)	Bahia	10
Santana et al. (2006)	Bahia	8
Almeida (2013)	Ceará	2
Aguiar (2008)	Ceará	3
Borges et al. (2009)	Distrito Federal	15
Campos (2009)	Distrito Federal	4
Cavedon and Sommer (1990)	Distrito Federal	5
Oliveira (2005)	Distrito Federal	16
Souza et al. (2014)	Espírito Santo	24
Mundim et al. (2018)	Espírito Santo	16
Amorim et al. (2011)	Espírito Santo	1
Sperandio and Cecílio (2017)	Espírito Santo	2
Martins et al. (2010)	Espírito Santo	9
Ramos (2018)	Espírito Santo	24
Guerra et al. (2018)	Espírito Santo	8
Andrade et al. (2020)	Goiás	6
Silva (2021)	Goiás	8
Cunha et al. (2015)	Goiás	2
Silva et al. (2003)	Goiás	12
Medrado (2021)	Goiás	3
Sales et al. (2010)	Goiás	10
Mascarenhas et al. (2015)	Goiás	14
Oliveira (2009)	Goiás	3
Gravina (2021)	Goiás	6
Silva et al. (2001)	Goiás	1
Andrade and Stone (2009)	Goiás	88
Santos et al. (2011)	Goiás	32
Rodrigues et al. (1991)	Maranhão	5
Teixeira et al. (2020)	Maranhão	7

Continue

Continuation

References	Brazilian states	Number of records
Martins (2006)	Maranhão	1
Moura (1991)	Maranhão	4
Lumbreras (1996)	Maranhão	19
Valadão et al. (2011)	Mato Grosso	4
Scheffler et al. (2011)	Mato Grosso	9
Bocuti et al. (2020)	Mato Grosso	5
Souza et al. (2014)	Mato Grosso	5
Vilarinho et al. (2019)	Mato Grosso	2
Silva et al. (2008)	Mato Grosso	6
Panachuki et al. (2011)	Mato Grosso do Sul	9
Tenfen (2014)	Mato Grosso do Sul	5
Sone et al. (2020)	Mato Grosso do Sul	8
Tomasini et al. (2010)	Mato Grosso do Sul	3
Sone et al. (2019)	Mato Grosso do Sul	18
Alves Sobrinho et al. (2003)	Mato Grosso do Sul	4
Almeida et al. (2018)	Mato Grosso do Sul	24
Pavei et al. (2018)	Mato Grosso do Sul	5
Souza et al. (2019)	Mato Grosso do Sul	3
Bono et al. (2012)	Mato Grosso do Sul	35
Silva (2016)	Mato Grosso do Sul	5
Scorza Junior and Silva (2007)	Mato Grosso do Sul	21
Panachuki (2003)	Mato Grosso do Sul	6
Melo (2020)	Minas Gerais	22
Oliveira et al. (2010)	Minas Gerais	18
Aguiar (2008)	Minas Gerais	3
Amaral (2018)	Minas Gerais	20
Sales et al. (1999)	Minas Gerais	4
Ribeiro et al. (2007)	Minas Gerais	6
Faria and Caramori (1986)	Paraná	1
Pruski et al. (1997)	Paraná	8
Oliveira et al. (2019)	Paraná	5
Polizeli et al. (2009)	Paraná	4
Leonardo (2020)	Paraná	30
Costa et al. (2003)	Paraná	9
Moraes et al. (2016)	Paraná	10
Pequeno (2016)	Paraíba	12
Silva et al. (2019)	Paraíba	10
Oliveira Junior et al. (1998)	Pará	9
Oliveira Junior et al. (1997)	Pará	2
Rodrigues et al. (1991)	Pará	46
Oliveira Junior et al. (1999)	Pará	23
Marques (2004)	Pernambuco	16
Silva et al. (2012)	Pernambuco	16
Ortiz et al. (2020)	Pernambuco	3
Melo (2013)	Pernambuco	4
Soares et al. (2020)	Pernambuco	2
Schossler et al. (2018)	Piauí	48
Santos et al. (2021)	Piauí	6

Continue

Continuation

References	Brazilian states	Number of records
Dias (2018)	Rio Grande do Norte	4
Farias (2019)	Rio Grande do Norte	17
Costa et al. (2020)	Rio Grande do Norte	15
Mendes et al. (2018)	Rio Grande do Norte	2
Cavalli (2017)	Rio Grande do Sul	28
Rojas (1998)	Rio Grande do Sul	28
Avila (2014)	Rio Grande do Sul	25
Suzuki et al. (2012)	Rio Grande do Sul	24
Mentges et al. (2010)	Rio Grande do Sul	8
Facco (2017)	Rio Grande do Sul	21
Dalbianco (2009)	Rio Grande do Sul	66
Pedron et al. (2011)	Rio Grande do Sul	11
Andriollo (2015)	Rio Grande do Sul	71
Oliveira (2015)	Rio Grande do Sul	12
Gomes (1972)	Rio Grande do Sul	14
Boeno (2019)	Rio Grande do Sul	15
Silva et al. (2005)	Rio Grande do Sul	16
Alves and Cabeda (1999)	Rio Grande do Sul	4
Leal (2011)	Rio de Janeiro	36
Silva (2011)	Rio de Janeiro	48
Bernardes (2005)	Rio de Janeiro	69
Sondatécnica (1983)	Rio de Janeiro	610
Bhering (2007)	Rio de Janeiro	9
Nacinovic (2013)	Rio de Janeiro	24
Fabian and Ottoni Filho (1997)	Rio de Janeiro	8
Batista et al. (2018)	Roraima	1
Bortolini et al. (2016)	Santa Catarina	12
Bertol and Santos (1995)	Santa Catarina	4
Camargo (2011)	Santa Catarina	9
Epagri-Embrapa Solos (2008)	Santa Catarina	16
Costa et al. (2016)	Santa Catarina	25
Bertol et al. (2001)	Santa Catarina	3
Andognini et al. (2020)	Santa Catarina	20
Cintra (1997)	Sergipe	5
Espírito Santo (1998)	São Paulo	11
Toma (2012)	São Paulo	12
Cooper et al. (2013)	São Paulo	14
Juhász et al. (2007)	São Paulo	17
Cooper et al. (2012)	São Paulo	19
Cooper database*	São Paulo	9
Martíni et al. (2021)	São Paulo	4
Angelotti Netto and Fernandes (2005)	São Paulo	10
Ghiberto and Moraes (2011)	São Paulo	10
Uyeda (2009)	São Paulo	3
Berreta (1999)	São Paulo	8
Klein (1998)	São Paulo	39

Continue

Continuation

References	Brazilian states	Number of records
Santos (2020)	São Paulo	6
Pott (2001)	São Paulo	9
Total		2579

* Soil database of the state of São Paulo was provided by the researcher Miguel Cooper from ESALQ/USP – Brazil and first published in HYBRAS (Ottoni et al., 2018). Authorization to disclose this soil database was granted in 2014.

Table 2. Description of SSIR-Ksat-DB fields, Brazil

Field	Description	Format	Unit
Code	soil sample id	Integer	-
City	Brazilian city, according to IBGE (Brazilian Institute of Geography and Statistics)	Text	-
State	Brazilian state, according to IBGE (Brazilian Institute of Geography and Statistics)	Text	-
UF	state acronym	Text	-
LatitudeOR	latitude, in decimal degrees, of the study location	Decimal	decimal degree
LongitudeOR	longitude, in decimal degrees, of the study location	Decimal	decimal degree
Datum	coordinate system (e.g., WGS-84; SAD-69)	Text	-
Comments_coordinates	description of the coordinate origin. E.g., coordinates extracted from the original work; coordinates estimated by description of the experiment location	Text	-
Coordinate_qual	classification of coordinates according to their method of determination. 0, when the coordinate was estimated or corrected; 1, when obtained from the original work and without changing location	Text	-
Elev	elevation above sea level (m)	Decimal	m
Description	general description of the experimental area	Text	-
Description_detail	additional description of the experimental area	Text	-
Original Soil classification	soil classification as described in the study (description, according to the SiBCS version at the time of the study, when available)	Text	-
Soil_Class_u2NC	reclassification of soils according to SiBCS 5 ed at the first and second categorical level	Text	-
SiBCS 5ed 1NC	reclassification of soils according to SiBCS 5 ed at the first categorical level	Text	-
SiBCS 5ed 2NC	reclassification of soils according to SiBCS 5 ed at the second categorical level	Text	-
WRB/FAO	reclassification of soils according to FAO/WRB system - IUSS Working Group WRB (2022)	Text	-
Land use	dominant land use at the experiment site at the time of sample evaluation/collection	Text	-
Land_use_mapbiomas_en	land use system by MapBiomas classes (1st level of classification – separating the class farming into agriculture and pasture) - English version	Text	-
Land_use_mapbiomas_por	land use system by MapBiomas classes (1st level of classification - separating the class farming into agriculture and pasture) - Portuguese version	Text	-
Horizon nomenclature	soil horizon nomenclature (following Brazilian guidelines)	Text	-
Soil Depth_thickness	soil depth in cm or depth range in cm. If the steady-state infiltration rate (SSIR) is measured at the surface, soil depth=0 cm	Decimal	cm
Upper_Hor	upper limit of the soil horizon	Decimal	cm
Lower_Hor	lower limit of the soil horizon	Decimal	cm

Continue

Continuation

Field	Description	Format	Unit
Class Horizon	horizon classification: topsoil or subsoil. If the average between Upper_Hor and Lower_Hor was lower or equal to 30 cm, the Class Horizon was defined as topsoil, if not, as subsoil.	Text	-
Clay	clay percentage - particles < 0.002 mm	Decimal	%
Silt	silt percentage - 0.002 mm < particles < 0.05 mm	Decimal	%
Fine sand	sand percentage - 0.05 mm < particles < 0.20 mm	Decimal	%
Coarse sand	sand percentage - 0.20 mm < particles < 2.00 mm	Decimal	%
Total sand	sand percentage - 0.05 mm < particles < 2.00 mm	Decimal	%
Sum_textural_fractions	sum of total sand + silt + clay	Decimal	%
Texture_en	textural class according to USDA - English version	Text	-
Texture_detail_en	textural class according to Santos et al. (2015) - English version	Text	-
Texture_por	textural class according to USDA - Portuguese version	Text	-
Texture_detail_por	textural class according to Santos et al. (2015) - Portuguese version	Text	-
bulk_den	bulk density	Decimal	kg dm^{-3} (or g cm^{-3})
par_den	particle density	Decimal	kg dm^{-3} (or g cm^{-3})
Porosity	total soil porosity	Decimal	cm^3 cm^{-3}
org_carb	organic carbon content	Decimal	g kg^{-1}
pH	soil pH	Decimal	-
CEC weight	cation exchange capacity at pH 7 in unit of mass	Decimal	$cmol_c$ kg^{-1}
CEC volume	cation exchange capacity at pH 7 in unit of volume	Decimal	$cmol_c$ dm^{-3}
base saturation V	base saturation, V=100.S/CEC, where S refers to the sum of exchangeable cations	Decimal	%
Kfs	saturated hydraulic conductivity measured in the field	Decimal	mm h^{-1}
Kslab	saturated hydraulic conductivity measured in the laboratory	Decimal	mm h^{-1}
SSIR	steady-state infiltration rate	Decimal	mm h^{-1}
WRetention_Consistency	water retention data inconsistency description	Text	-
TH0	volumetric water content at suction 0 kPa. If the data was on a gravimetric basis, it was converted to a volumetric basis using bulk density	Decimal	cm^3 cm^{-3}
TH6	volumetric water content at suction 6 kPa. If the data was on a gravimetric basis, it was converted to a volumetric basis using bulk density	Decimal	cm^3 cm^{-3}
TH10	volumetric water content at suction 10 kPa. If the data was on a gravimetric basis, it was converted to a volumetric basis using bulk density	Decimal	cm^3 cm^{-3}
TH33	volumetric water content at suction 33 kPa. If the data was on a gravimetric basis, it was converted to a volumetric basis using bulk density	Decimal	cm^3 cm^{-3}
TH1500	volumetric water content at suction 1500 kPa. If the data was on a gravimetric basis, it was converted to a volumetric basis using bulk density	Decimal	cm^3 cm^{-3}
AW	available soil water (TH33-TH1500)	Decimal	cm^3 cm^{-3}
EP	effective soil porosity [TH0(or TP)-TH33], considering soil saturation water content (TH0) or total porosity (TP), if the former was not available	Decimal	cm^3 cm^{-3}
Kfs_Method	method of determining saturated hydraulic conductivity in the field: Guelph permeameter, well method, other	Text	-
Kfs_Detail	details of the Kfs determination method. E.g., if it was the Guelph method, the diameter of the well, the water head applied, and the calculation method (1 or 2 water heads)	Text	-

Continue

Continuation

Field	Description	Format	Unit
Kslab_Method	method of determining saturated hydraulic conductivity in the laboratory: constant head permeameter, falling head permeameter, other	Text	-
Kslab_Sample_Type	type of soil sample used (disturbed or undisturbed) in determining Kslab	Text	-
Kslab_Sample_diameter	diameter of the undisturbed sample in cm, when using the laboratory determination method	Decimal	cm
Kslab_Sample_height	height of the undisturbed sample in cm, when using the laboratory determination method	Decimal	cm
WR_sample_TP	type of sample used to measure the water retention curve: undisturbed or disturbed	Text	-
WR_Method	water retention determination method: Richards pressure plate, tension table, porous plate funnel, filter paper, centrifuge, psychrometer (WP4)	Text	-
TIB_Method	infiltration test determination method: double ring, single ring, rainfall simulator, cornell	Text	-
TIB_Surface_Crust	Is there a surface seal? Yes or No	Text	-
Reference	publication reference according to ABNT (Brazilian Association of Technical Standards)	Text	-
Reference_simplif	simplified reference for in-text citation	Text	-
Year_Publicn	Year of publication	Text	-
Data_entrance	data entry in the WG spreadsheet - hydraulic properties	Text	-
Typist	name or/and email of the person who entered the data	Text	-
OBS1	additional observations related to the data origin, changes made to the data, determination methods not included in the publication, etc	Text	-
OBS2	additional observations related to the data origin, changes made to the data, determination methods not included the publication, etc	Text	-

To assess the representativeness of the average Ksat values in the different groups evaluated, the Ksat data variability was analyzed, using the 10th and 90th percentiles. The minimum and maximum values of Ksat were not included as data extreme limits to avoid the inclusion of very anomalous magnitudes. Only Kslab data were used in this exercise, as it contains a more significant quantity of data in the different studied groupings.

Furthermore, the evaluation of soil groups or combinations among them that recorded the lowest Ksat weighted mean standard deviation ($wstd_g$) was performed (Equation 1) to indicate the best group to be used to represent Ksat:

$$wstd_g = \frac{\sum_{i=1}^{N} (std_i \times weight_i)}{\sum_{i=1}^{N} weight_i} \quad \text{Eq. 1}$$

in which: std_i is the standard deviation of the logarithms of Ksat values, in mm h^{-1}; $weight_i$ is the number of soil samples contained in the different classes (i) of the groups; and N is the maximum number of classes predicted at the groups.

The Ksat weighted mean standard deviation ($wstd_g$) was computed for the following groups:

- Isolated groups: Textural classes (Santos et al., 2015); Soil classes at the first category level of SiBCS (Santos et al., 2018) (Soil Class 1CL); Soil classes at the second category level of SiBCS (Santos et al., 2018) (Soil Class 2 CL); Land use classes (MapBiomas Project, 2022); Porosity classes (defined arbitrarily in this study).

- Groups in combination: Textural classes × Porosity classes; Soil Class 1CL × Textural classes; Soil Class 1CL × Porosity classes; Soil Class 2CL × Textural Classes; Soil Class 2CL × Porosity.

The land use classes grouping did not have its classes combined with those of other groups under investigation, since, in this case, only topsoil samples were used at calculation of the Ksat statistics, while in the other groupings the complete database was used.

The weighted t-test hypothesis (similar to the student's t-test for evaluating similarity between means) (Yuen, 1974) was used to investigate the similarity of the weighted mean standard deviation among groups (p-value≥0.05 indicates similarity among groups).

RESULTS AND DISCUSSION

Data Coverage

The 2,579 catalogued data cover the 26 Brazilian states and the Federal District, except the state of Rondônia (RO). They correspond to 409 sampling sites, as shown in figure 1. Figure 1 presents the sampling locations discriminated by the method used to determine the geographic coordinates: (1) original, when the coordinates were extracted directly from the study; or (2) estimated, when the location of the sampling point was predicted, according to the methodology described in the Supplementary Material (Section B). Most of the sampling sites (~55 %) had the geographical coordinates extracted as described in the original work, which may indicate a higher resolution of their geographic positioning. This information can be useful in producing hydraulic property maps at different spatial resolutions.

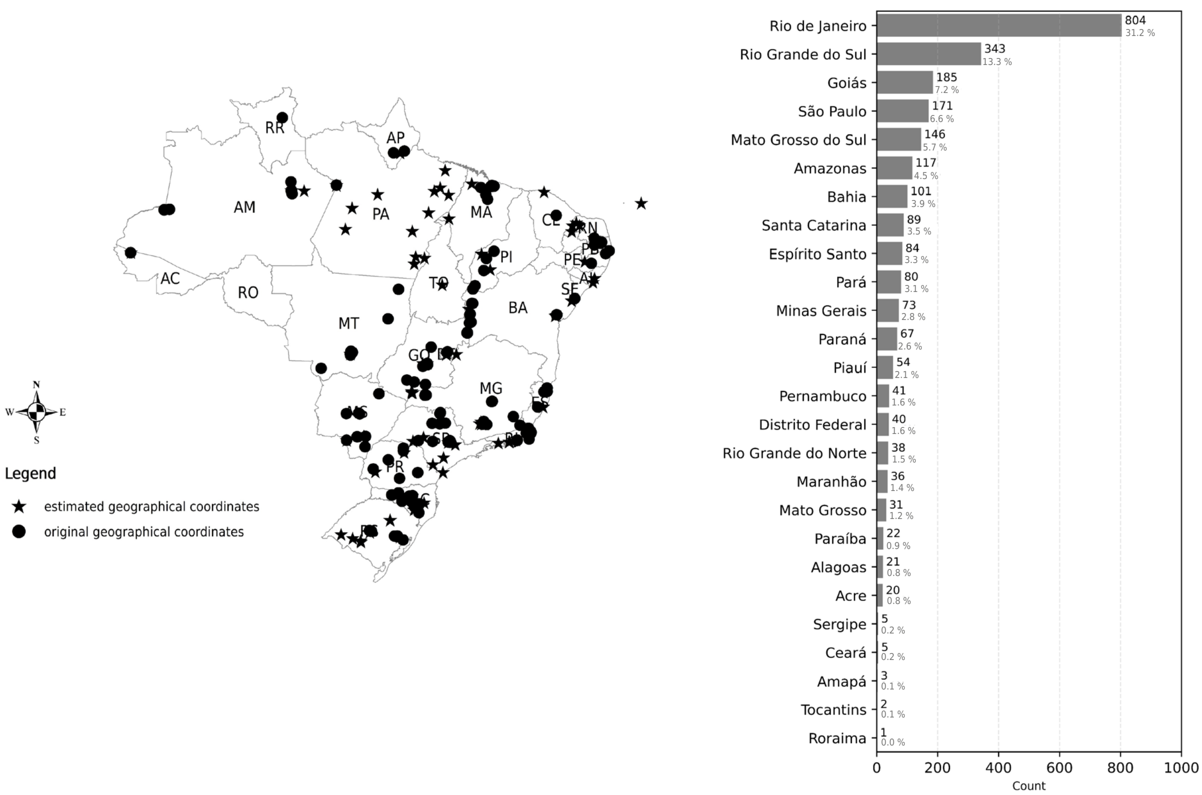

Figure 1. Distribution of Ksat-SSIR-DB's sampling sites in Brazil (a) and in the federative states of Brazil (b). (AC) - Acre, (AL) - Alagoas, (AP) - Amapá, (AM) - Amazonas, (BA) - Bahia, (CE) - Ceará, (DF) - Distrito Federal, (ES) - Espírito Santo, (GO) - Goiás, (MA) - Maranhão, (MT) - Mato Grosso, (MS) - Mato Grosso do Sul, (MG) - Minas Gerais, (PA) - Pará, (PB) - Paraíba, (PR) - Paraná, (PE) - Pernambuco, (PI) - Piauí, (RJ) - Rio de Janeiro, (RN) - Rio Grande do Norte, (RS) - Rio Grande do Sul, (RO) - Rondônia, (RR) - Roraima, (SC) - Santa Catarina, (SP) - São Paulo, (SE) - Sergipe, and (TO) - Tocantins.

The states of Rio de Janeiro (RJ) and Rio Grande do Sul (RS), alone comprised 44 % of the total number of samples (Figure 1). The states of Sergipe (SE), Ceará (CE), Amapá (AM) and Tocantins (TO) had low availability of Ksat-SSIR data; in Roraima (RR) only one record was observed.

Table 3 presents the quantitative records of soil properties available in the Ksat-SSIR-DB and the descriptive statistics: arithmetic mean, minimum, maximum, median, and standard deviation. All 2,579 records in the database contained sand, silt, and clay contents, of which 1,386 included information on fine sand and coarse sand contents. Bulk density data comprised 2,183 records; organic carbon content data totaled 1,494 records; particle density data totaled 1,068 records; pH values totaled 869 records; base saturation data totaled 455 records; and CEC at pH 7 totaled 34 records.

As for soil hydraulic property data, 1,842 soil samples had Kslab measurements, followed by 502 Kfs, and 425 SSIR. Simultaneous measurements of these properties at the same location were also observed (Kslab and Kfs - 65 samples; Kslab and SSIR - 145 samples; Kfs and SSIR - 14 samples; Kslab, Kfs, and SSIR - 9 samples). Among the water retention measurements available in the database, total porosity, TH1500, and TH33, showed, in this sequence, a greater quantity of data, with 2,065, 1,272, and 947 samples, respectively. Total available water values (AW) were represented in a reasonable number of samples (944), with only 358 records for effective porosity (EP).

Out of the 1,842 Kslab measurements with particle size fraction information, 1,741 records include bulk density data, 1,216 records include organic carbon content, 815 records include TH33, and 1,118 records include TH1500, while 1,178 records include bulk

Table 3. Descriptive statistics of soil properties from the the Ksat-SSIR-DB

Parameter	Count	Mean	Min	Max	Median	Std
Clay (%)	2579	41	0	96	40	22
Silt (%)	2579	18	0	86	14	13
Fine Sand (%)	1386	22	0	97	16	20
Coarse Sand (%)	1386	18	0	76	14	18
Total Sand (%)	2579	41	0	99	39	27
Bulk Density (g cm^{-3})	2183	1.27	0.26	2.36	1.27	0.24
Particle Density (g cm^{-3})	1068	2.60	1.33	3.09	2.60	0.15
Total Porosity (cm^3 cm^{-3})	2065	0.51	0.2	0.87	0.52	0.09
Organic Carbon (g kg^{-1})	1494	16.6	0.1	233.5	10.4	20.9
pH	869	5.2	2.2	11.6	4.9	1.0
CEC weight ($cmol_c$ kg^{-1})	34	6.2	2.0	18.3	5.9	3.1
CEC volume ($cmol_c$ dm^{-3})	34	8.7	0.1	28.8	7.2	6.4
Base Saturation (%)	455	42	1	100	39	28
Kfs (mm h^{-1})	502	29.8*	0.1	2784.0	-	6.5**
Kslab (mm h^{-1})	1842	24.9*	0.1	4038.0	-	7.0**
SSIR (mm h^{-1})	425	54.4*	0.3	2353.0	-	4.5**
TH0 (cm^3 cm^{-3})	561	0.51	0.26	0.87	0.52	0.1
TH6 (cm^3 cm^{-3})	654	0.34	0.03	0.75	0.36	0.11
TH10 (cm^3 cm^{-3})	754	0.31	0.03	0.72	0.33	0.12
TH33 (cm^3 cm^{-3})	947	0.37	0.04	0.75	0.38	0.14
TH1500 (cm^3 cm^{-3})	1272	0.24	0	0.56	0.24	0.11
AW (cm^3 cm^{-3})	944	0.10	0.01	0.29	0.09	0.05
EP (cm^3 cm^{-3})	358	0.20	0.09	0.44	0.19	0.07

std: standard deviation; * saturated hydraulic conductivity calculated as the geometric mean; ** geometric standard deviation (σg) ($σg = 10^{σ}$, in which σ is the logarithmic standard deviation at base 10); σg is dimensionless.

density measurements and organic carbon content together, and 672 records include data on these last two soil properties in addition to information from TH33 and TH1500 data. These numbers reveal excellent perspectives for the development of a national hierarchical pedotransfer functions for Kslab.

Soil samples in Ksat-SSIR-DB include all soil classes at the first category level of SiBCS (Santos et al., 2018). The greatest concentration of data occurred in the *Latossolos* (Ferralsols) and *Argissolos* (Acrisols, Lixisols, or Alisols) classes, with 54 % of the total (Figure 2a). At the second category level of SiBCS, there was a broad representation of data in the classes included as *Latossolos*, *Argissolos*, *Cambissolos* (Cambisols), *Neossolos* (Inceptisols and Entisols), and *Gleissolos* (Gleysols) (Figure 2b).

Figure 3 shows the coverage of Ksat-SSIR-DB on a textural triangle, showing broad data coverage over the 13 textural classes. The classes with large numbers of data were very clayey, clay, and sandy clay loam, in that order, together accounting for approximately 58 % of the total. The silt class recorded only one occurrence, in line with its known scarcity due to the high degree of weathering of most Brazilian upland soils. Silt and silt loam soils are common in temperate soil database of Ksat (Rahmati et al., 2018, Gupta et al., 2021). These soil textural classes occur in Brazil, mainly in the soils of the Amazon Floodplains (Teixeira et al., 2019).

As for land use classes, the Agriculture and Pasture classes had broad representation, concentrating around 63 % of the data, followed by the Forest and Non- Forest Natural Formation classes, together making up around 20 % of the total number of records (Figure 4).

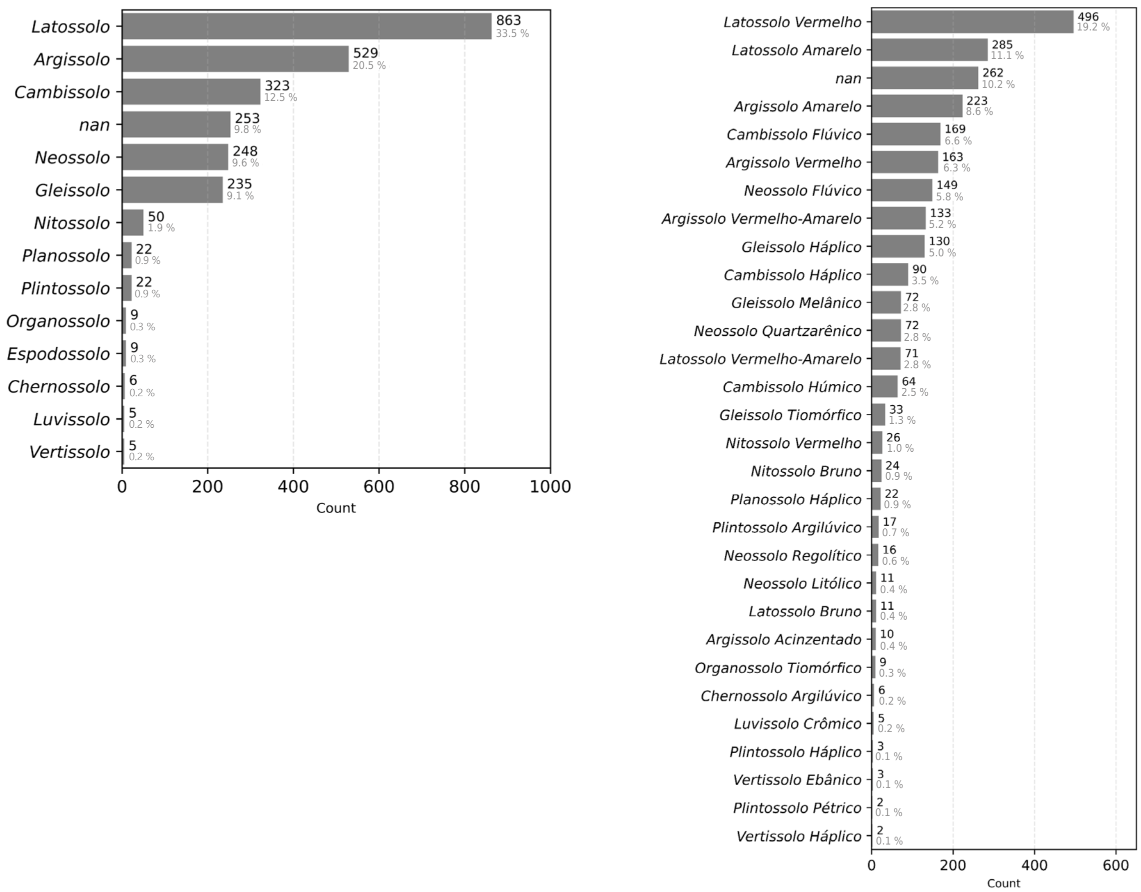

Figure 2. Distribution of the Ksat-SSIR-DB in the Brazilian Soil Classification System (SiBCS) (Santos et al., 2018) at the first category level (a) and at the second categorical level (b). nan indicates that there is no data representation. (AC) - Acre, (AL) - Alagoas, (AP) - Amapá, (AM) - Amazonas, (BA) - Bahia, (CE) - Ceará, (DF) - Distrito Federal, (ES) - Espírito Santo, (GO) - Goiás, (MA) - Maranhão, (MT) - Mato Grosso, (MS) - Mato Grosso do Sul, (MG) - Minas Gerais, (PA) - Pará, (PB) - Paraíba, (PR) - Paraná, (PE) - Pernambuco, (PI) - Piauí, (RJ) - Rio de Janeiro, (RN) - Rio Grande do Norte, (RS) - Rio Grande do Sul, (RO) - Rondônia, (RR) - Roraima, (SC) - Santa Catarina, (SP) - São Paulo, (SE) - Sergipe, and (TO) - Tocantins.

Ksat-SSIR-DB measurement methods

The methods for determining saturated hydraulic conductivity and steady-state infiltration rate are presented in table 4. Most Ksat-SSIR-DB records with Kfs data were carried out with a Guelph permeameter. For Kslab, the constant head permeameter was the mostly used, followed by the falling head method. For SSIR, the double ring method was most used (277 records), while the single ring method was used for only 16 records.

Regarding water retention data, the combined methods of tension table for lower suction ranges and porous plate pressure chamber for higher suctions prevailed, with only around 6 % of the data being measured using the porous plate funnel method for water retention measurement at low suctions (Figure 5).

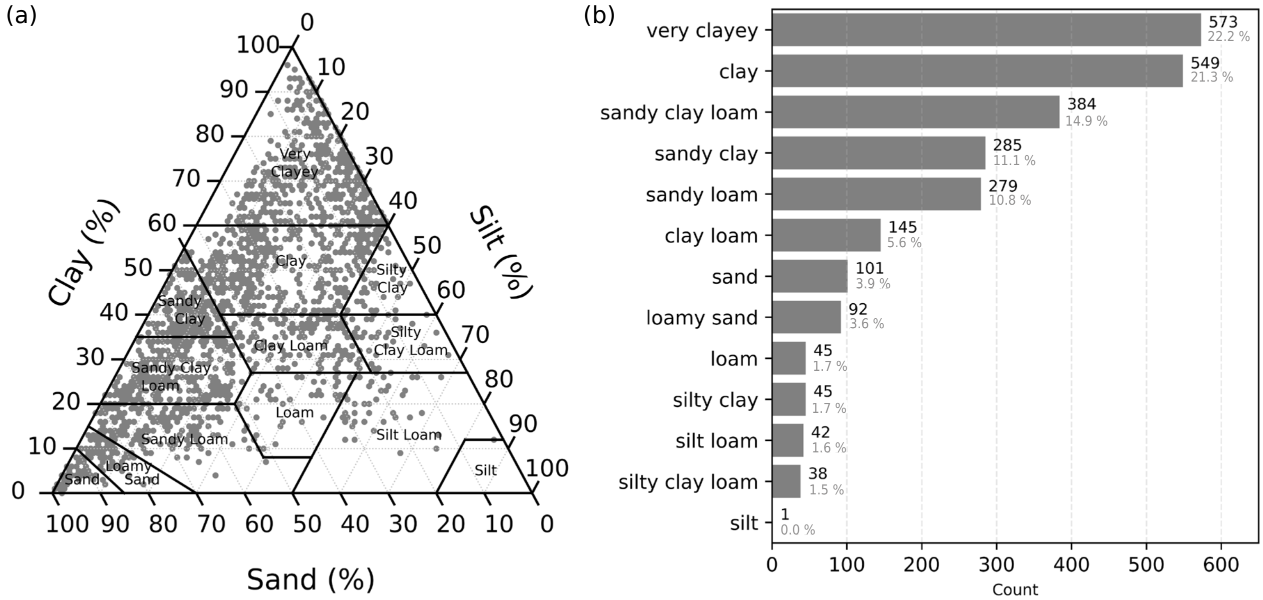

Figure 3. Distribution of the Ksat-SSIR-DB in the textural triangle (a) and its coverage in the 13 textural classes, according to Santos et al. (2015) (b).

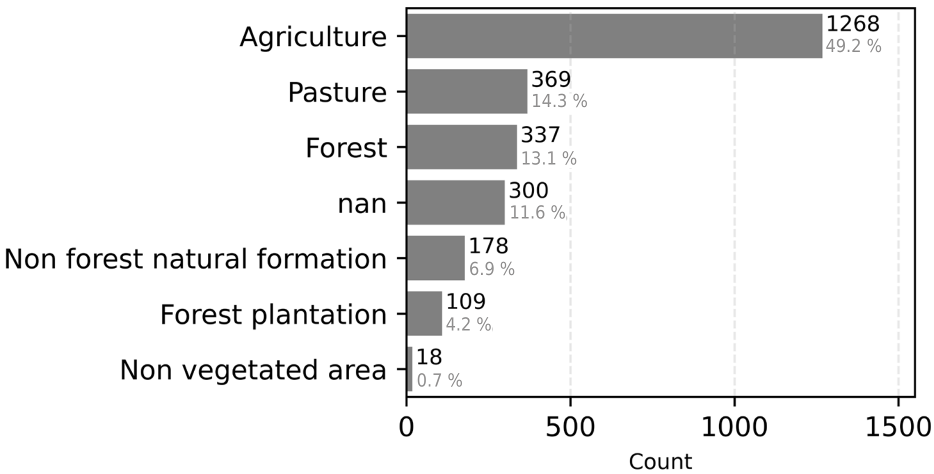

Figure 4. Distribution of the Ksat-SSIR-DB in the land use classes, according to MapBiomas (MapBiomas Project, 2022). nan indicates that there is no data representation.

Table 4. Methods used for determining Kfs, Kslab, and SSIR in the Ksat-SSIR-DB and the corresponding number of records

Methods	Kfs	Kslab	SSIR
Guelph permeameter	415	-	-
Constant head permeameter	-	1,584	-
Falling head permeameter	-	201	-
Double ring	-	-	277
Rainfall simulator	-	-	92
Single ring	-	-	16
Other	87	57	40
Sum of all records	502	1,842	425

Average values of Kfs, Kslab, and SSIR for classes of different soil groupings

Table 5 shows geometric means of Kfs, SSIR, and Kslab by textural classes, in addition to the Kslab data compiled by Gupta et al. (2021), used as reference of Kslab data in temperate soils. In this table, as in the others in this section, Kfs, SSIR, and Kslab values were highlighted in different colors, with blue representing values considered high, orange, moderate, and red, low.

In general, higher values of the three hydraulic properties were recorded in the textural classes with the higher sand content, with emphasis on the sandy soil class, with a geometric mean of 126 mm h^{-1} for Kfs and 298 mm h^{-1} for Kslab. Conversely, regarding the Kslab and Kfs results, the fine-textured classes, showed lower average values than the coarse and medium textured classes, recording values of 18.9 and 19.5 mm h^{-1}, respectively. The expected reduction in Ksat values from coarse-textured soils to medium- and fine-textured soils was confirmed.

Despite the similarity observed between average values of Kfs and Kslab in the fine-textured soils, the average results for Kfs showed greater variability compared to Kslab within this textural group (Table 5). For the SSIR variable, no clear trends were observed in reducing SSIR values from medium to fine-textured classes. The mean SSIR values in these two groups (medium- and fine-textured classes) were similar (~51 mm h^{-1}). The similarity of structure functionality may help to explain these findings.

In the class of very clayey soils, Kfs and SSIR mean values were high and almost twice as high as for Kslab (Table 5). In the sandy clay class, SSIR is greater than Kslab approximately six times. These results suggest that field tests (Kfs and SSIR) are more sensitive to assessing variations in soil macropores arrangement, responsible for high Ksat values compared to the small-size samples used to determine Kslab, which usually are not able to reproduce the macrospace of the soils adequately. More details about the effect of sample size on Kslab determination is described in the section "Laboratory versus Field Saturated Hydraulic Conductivity". However, an opposite trend was also observed, with mean Kslab values higher than SSIR values in the clay loam class.

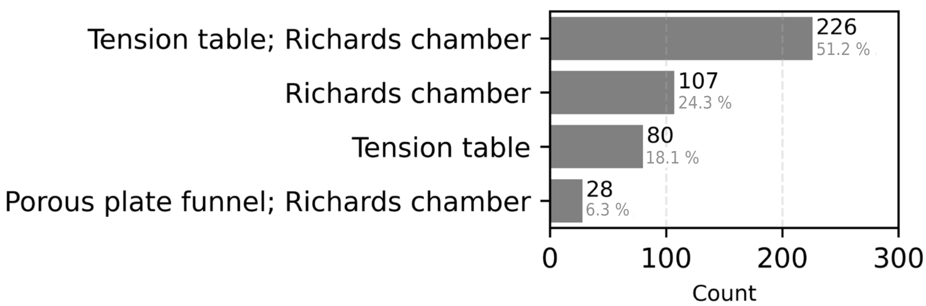

Figure 5. Methods for determining water retention of soil samples from the Ksat-SSIR-DB.

Table 5. Geometric mean of Kfs, SSIR, and Kslab values recorded in Ksat-SSIR-DB and compiled by Gupta et al. (2021) by textural classes and textural groups

Textural Classes	Ksat-SSIR-DB			Gupta et al. (2021)
	Kfs	SSIR	Kslab	Kslab
	mm h^{-1}			
sand	126.3 (22)	-	298 (76)	203.5 (4410)
loamy sand	45.6 (29)	91.9 (17)	64.9 (50)	39.7 (637)
Textural Group COARSE	**70.8** (51)	**135.2** (22)	**162.7** (126)	**165.6** (5047)
sandy loam	60.8 (65)	54.6 (69)	31.9 (159)	16 (1054)
loam	-	-	40.7 (44)	15.8 (226)
silt loam	-	-	31.6 (36)	11 (373)
sandy clay loam	38.4 (105)	49.8 (56)	28.4 (238)	7.3 (821)
silt	-	-	-	6.6 (31)
Textural Group MEDIUM	**45.8** (174)	**50.9** (130)	**30.8** (477)	**11.6** (2505)
clay loam	53.6 (18)	9.6 (16)	25.7 (122)	7.4 (112)
silty clay loam	-	-	30 (30)	5.3 (81)
silty clay	6.3 (7)	-	25.4 (35)	8.5 (57)
sandy clay	15.7 (60)	139.8 (72)	24.7 (156)	4.6 (138)
clay	10.7 (113)	36.6 (71.0)	15.8 (447)	3 (281)
very clayey	50.8 (74)	40.4 (104)	17.9 (449)	-
Textural Group FINE	**19.5** (277)	**52.1** (273)	**18.9** (1239)	**4.5** (669)

Values in parentheses refer to the number of samples recorded in each class. The blue color represents values considered high (>36 mm h^{-1}), orange, moderate (3.6-36 mm h^{-1}), and red, low (<3.6 mm h^{-1}).

The findings described above reinforce the difficulty in establishing reference values for Ksat by textural classes, considering that the method of determining Ksat presents its specificities and methodological uncertainties and that it is not always possible to faithfully reproduce the complex physical hydraulic processes inherent to the intricate soil porous system. Nevertheless, the results in table 5 show trends of orders of magnitude in the values of these properties in the various soil textural classes, which may of use for specific purposes.

Regarding the comparison of Kslab results from the Ksat-SSIR-DB to those compiled by the international soil database (Gupta et al., 2021), much higher values are observed in the medium- and fine-textured groups for the Brazilian soils. In these two textural groups, the Kslab results of the Brazilian soil database were around three to five times greater than that recorded in the international soil database, a discrepancy not observed for soils in the coarse-textured group. In the clayey soil class, it was greater by a factor of 5.3. Presence of silt-sized (Vitorino et al., 2003), as well as sand-sized flocculated clays, containing minerals of high thermodynamic stability, with emphasis on gibbsite (high flocculating power) (Resende, 1982; Ferreira et al., 1999), favors clayey and very clayey highly weathered soils, such as the *Latossolos* (Ferralsols) in Brazil, with high values of macroporosity and water flow. These results emphasize the need for caution when using data on hydraulic properties determined in soils from temperate regions to estimate the hydraulic behavior of Brazilian soils with a finer texture (Hodnett and Tomasella, 2002; Teixeira et al., 2014; Ottoni et al., 2018; Ottoni et al., 2019). Therefore, there is a strong need to develop models for Brazil that estimate the hydraulic properties of soils.

Regarding the Ksat results according to soil class at the first category level of SiBCS (Table 6), there is no defined pattern of ordering the mean values relative to the variables Kfs, Kslab, and SSIR. While for Kfs, the highest mean value occurred in the *Neossolos* (young soils) class (278.4 mm h^{-1}), for Kslab, this occurred in the *Organossolos* (Histosols) class (48.6 mm h^{-1}), and for SSIR in the *Planossolos* (Planosols) class (101.9 mm h^{-1}). *Plintossolos* (Plinthosols) and *Nitossolos* (Nitisols, Lixisols, or Alisols) classes presented the lowest value in one of the three hydraulic variables, with values falling into low to moderate classes (3.6 to 8 mm h^{-1}). Furthermore, in the same soil class, values among the three parameters may be discrepant. In *Neossolos*, for example, the mean Kfs was greater than the mean for other properties (Kslab and SSIR) by around eight times. A similar result occurred in the *Gleissolos* (Gleysols) class, in which the mean Kfs value was around 92 mm h^{-1}, and for Kslab and SSIR it was only 11 and 16 mm h^{-1}, respectively. Even for tests carried out in field, as for Kfs and SSIR, the results may be quite variable. Differences of methodologies on determining the soil hydraulic properties may explain such variability.

Mean values of Kfs, Kslab, and SSIR by land use classes (according to MapBiomas - MapBiomas Project, 2022), only considering the soil samples from the Ksat-SSIR-DB framed as 'topsoils', are shown in table 7. No deeper interpretation of these results was proposed here, as they are possibly biased due to the different soil types and textures within the land use classes. Furthermore, installation time and management practices are likely to be different among Ksat-SSIR-BD's soil samples from the same land use class. The results presented below are more descriptive, highlighting general trends in hydraulic properties across land use classes.

Table 7 shows a clear distinction in the values recorded for the three hydraulic variables for Forest and Pasture classes, the first concentrating higher mean values (blue color) compared to those cataloged at the other classes, as usually expected. The Forest Plantation class recorded mean results of Kfs, Kslab, and SSIR lower than those presented in the Forest class, which is possibly related to human interventions, mainly in the first three years of forestry implementation in the first case. The Agriculture class revealed higher values than those for Pasture class.

The geometric mean values of Kfs, Kslab, and SSIR are recorded in the porosity classes, where the highest values were concentrated in the 0.6-0.7 cm^3 cm^{-3} range, representing high porosity values (Table 8). However, at very high porosities (>0.7 cm^3 cm^{-3}) a low mean Kslab value is noted, close to that recorded for lower porosity classes (0.3-0.4 cm^3 cm^{-3}). The SSIR results were higher than those of Kfs and Kslab in most porosity classes. An increase pattern in SSIR values with increasing porosity value ranges was also not observed. These results suggest that the total porous space, despite enabling the soil to store greater water content, may not be capable of conducting greater water flows under saturation conditions, as shown in table 8. The information presented in the Ksat-SSIR-DB (such as textural classes, soil class, land use classes, etc.) is not sufficient to explain the relationship between porosity and hydraulic conductivity, but we expect that factors such as pore connectivity and soil structure may be influencing. Further investigation based mainly on macroporosity (e.g.: EP) is necessary to clarify relationships between soil pore space and hydraulic conductivity.

Table 6. Geometric mean values of Kfs, Kslab, and SSIR by soil classes in the first categorical level of SiBCS

Soil Classes	Kfs	Kslab	SSIR
	mm h^{-1}		
Latossolos	34.2 (267)	46 (510)	79.7 (159)
Nitossolos	7.8 (11)	6.5 (31)	-
Argissolos	21.8 (137)	28.3 (345)	43.5 (82)
Cambissolos	8.1 (28)	12.1 (266)	46.7 (51)
Neossolos	278.4 (17)	30.8 (219)	36.3 (36)
Luvissolos	-	-	-
Chernossolos	-	-	-
Planossolos	-	18.2 (15)	101.9 (6)
Plintossolos	-	3.6 (15)	-
Vertissolos	-	-	-
Gleissolos	91.6 (13)	11.4 (218)	15.8 (43)
Organossolos		48.6 (8)	
Espodossolos	62.9 (9)	-	-

Values in parentheses indicate the number of soil samples evaluated. Blue color represents values considered high (>36 mm h^{-1}), orange, moderate (3.6-36 mm h^{-1}), and red, low (<3.6 mm h^{-1}).

Table 7. Geometric mean values of Kfs, Kslab, and SSIR for the land use and cover classes of MapBiomas

Land Cover Classes	Kfs	Kslab	SSIR
	mm h^{-1}		
Agriculture	25.0 (98)	39.9 (404)	48.5 (264)
Pasture	9.7 (38)	16.7 (171)	26.1 (45)
Forest	125.6 (43)	78.6 (109)	174.9 (38)
Forest plantation	46.7 (12)	37.7 (35)	112.1 (9)
Non forest natural formation	28.7 (32)	36.4 (65)	90.2 (26)
Non vegetated area	23 (6)	-	43.8 (10)

Values in parentheses indicate the number of soil samples evaluated. The blue color represents values considered high (>36 mm h^{-1}), orange, moderate (3.6-36 mm h^{-1}), and red, low (<3.6 mm h^{-1}).

The results presented for Kfs, Kslab and SSIR averages by different soil groups (Tables 5, 6, 7 and 8) is the first version in Brazil of reference values of such hydraulic properties for soil group classes in which these data are commonly required. To date, there is no information available on these soil variables for Brazilian soils and, in many cases, researchers use data published at international literature (which usually comes from temperate soils), that, as already mentioned, may not represent the tropical soils of Brazil in terms of hydraulic properties. Some general interpretations of the results were made to promote discussion and instigate future investigations, but they are very simplistic and descriptive, and should be viewed with caution for more specific studies. Moreover, the soil groups classes used to compute average Ksat and SSIR are too generic to make very deep interpretations. In the following section, we make a more in-depth assessment of Ksat data variability in these soil groups.

Ksat data variability

Box-plots of Kslab data from the Ksat-SSIR-DB are presented by textural classes, soil classes at first category level of SiBCS, land use classes, and porosity classes (Figure 6). The 10th and 90th percentile values are identified at figure, as an indicator of Ksat values variation in classes of each grouping.

Many classes of the different investigated groupings presented Ksat magnitudes that varied within two orders of magnitude, considering the extreme limits of values contained in each class as 10th and 90th percentiles (Figure 6). The class of very clayey soils, for example, the predominant textural class in the Ksat-SSIR-DB, presented these percentiles from 2.0 to 380 mm h^{-1} (Figure 6a). *Latossolos* and *Neossolos* classes also recorded wide variation, with values of these percentiles between 3.0 and 429 mm h^{-1}, and between 2.0 and 421 mm h^{-1}, respectively (Figure 6b).

The Forest Plantation class was the land use class that stood out in the Ksat data variability (Figure 6c), concentrating values of these percentiles ranging from 4.7 to 2,597 mm h^{-1}. The Ksat data for soil classes at the second category level of SiBCS (Figure 7) show a greater homogenization. It is clear when compared to the variability observed at groupings in figure 6. For example, it can be seen at figure 7 that many soil classes percentile values varied by one order of magnitude (72 % of cases).

Table 8. Geometric mean values of Kfs, Kslab, and SSIR for the porosity classes represented in the Ksat-SSIR-DB

Porosity Classes	Kfs	Kslab	SSIR
		mm h^{-1}	
<0.3 cm^3 cm^{-3}	-	14.1 (7)	-
0.3-0.4 cm^3 cm^{-3}	13.1 (50)	17.4 (187)	61.6 (23)
0.4-0.5 cm^3 cm^{-3}	38.8 (148)	33.5 (522)	53 (71)
0.5-0.6 cm^3 cm^{-3}	30.2 (74)	17.4 (742)	26.7 (120)
0.6-0.7 cm^3 cm^{-3}	38 (36)	40.4 (211)	72 (21)
>0.7 cm^3 cm^{-3}	-	16.8 (28)	40.4 (7)

Values in parentheses indicate the number of soil samples evaluated. The blue color represents values considered high (>36 mm h^{-1}), and the orange, moderate (3.6-36 mm h^{-1}).

Even so, the data variation ranges (between 10th and 90th percentiles) in soil classes at second category level of SiBCS still remain high (Figure 7), suggesting caution when adopting a single mean value of Ksat to represent this soil property in the groupings. Adoption of value ranges between 25th and 75th percentiles and 10th to 90th percentiles, for example, can be investigated in future studies.

Selecting the best soil grouping for estimating Ksat

Figure 8 illustrates the distribution of standard deviation data recorded for each of the grouping classes and their combinations. The weighted mean standard deviations were smaller when considering the discretization of soil classes at the second category level of SiBCS, already expected accordingly to the results previously presented (Figure 7). The groupings with the lowest Ksat standard deviation were the combination of textural classes and soil classes at second category level of SiBCS, and porosity classes and soil classes at second category level of SiBCS. According to the weighted t-test, both weighted mean standard deviations were not statistically different from each other (0.63 and 0.64, respectively), and they were statistically smaller when compared two by two with other groupings. These results indicate that the Ksat values within each of the predicted classes in these two combinations tend to be 4 times ($10^{0.62}$ or $10^{0.63}$ ~ 4) higher and lower than the mean Ksat values recorded in the corresponding classes. For example, the combination of *Latossolo Vermelho* and clayey texture resulted in a geometric mean Ksat of 25.4 mm h^{-1}. From results above, the Ksat values in this group would tend to range approximately from 6.3 mm h^{-1} (25.4/4) to 102 mm h^{-1} (25.4*4), close to that observed for the 10th and 90th percentiles of Ksat recorded in this grouping (3 and 122 mm h^{-1}, respectively).

The groupings with the highest standard deviation in Ksat data were always the isolated groups. Among these, the worst performing was for the porosity group, and the best performing was for the soil class at the second category level of SiBCS. The mean

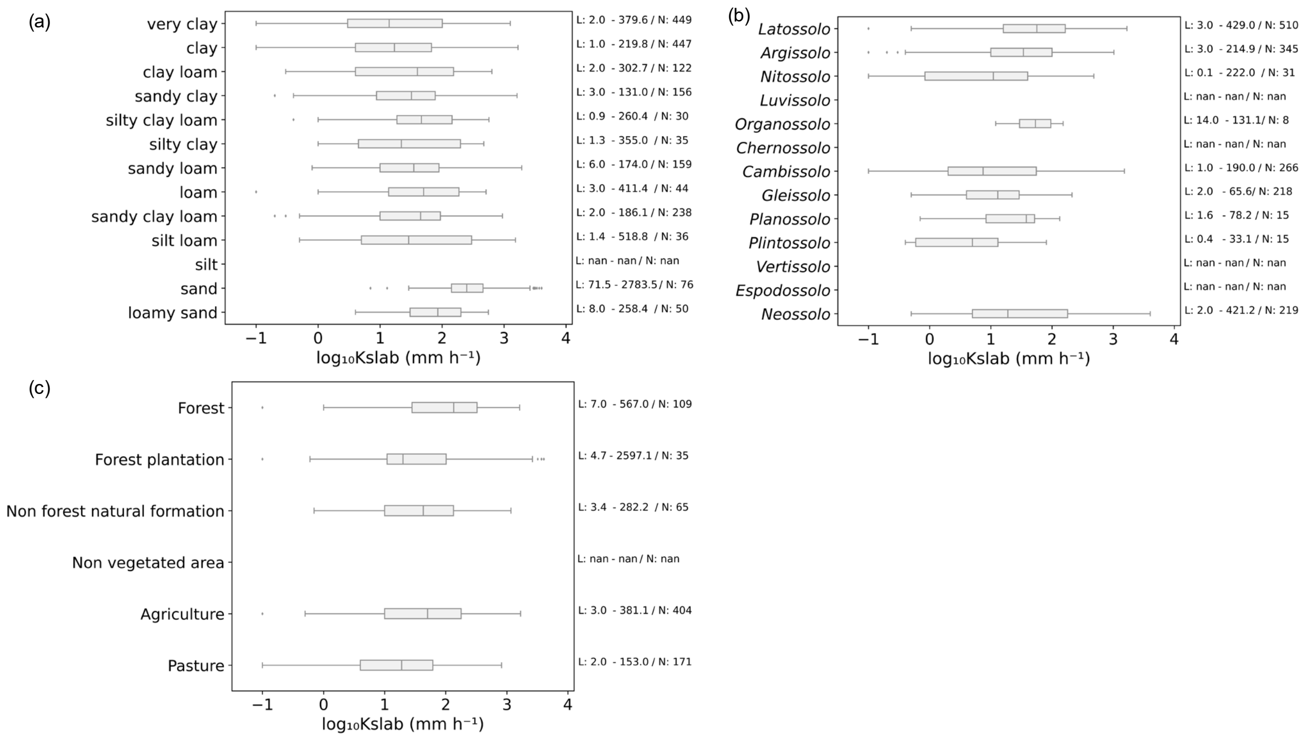

Figure 6. Box-plots of Kslab data by textural classes (a), soil classes in the first categorical level of SiBCS (b); and land use and cover classes according to MapBiomas (c). Values indicated on the right side of the graphs represent the 10th and 90th percentiles of Kslab values (mm h^{-1}) in each grouping (L). Next to these values is indicated the number of soil samples included in each group (N). Groups with a number of samples less than or equal to 5 did not have data presented. nan indicates that there is no data representation.

values (geometric mean) of Ksat for the two best-represented groupings can be found at Supplementary Material (Section C).

Laboratory *versus* field saturated hydraulic conductivity

The records with joint measurements of Kslab and Kfs are presented in figure 9. According to this figure, the Kslab values are clearly greater than Kfs, where each pair refers to measurements of these properties carried out at the same location in the soil profile and, mostly, in clayey soils.

According to de Jong van Lier (2020), greater Kslab values are expected than Kfs values, as pores in a soil profile are unlikely to be fully saturated in field tests. In the laboratory, the saturation process is more controlled, which favors the total expulsion of air trapped in pores. However, this may be time-consuming. In contrast, Gupta et al. (2021), in an evaluation of Ksat data from international soils, reported an inverse tendency (Kfs > Kslab). The authors justified this trend because field tests are capable of reproducing flows in the soil structure in real conditions, a fact that does not occur in laboratory environments. Using data reported by Gupta et al. (2021), comparisons between Kslab

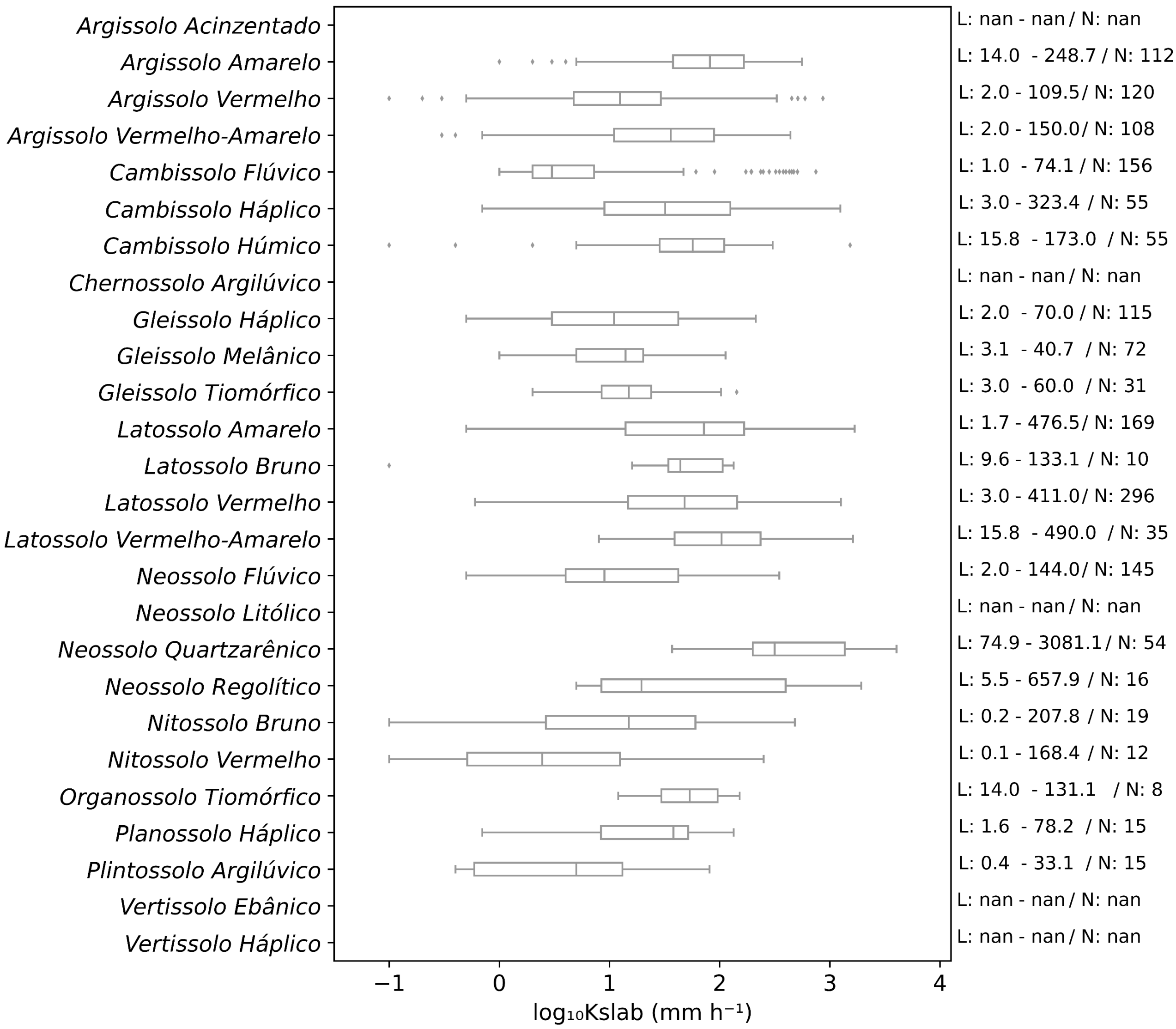

Figure 7. Box-plots of Kslab values for soil classes in the second categorical level of SiBCS. Values indicated on the right side of the graphs represent the 10th and 90th percentiles of Kslab values (mm h^{-1}) in each grouping (L). Next to these values is indicated the number of soil samples included in each group (N). Groups with a number of samples less than or equal to 5 did not have data presented. nan indicates that there is no data representation.

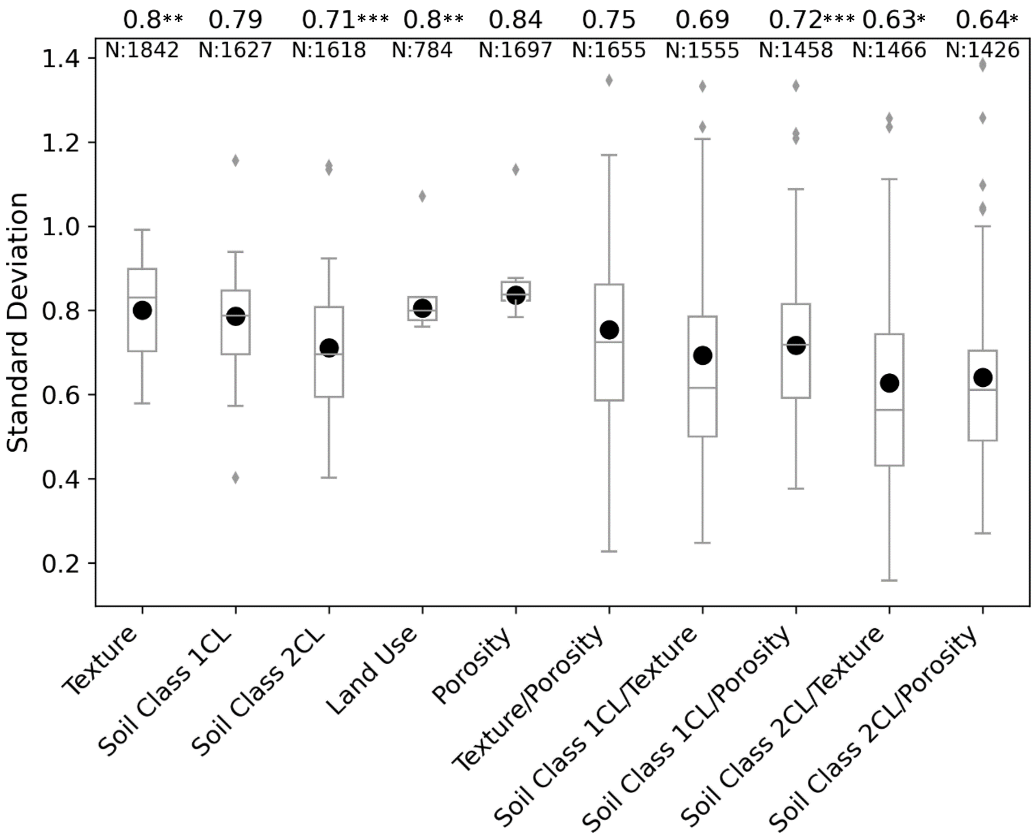

Figure 8. Box-plots of Kslab standard deviation values on a logarithmic basis recorded for the tested groupings and combinations between them. Full black circle indicates the weighted mean standard deviation value, also reproduced at the top of the graph, accompanied by indexes *, **, ***. The same indexes mark significant similarity (p-value≥0.05) between values in the same line, according to the weighted t-test. Soil Class 1CL: soil classes in the first categorical level of SiBCS; Soil Class 2CL: soil classes in the second categorical level of SiBCS.

and Kfs were carried out for mean values computed in three groupings of textural classes, not considering the measurements of these variables carried out in the same location, as investigated in the present study.

In *Latossolos* in the Cerrado and Forest biomes vertical cracks are common, and in *Nitossolos* in the Forest biome, both vertical and horizontal cracks are frequent, all these cracks resulting from drying out in the dry season. Also, in *Vertissolos* (Vertisols) and other soils with high clay activity, cracks are common features in the dry period. These aspects add variability to Ksat measurements in the field.

Comparative investigation on methods to obtain Ksat should be considered to guide the most suitable methods for different users. For example, if the goal is to develop mathematical models for Ksat prediction, Ksat data obtained by laboratory methods is possibly the most recommended. Such conclusion comes from the fact that Kslab measurements occur in soil samples extracted at the same location as those used to measure the predictor properties, allowing direct relationships to be established between Ksat and soil properties. These direct relationships between Ksat and predictor properties are impaired for Kfs data, since their determination involves the entire soil profile. To measure Kslab with the greatest possible reproducibility of the soil structure, sampling rings with adequate size must be chosen (Jafari et al., 2017; Kaminski et al., 2023). Several research efforts have shown high variability of saturated hydraulic conductivity values among samples collected even close to each other. This is partially related to the volume of the soil samples, normally 100 cc (5 cm height and 5 cm diameter). This is smaller than the representative volume (REV) suggested to measure Kslab for many soils (Bear, 1972; Lauren et al., 1998; Teixeira, 2001). For example, Khodaverdiloo et

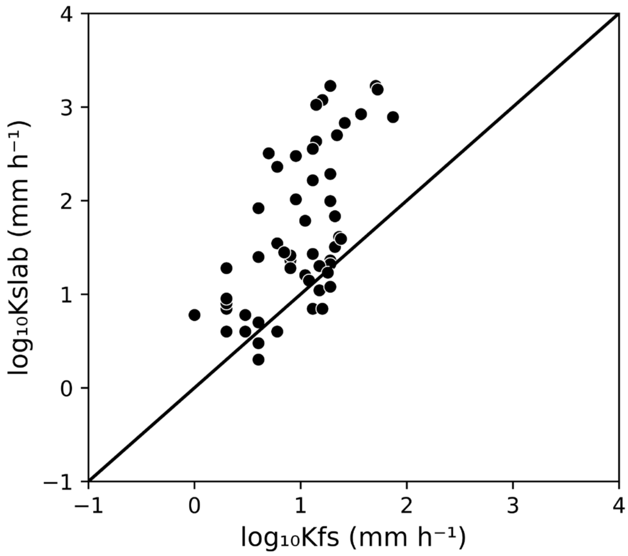

Figure 9. Comparison between the values of Kslab and Kfs in the Ksat-SSIR-DB.

al. (2017) reported that hydraulic conductivity increased 2.3 times as ring diameter varied from 5.5 to 31.8 cm. This variation can be explained by preferential flow of water through the space between soil sample and ring wall. The open-ended macropores over the length of soil samples may cause piping effects, i.e., soil particles are carried out from sample opening space for larger water flow (Mohanty et al., 1994). Anderson and Bouma (1973) also demonstrated relationships between Kslab and core height. High variability in Kslab reflects not only the true variability of Ksat but also bias introduced by the method (Teixeira, 2001; Ghanbarian et al., 2015; Kaminski et al., 2023).

Conversely, if one wants to know the hydrodynamic nature of soil, Kfs measurements are very useful, as they involve the entire soil profile. Besides, for many practical problems of large-scale significance, an estimation of Ksat relative to the whole soil profile may be more useful than a precise estimation of Kslab of one soil horizon. However, the limitations of these *in situ* methods are known, starting with the long time demanded to saturate the soil and the various theoretical simplifications in Kfs calculation procedures, such as the assumptions of isotropic flow, soil profile homogeneity, and initial water content homogeneity along the profile.

Limitations of the Ksat-SSIR-BD

The Ksat-SSIR-BD was developed through the transfer of data by several partners in this project, who were not always able to inform the positioning of the soil samples accurately. This location accuracy of the database sample points becomes important when one intends to interpolate Ksat data in a certain area or region of interest, or to extract geoenvironmental information to be used as predictor variables in Ksat prediction models.

Applications of the Ksat-SSIR-BD

The immediate application of this database consists of Ksat and SSIR values being easily available. Developing and testing different Ksat prediction models for soils of Brazilian territory, using machine learning techniques, as the so-called pedotransfer functions, are also important applications. Another relevant application, especially for distributed hydrological and climatological modeling studies at the national level, is the generation of maps of these hydraulic properties in Brazil, which can be developed based on Ksat pedotransfer functions and raster maps of potential predictors, recently (in 2021) made available on the Embrapa website (https://geoinfo.dados.embrapa.br/#/). The mean Ksat results for the different groupings are also relevant as a source of reference for different geoenvironmental applications and particularly for lumped and semi-distributed land surface modeling.

Recommendation for data reusability

A detailed description of the sampling site and the methods of determination of soil properties measured in the field and/or in the laboratory is crucial for a comprehensive soil investigation and subsequent data reuse. In the case of Kfs and SSIR determinations we suggest detail description of the in situ test, including the procedures for installation and operation of the equipament at field. Photos of the experiment should also be provided to enhance the understanding of field procedures. For Kslab measurements, the sample size must be informed along with soil sampling depths and number of replicates, if any. Soil sampler driving procedure should also be detailed to provide information on soil structure preservation. The Brazilian Soil Science Society (SBCS), along with other relevant research institutions like universities, Embrapa, Geological Survey of Brazil, and State Research Stations, should consider standardizing these descriptions.

CONCLUSIONS

The Ksat-SSIR-DB presents 2,579 soil records, with information on saturated hydraulic conductivity – from laboratory and field experiments – and on steady-state infiltration rate. The average values of Ksat and SSIR of soil classes at the first category level of SiBCS, as well as textural and porosity classes and land use classes are provided. Variability of the Ksat data in these groups (including the soil classes at the second category level of SiBCS) was also investigated, showing wide variation in values within classes of these groupings. Indication of groupings or combinations among them that best represented Ksat data was also presented. The two combinations that recorded less variability in Ksat data were soil class at the second category level of SiBCS with textural class, and soil class at the second category level of SiBCS with porosity class.

The great difference between the Ksat values in most Brazilian clayey and very clayey soils compared to clayey soils from temperate regions is worth noting. The Ksat values are consistently much higher in clayey Brazilian soils, possibly due to the strong aggregation of clay particles provided by iron and aluminum oxides.

Comparisons between pairs of Kfs and Kslab values from measurements carried out at the same location in the soil profile indicate that Ksat is a hydraulic property that must be measured according to the hydrological process that is aimed to be reproduced.

Adoption of Ksat values from international literature in irrigation, hydrology, soil conservation procedures, and lining of landfill projects in Brazil, for example, is subject to high inaccuracy. The Ksat-SSIR-DB has potential for diverse applications, including the development and testing of Ksat pedotransfer functions in Brazilian soils, and generation of national maps of this soil hydraulic property. Recommendations for researchers on how to better document their data for improved reusability were provided.

SUPPLEMENTARY MATERIALS

Supplementary data to this article can be found online at https://www.rbcsjournal.org/wp-content/uploads/articles_xml/1806-9657-rbcs-49-e0240003/1806-9657-rbcs-49-e0240003-suppl01.pdf

DATA AVAILABILITY

Ksat-SSIR-DB is an open access database and can be reached at the link https://www.sgb.gov.br/ksat-ssir-db-base-de-dados-de-condutividade-hidraulica-saturada-e-de-taxa-de-infiltracao-basica-em-solos-brasileiros, which also includes the python script for data analysis.

ACKNOWLEDGEMENTS

We gratefully thank the Editor and Reviewers for their valuable comments. We also thank Dr. Luiz Antonio Lima, full professor from the Federal University of Lavras (UFLA)/Brazil, and Dr Quirijn de Jong van Lier, full professor from the University of São Paulo (CENA/USP)/Brazil, for their comments that have improved the quality of this paper. We also acknowledge the Brazilian Soil Science Society for allowing the creation of the working group that compiled the Ksat-SSIR-DB. The study was supported by TED No. 016/CPRM/2021, signed between The Geological Survey of Brazil (SGB/CPRM) and Federal University of Lavras (UFLA), with Zetta UFLA Agency for Innovation, Geotechnology and Intelligent Systems as the executing unit.

AUTHOR CONTRIBUTIONS

Conceptualization: Marta Vasconcelos Ottoni (equal) and Wenceslau Geraldes Teixeira (equal).

Data curation: Ademir Fontana (equal), Adriana Monteiro da Costa (equal), Alba Leonor da Silva Martins (equal), Aline Mari Huf dos Reis (equal), Gabrielle Fernandes de Brito (equal), Glenio Guimarães Santos (equal), Jackson Adriano Albuquerque (equal), Jean Dalmo de Oliveira Marques (equal), Jeane Cruz Portela (equal), João Herbert Moreira Viana (equal), José Coelho de Araújo Filho (equal), José Miguel Reichert (equal), Karina Maria Vieira Cavalieri-Polizeli (equal), Letícia Guimarães Pimentel (equal), Lucas de Castro Medrado (equal), Luciana Rodrigues Souza (equal), Luís Gustavo Henriques do Amaral (equal), Margareth Lopes de Moraes (equal), Marlen Barros e Silva (equal), Marta Vasconcelos Ottoni (equal), Michele Bruna de Souza do Nascimento (equal), Milson Evaldo Serafim (equal), Norberto Cornejo Noronha (equal), Pablo Nieto Campos (equal), Pedro Gomes de Campos do Valle (equal), Ricardo Duarte de Oliveira (equal), Silvio Barge Bhering (equal), Sueli Rodrigues (equal), Valdinar Ferreira Melo (equal), Wenceslau Geraldes Teixeira (equal) and Wilk Sampaio de Almeida (equal).

Formal analysis: Ademir Fontana (equal), Aline Mari Huf dos Reis (equal), Glenio Guimarães Santos (equal), Letícia Guimarães Pimentel (equal), Lucas de Castro Medrado (equal), Lúcia Helena Cunha dos Anjos (equal), Marta Vasconcelos Ottoni (equal), Nilton Curi (equal) and Wenceslau Geraldes Teixeira (equal).

Investigation: Aline Mari Huf dos Reis (equal), Letícia Guimarães Pimentel (equal), Marta Vasconcelos Ottoni (equal), Nilton Curi (equal) and Wenceslau Geraldes Teixeira (equal).

Methodology: Aline Mari Huf dos Reis (equal), Letícia Guimarães Pimentel (equal), Luciana Rodrigues Souza (equal), Marta Vasconcelos Ottoni (equal) and Wenceslau Geraldes Teixeira (equal).

Project administration: Marta Vasconcelos Ottoni (equal), Nilton Curi (equal) and Wenceslau Geraldes Teixeira (equal).

Supervision: Marta Vasconcelos Ottoni (equal) and Wenceslau Geraldes Teixeira (equal).

Visualization: Marta Vasconcelos Ottoni (equal) and Wenceslau Geraldes Teixeira (equal).

Writing – original draft: Marta Vasconcelos Ottoni (equal)

Writing – review & editing: Jackson Adriano Albuquerque (equal), João Herbert Moreira Viana (equal), José Miguel Reichert (equal), Karina Maria Vieira Cavalieri-Polizeli (equal), Lúcia Helena Cunha dos Anjos (equal), Marta Vasconcelos Ottoni (equal), Nilton Curi (equal), Valdinar Ferreira Melo (equal) and Wenceslau Geraldes Teixeira (equal).

REFERENCES

Aguiar MI. Qualidade física do solo em sistemas agroflorestais [dissertation]. Viçosa, MG: Universidade Federal de Viçosa; 2008.

Agyare WA, Park SJ, Vlek PLG. Artificial neural network estimation of saturated hydraulic conductivity. Vadose Zone J. 2007;6:423-31. https://doi.org/10.2136/vzj2006.0131

Ahuja LR, Cassel DK, Bruce RR, Barnes BB. Evaluation of spatial distribution of hydraulic conductivity using effective porosity data. Soil Sci. 1989;148:404-11. https://doi.org/10.1097/00010694-198912000-00002

Almeida EL. Medida da condutividade hidráulica e curva de retenção de água por diferentes métodos e predição de atributos físicos do solo pela krigagem [dissertation]. Fortaleza: Universidade Federal do Ceará; 2013.

Almeida WS, Panachuki E, Oliveira PTS, Menezes RS, Alves Sobrinho T, Carvalho DF. Effect of soil tillage and vegetal cover on soil water infiltration. Soil Till Res. 2018;175:130-8. https://doi.org/10.1016/j.still.2017.07.009

Alves MC, Cabeda MSV. Infiltração de água em um Podzólico Vermelho-Escuro sob dois métodos de preparo usando chuva simulada com duas intensidades. Rev Bras Cienc Solo. 1999;23:753-61. https://doi.org/10.1590/S0100-06831999000400001

Alves Sobrinho T, Vitorino ACT, Souza LCF, Gonçalves MC, Carvalho DF. Infiltração de água no solo em sistemas de plantio direto e convencional. Rev Bras Eng Agr Amb. 2003;7:191-6. https://doi.org/10.1590/S1415-43662003000200001

Amaral JR. Caracterização físico-hídrica dos solos da bacia do Córrego Marinheiro, Sete Lagoas - MG [dissertation]. Belo Horizonte: Universidade Federal de Minas Gerais; 2018.

Amorim DD, Gontijo I, Santos EOJ, Nicole LR. Correlação espacial entre a condutividade hidráulica e atributos físicos do solo. Encicl Biosfera. 2011;7:263-5.

Anderson JL, Bouma J. Relationships between saturated hydraulic conductivity and morphometric data of an argilic horizon. Soil Sci Soc Am J. 1973;37:408-13. https://doi.org/10.2136/sssaj1973.03615995003700030029x

Anderson SH. Tomography-measured macropore parameters to estimate hydraulic properties of porous media. Procedia Comput Sci. 2014;36:649-54. https://doi.org/10.1016/j.procs.2014.09.069

Andognini J, Albuquerque JA, Warmling MI, Teles JS, Silva GB. Soil compaction effect on black oat yield in Santa Catarina, Brazil. Rev Bras Cienc Solo. 2020;44:e0190157. https://doi.org/10.36783/18069657rbcs20190157

Andrade CAO, Silva GC, Corrêa MC, Collier LS, Correchel V. Condutividade hidráulica e atributos físicos de um Latossolo Vermelho sob sistemas de manejo no cerrado Goiano. Agrarian. 2020;13:385-92. https://doi.org/10.30612/agrarian.v13i49.9519

Andrade RS, Stone LF. Uso do índice S na determinação da condutividade hidráulica não-saturada de solos do cerrado brasileiro. Rev Bras Eng Agr Amb. 2009;13:376-81. https://doi.org/10.1590/S1415-43662009000400002

Andriollo DD. Florística, solos e abundância isotópica de ^{13}C em áreas de floresta e de campo no Bioma Pampa [dissertation]. Santa Maria: Universidade Federal de Santa Maria; 2015.

Angelotti Netto A, Fernandes EJ. Condutividade hidráulica de um Latossolo Vermelho em pousio e cultivo intensivo. Pesq Agropec Bras. 2005;40:797-802. https://doi.org/10.1590/S0100-204X2005000800010

Aquino RNA. Utilização de espécies vegetais na recuperação de solo sob área degradada Manaus-AM [dissertation]. Manaus: Universidade Federal do Amazonas; 2012.

Avila CB. Variação da infiltração devido a alterações de uso do solo: Estudo de caso de implantação de floresta em bioma Pampa [dissertation]. Santa Maria: Universidade Federal de Santa Maria; 2014.

Bagarello V, Cecere N, David SM, Prima SDi. Determining short-term changes in the hydraulic properties of a sandy-loam soil by a three-run infiltration experiment. Hydrolog Sci J. 2020;65:1191-203. https://doi.org/10.1080/02626667.2020.1735637

Batista KD, Lumbreras JF, Coelho MR, Oliveira VA, Vale Júnior JF. Guia de campo da XI Reunião Brasileira de Classificação e Correlação de Solos: RCC de Roraima. Brasília, DF: Embrapa; 2018.

Bear J. Dynamics of fluids in porous media. New York: Dover Publications; 1972.

Bernardes RS. Condutividade hidráulica de três solos da região norte fluminense [dissertation]. Rio de Janeiro: Universidade Estadual do Norte Fluminense Darcy Ribeiro; 2005.

Berreta ALO. Condutividade hidráulica obtida pelo método do perfil instantâneo utilizando curva de retenção e sonda de nêutrons e pelo modelo de Genuchten [dissertation]. São Paulo: Universidade de São Paulo; 1999.

Bertol I, Beutler JF, Leite D, Batistela O. Propriedades físicas de um Cambissolo Húmico afetadas pelo tipo de manejo do solo. Sci Agric. 2001;58:555-60. https://doi.org/10.1590/S0103-90162001000300018

Bertol I, Santos JCP. Uso do solo e propriedades físico-hídricas no planalto catarinense. Pesq Agropec Bras. 1995;30:263-7.

Bhering SB. Influência do manejo do solo e da dinâmica da água no sistema de produção do tomate de mesa: subsídios à sustentabilidade agrícola do Noroeste Fluminense [thesis]. Rio de Janeiro: Universidade Federal do Rio de Janeiro; 2007.

Bilardi S, Ielo D, Moraci N. Predicting the saturated hydraulic conductivity of clayey soils and clayey or silty sands. Geosciences. 2020;10:393. https://doi.org/10.3390/geosciences10100393

Bocuti ED, Amorim RSS, Raimo LADiLDi, Magalhães WA, Azevedo EC. Effective hydraulic conductivity and its relationship with the other attributes of Cerrado soils. Rev Bras Eng Agr Amb. 2020;24:357-63. https://doi.org/10.1590/1807-1929/agriambi.v24n6p357-363

Boeno D. Fluxo lateral na infiltração de água medida com duplo anel concêntrico [dissertation]. Santa Maria: Universidade Federal de Santa Maria; 2019.

Bono JAM, Macedo MCM, Tormena CA, Nanni MR, Gomes EP, Müller MML. Infiltração de água no solo em um Latossolo Vermelho da região sudeste dos cerrados com diferentes sistemas de uso e manejo. Rev Bras Cienc Solo. 2012;36:1845-53. https://doi.org/10.1590/S0100-06832012000600019

Borges TA, Oliveira FA, Silva EM, Goedert WJ. Avaliação de parâmetros físico-hídricos de Latossolo Vermelho sob pastejo e sob Cerrado. Rev Bras Eng Agr Amb. 2009;13:18-25. https://doi.org/10.1590/S1415-43662009000100003

Borkowski JP, Silva PJ. Infiltração de água em solos sob uso agrícola e pousio no estado do Amapá [tcc]. Macapá: Universidade Federal Rural da Amazônia; 2021. Available from: https://bdta.ufra.edu.br/jspui/bitstream/123456789/1825/1/Infiltra%C3%A7%C3%A3o%20de%20%C3%A1gua%20em%20solos%20sob%20uso%20agr%C3%ADcola%20e%20pousio%20no%20Estado%20do%20Amap%C3%A1.pdf.

Bortolini D, Albuquerque JA, Rech C, Mafra AL, Ribeiro Filho HMN, Pértile P. Propriedades físicas do solo em sistema de integração lavoura pecuária em Cambissolo Húmico. Rev Cienc Agrovet. 2016;15:60-7. https://doi.org/10.5965/223811711512016060

Bouma J. Using soil survey data for quantitative land evaluation. Adv Soil Sci. 1989;9:177-213. https://doi.org/10.1007/978-1-4612-3532-3_4

Camargo ES. Manejo conservacionista do solo com rotação de culturas para cebola [dissertation]. Lages: Universidade do Estado de Santa Catarina; 2011.

Campos PM. Influência físico-hídrica nos atributos diagnósticos em Latossolos do Distrito Federal [dissertation]. Brasília, DF: Universidade de Brasília; 2009.

Carsel RF, Parrish RS. Developing joint probability distributions of soil water retention characteristics. Water Resour Res. 1988;24:755-69. https://doi.org/10.1029/WR024i005p00755

Cassel DK, Ratliff LF, Ritchie JT. Models for estimating in-situ potential extractable water using soil physical and chemical properties. Soil Sci Soc Am J. 1983;47:764-9. https://doi.org/10.2136/sssaj1983.03615995004700040031x

Cavalli JP. Produtividade de *Eucalyptus saligna* com base nas propriedades físico-hídricas do solo e parametrização do modelo ecofisiológico 3-PG [thesis]. Santa Maria: Universidade Federal de Santa Maria; 2017.

Cavedon AD, Sommer S. Jardim Botânico de Brasília, DF: Levantamento semidetalhado dos solos escala 1:10.000. Brasília, DF: Fundação Zoobotânica do Distrito Federal; 1990. Available from: https://www.infraestruturameioambiente.sp.gov.br/institutodebotanica/1990/01/jardim-botanico-de-brasilia-levantamento-semidetalhado-dos-solos-escala-110-000/.

Centeno LN, Timm LC, Reichardt K, Beskow S, Caldeira TL, Oliveira LM, Wendroth O. Identifying regionalized co-variate driving factors to assess spatial distributions of saturated soil hydraulic conductivity using multivariate and state-space analyses. Catena. 2020;191:104583. https://doi.org/10.1016/j.catena.2020.104583

Cintra FLD. Disponibilidade de água no solo para porta-enxertos de citros em ecossistema de Tabuleiro Costeiro [thesis]. Piracicaba: Escola Superior de Agricultura "Luiz de Queiroz"; 1997.

Coelho MR, Fidalgo ECC, Araújo FO, Santos HG, Santos MLM, Pérez DV, Moreira FMS. Levantamento pedológico de uma área-piloto relacionada ao Projeto BiosBrasil (Conservation and sustainable management of Below-Ground Biodiversity: phase I), município de Benjamin Constant (AM): Janela 6. Rio de Janeiro: Embrapa Solos; 2005. (Boletim de pesquisa e desenvolvimento, 68).

Cooper M, Medeiros JC, Rosa JD, Soria JE, Toma RS. Soil functioning in a toposequence under rainforest in São Paulo, Brazil. Rev Bras Cienc Solo. 2013;37:392-9. https://doi.org/10.1590/S0100-06832013000200010

Cooper M, Rosa JD, Medeiros JC, Oliveira TC, Toma RS, Juhász CEP. Hydro-physical characterization of soils under tropical semi-deciduous forest. Sci Agric. 2012;69:152-9. https://doi.org/10.1590/S0103-90162012000200011

Corrêa JC. Características físicas de um Latossolo Amarelo muito argiloso (Typic Acrorthox) do estado do Amazonas, sob diferentes métodos de preparo do solo. Pesq Agropec Bras. 1985;20:1381-7.

Cosby BJ, Hornberger GM, Clapp RB, Ginn TR. A statistical exploration of the relationships of soil-moisture characteristics to the physical-properties of soils. Water Resour Res. 1984;20:682-90. https://doi.org/10.1029/WR020i006p00682

Costa A, Albuquerque JA, Costa A, Warmling MT, Magro BA. Pine harvest impact on soil structure of a Dystric Cambisol. Rev Bras Cienc Solo. 2016;40:e0140643. https://doi.org/10.1590/18069657rbcs20140643

Costa FS, Albuquerque JA, Bayer C, Fontoura SMV, Wobeto C. Propriedades físicas de um Latossolo Bruno afetados pelos sistemas plantio direto e preparo convencional. Rev Bras Cienc Solo. 2003;27:527-35. https://doi.org/10.1590/S0100-06832003000300014

Costa JD, Portela JC, Farias PKP, Medeiros JF, Soares Dias PM, Melo SB, Batista RO, Gondim JRF, Ribeiro MA. Physical indicators of Cambisols under agricultural uses in Chapada do Apodi, semiarid region of Brazil. J Agric Sci. 2020;12:170-81. https://doi.org/10.5539/jas.v12n6p170

Cunha FN, Silva NF, Moura LMF, Teixeira MB, Carvalho JJ, Silva RT. Influência da difusividade e condutividade hidráulica na infiltração de água em um Latossolo Vermelho sob diferentes sistemas de cultivo. Rev Bras Agric Irrig. 2015;9:102-12. https://doi.org/10.7127/rbai.v9n300276

Dalbianco L. Variabilidade espacial e estimativa da condutividade hidráulica e caracterização físico-hídrica de uma microbacia hidrográfica rural [dissertation]. Santa Maria: Universidade Federal de Santa Maria; 2009.

de Jong van Lier QJ. Física do solo - baseada em processos. Piracicaba: Edição do autor; 2020.

Dias PMS. Levantamento de solos e classificação da capacidade de uso das terras no projeto de assentamento Moacir Lucena, Apodi-RN [thesis]. Mossoró: Universidade Federal Rural do Semi-Árido; 2018.

Duan R, Fedler CB, Borrelli J. Comparison of methods to estimate saturated hydraulic conductivity in Texas soils with grass. J Irrig Drain Eng. 2012;138:322-7. https://doi.org/10.1061/(ASCE)IR.1943-4774.0000407

Ebrahimi M, Moradi SA. Comparison of Guelph Permeameter and Double Ring Infiltrometer Methods for estimating the saturated hydraulic conductivity in sandy soils. Int J Res Eng Adv Tec. 2015;3:218-22.

Eger GZS, Silva Junior GC, Marques EAG, Leão BRC, Rocha DGTB, Gilmore TE, Amaral LGH, Silva JAO, Neale C. Recharge assessment in the context of expanding agricultural activity: Urucuia Aquifer System, western state of Bahia, Brazil. J South Am Earth Sci. 2021;112:106601. https://doi.org/10.1016/j.jsames.2021.103601

Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina – Epagri, Empresa Brasileira de Pesquisa Agropecuária - Embrapa Solos. Guia de Excursão da VIII Reunião Nacional de Correlação e Classificação de Solos. Santa Catarina. Brasília, DF: Embrapa; 2008.

Espírito Santo FRC. Retenção e transmissão de água em um Latossolo roxo sob diferentes sistemas de cultivo [thesis]. Piracicaba: Universidade de São Paulo; 1998. https://doi.org/10.11606/T.11.2020.tde-20200111-132330

Fabian AJ, Ottoni Filho TB. Determinação de curvas de infiltração usando uma câmara de fluxo. Rev Bras Cienc Solo. 1997;21:325-33.

Facco R. Influência dos parâmetros físico-hídricos do solo na conformação das vertentes na formação Santa Maria (membro Alemoa) no bairro Camobi e distrito de Pains, Santa Maria, RS [dissertation]. Santa Maria: Universidade Federal de Santa Maria; 2017.

Faria RT, Caramori PH. Caracterização físico-hídrica de um Latossolo Roxo distrófico do município de Londrina, PR. Pesq Agropec Bras. 1986;21:1303-11.

Farias PKP. Caracterização, classificação e as inter-relações entre os atributos do solo em agroecossistemas, Martins-RN [thesis]. Mossoró: Universidade Federal Rural do Semi-Árido; 2019. Available from: https://repositorio.ufersa.edu.br/handle/prefix/5409.

Feng S, Vardanega PJ. Correlation of the hydraulic conductivity of fine-grained soils with water content ratio using a database. Environ Geot. 2019;6:253-68. https://doi.org/10.1680/jenge.18.00166

Ferreira MM, Fernandes B, Curi N. Influência da mineralogia da fração argila nas propriedades físicas de Latossolos da região sudeste do Brasil. Rev Bras Cienc Solo. 1999;23:515-24. https://doi.org/10.1590/S0100-06831999000300004

Fontana A, Teixeira WG, Balieiro FC, Moura TPA, Menezes AR, Santana CI. Características e atributos de Latossolos sob diferentes usos na região oeste do estado da Bahia. Pesq Agropec Bras. 2016;51:1457-65. https://doi.org/10.1590/S0100-204X2016000900044

García-Gutiérrez C, Pachepsky Ya, Martín MA. Saturated hydraulic conductivity and textural heterogeneity of soils. Hydrol Earth Syst Sci. 2018;22:3923-32. https://doi.org/10.5194/hess-22-3923-2018

Ghanbarian B, Taslimitehrani V, Dong G, Pachepsky YA. Sample dimensions effect on prediction of soil water retention curve and saturated hydraulic conductivity. J Hydrol. 2015;528:127-37. https://doi.org/10.1016/j.jhydrol.2015.06.024

Ghiberto PJ, Moraes SO. Comparação de métodos de determinação da condutividade hidráulica em um Latossolo Vermelho-Amarelo. Rev Bras Cienc Solo. 2011;35:1177-88. https://doi.org/10.1590/S0100-06832011000400011

Gomes AS. Relações Solo-Água em solos argilosos-escuros da Campanha Sudoeste do Rio Grande do Sul [dissertation]. Porto Alegre: Universidade Federal do Rio Grande do Sul; 1972.

Gootman KS, Kellner E, Hubbart JA. A comparison and validation of saturated hydraulic conductivity models. Water. 2020;12:2040. https://doi.org/10.3390/w12072040

Gravina OS. Atributos físicos e hídricos do solo em ambientes de produção de cana-de-açúcar fertirrigada [dissertation]. Goiânia: Universidade Federal de Goiás; 2021.

Guerra AS, Campanharo A, Vignatti R, Bonomo R, Souza JM. Condutividade hidráulica do solo em área de cultivo de café Conilon submetida a subsolagem. In: Anais do 44º Congresso Brasileiro de Pesquisas Cafeeiras, 2018 Oct 23-26; Franca, São Paulo, Brazil; 2018. Brasília, DF: Embrapa Café; 2018. Available from: http://www.sbicafe.ufv.br/bitstream/handle/123456789/11661/210_44-CBPC-2018.pdf?sequence=1.

Gupta S, Hengl T, Lehmann P, Bonetti S, Or D. SoilKsatDB: Global database of soil saturated hydraulic conductivity measurements for geoscience applications. Earth Syst Sci Data. 2021;13:1593-612. https://doi.org/10.5194/essd-13-1593-2021

Hillel D. Environmental soil physics: Fundamentals, applications, and environmental considerations. Cambridge: Academic Press; 1998.

Hohenbrink TL, Jackisch C, Durner W, Germer K, Iden SC, Kreiselmeier J, Leuther F, Metzger JC, Naseri M, Peters A. Soil water retention and hydraulic conductivity measured in a wide saturation range. Earth Syst Sci Data. 2023;15:4417-32. https://doi.org/10.5194/essd-15-4417-2023

Horta A, Oliveira AR, Azevedo L, Ramos TB. Assessing the use of digital soil maps in hydrological modeling for soil-water budget simulations - implications for water management plans in southern Portugal. Geoderma R. 2024;36:e00741. https://doi.org/10.1016/j.geodrs.2023.e00741

IUSS Working Group WRB. World reference base for soil resources. International soil classification system for naming soils and creating legends for soil maps. 4th ed. Vienna, Austria: International Union of Soil Sciences; 2022.

Iversen BV, Lamandé M, Torp SB, Greve MH, Heckrath G, Jonge LW, Moldrup P, Jacobsen OH. Macropores and macropore transport: Relating basic soil properties to macropore density and soil hydraulic properties. Soil Sci. 2012;177:535-42. https://doi.org/10.1097/SS.0b013e31826dd155

Jafari R, Sheikh V, Hossein-Alizadeh M, Rezaii-Moghadam H. Effect of soil sample size on saturated soil hydraulic conductivity. Commun Soil Sci Plant Anal. 2017;48:908-19. https://doi.org/10.1080/00103624.2017.1323086

Juhász CEP, Cooper M, Cursi PR, Ketzer AO, Toma RS. Savanna woodland soil micromorphology related to water retention. Sci Agric. 2007;64:344-54. https://doi.org/10.1590/S0103-90162007000400005

Kaminski SJ, Ghanbarian B, Kulesza S, Iversen BoV, Patrignani A. Estimating scale dependence of saturated hydraulic conductivity in soils. Geoderma. 2023;436:116532. https://doi.org/10.1016/j.geoderma.2023.116532

Khodaverdiloo H, Cheraghabdal HK, Bagarello V, Iovino M, Asgarzadeh H, Dashtaki SG. Ring diameter effects on determination of field-saturated hydraulic conductivity of different loam soils. Geoderma. 2017;303:60-9. https://doi.org/10.1016/j.geoderma.2017.04.031

Klein VA. Propriedade físico-hídrico-mecânicas de um Latossolo Roxo, sob diferentes sistemas de uso e manejo [thesis]. Piracicaba: Universidade de São Paulo; 1998. https://doi.org/10.11606/T.11.2020.tde-20200111-151027

Lauren JG, Wagenet RJ, Bouma J, Wosten JHM. Variability of saturated hydraulic conductivity in a Glossaquic Hapludalf with macropores. Soil Sci. 1988;145:20-8. https://doi.org/10.1097/00010694-198801000-00003

Leal IF. Classificação e mapeamento físico-hídricos de solos do assentamento agrícola Sebastião Lan II, Silva Jardim - RJ [dissertation]. Rio de Janeiro: Universidade Federal do Rio de Janeiro; 2011.

Leonardo HCL. Funcionamento hidropedológico de uma topossequência e a produção de água em uma bacia hidrográfica de primeira ordem no oeste paranaense [thesis]. Piracicaba: Universidade de São Paulo; 2020.

Lumbreras JF. Regime hídrico do solo sob cobertura de floresta e de eucalipto na pré-amazônia maranhense [dissertation]. Seropédica: Universidade Federal Rural do Rio de Janeiro; 1996.

Maia JLT, Ribeiro MR. Propriedades de um Argissolo Amarelo fragipânico de Alagoas sob cultivo contínuo de cana-de-açúcar. Pesq Agropec Bras. 2004;39:79-87. https://doi.org/10.1590/S0100-204X2004000100012

MapBiomas Project. MapBiomas General "Handbook" Algorithm Theoretical Basis Document (ATBD) - Collection 7 – Version 1.0 [internet]; 2022. Available from: https://brasil.mapbiomas.org/.

Marques FA. Caracterização e classificação de solos da ilha de Fernando de Noronha (PE) [dissertation]. Recife: Universidade Federal Rural de Pernambuco; 2004.

Marques JDO, Libardi PL, Teixeira WG, Reis AM. Estudo de parâmetros físicos, químicos e hídricos de um Latossolo Amarelo, na região Amazônica. Acta Amazon. 2004;34:145-54. https://doi.org/10.1590/S0044-59672004000200002

Marques JDO, Teixeira WG, Reis AM, Cruz Junior OF, Martins GC. Avaliação da condutividade hidráulica do solo saturada utilizando dois métodos de laboratório numa topossequência com diferentes coberturas vegetais no Baixo Amazonas. Acta Amazon. 2008;38:193-206. https://doi.org/10.1590/S0044-59672008000200002

Marques JDO, Teixeira WG, Reis AM, Cruz Junior OF, Batista AM, Afonso MACB. Atributos químicos, físico-hídricos e mineralogia da fração argila em solos do Baixo Amazonas: Serra de Parintins. Acta Amazon. 2010;40:1-12. https://doi.org/10.1590/S0044-59672010000100001

Martíni AF, Valani GP, Silva, LFS da, Bolonhezi D, Di Prima S, Cooper M. Long-term trial of tillage systems for sugarcane: effect on topsoil hydrophysical attributes. Sustainability. 2021;13:3448. https://doi.org/10.3390/su13063448

Martins ALS. Indicadores de qualidade de um Plintossolo e relação com a produtividade do milho sob plantio direto em aléias [dissertation]. São Luis: Universidade Estadual do Maranhão; 2006.

Martins SG, Silva MLN, Avanzi JC, Curi N, Fonseca S. Fator cobertura e manejo do solo e perdas de solo e água em cultivo de eucalipto e em Mata Atlântica nos Tabuleiros Costeiros do estado do Espírito Santo. Sci For. 2010;38:517-26.

Mascarenhas YS, Gonçalves GMO, Caetano PHP, Madari BE, Correchel V, Silva MAS. Propriedades físicas do solo em áreas de várzeas tropicais sob cultivo de arroz irrigado por inundação. In: Anais do XXXV Congresso Brasileiro de Ciência do Solo; 2015 Aug 2-7; Natal, Rio Grande do Norte. Núcleo Regional Nordeste SBCS; 2015. Available from: https://eventosolos.org.br/cbcs2015/arearestrita/arquivos/2444.pdf.

Medrado LC. Desenvolvimento radicular da cana-de-açúcar em Latossolo Vermelho da depressão intermontana de Ceres [dissertation]. Goiânia: Universidade Federal de Goiás; 2021.

Mello CR, Horton LD, Pinto LCP, Curi N. Hydropedology in the Tropics. Lavras: Editora UFLA; 2019.

Melo DVM. Qualidade de solos coesos dos Tabuleiros Costeiros de Pernambuco em função do uso de poliacrilamida [dissertation]. Recife: Universidade Federal Rural de Pernambuco; 2013.

Melo LBB. Electrical resistivity and modified least limiting water range for physical quality assessment in tropical soils [dissertation]. Lavras: Universidade Federal de Lavras; 2020.

Mendes KR, Portela JC, Silva FWA, Oliveira MAS, Santos MM. Infiltração de água no solo em agroecossistemas. In: III Congresso Internacional das Ciências Agrárias; 2018 Dec 8 – 13; João Pessoa, Paraíba. PDVAGRO - Programa Despertando Vocações Para Ciências Agrárias; 2018.

Mentges MI, Reichert JM, Rosa DP, Vieira DA, Rosa VT, Reinert DJ. Propriedades físico-hídricas do solo e demanda energética de haste escarificadora em Argissolo compactado. Pesq Agropec Bras. 2010;45:315-21. https://doi.org/10.1590/S0100-204X2010000300012

Mohanty BP, Kanwar RS, Everts CJ. Comparison of saturated hydraulic conductivity measurement methods for a glacial-till soil. Soil Sci Soc Am J. 1994;58:672-7. https://doi.org/10.2136/sssaj1994.03615995005800030006x

Montzka C, Herbst M, Weihermüller L, Verhoef A, Vereecken H. A global data set of soil hydraulic properties and sub-grid variability of soil water retention and hydraulic conductivity curves. Earth Syst Sci Data. 2017;9:529-43. https://doi.org/10.5194/essd-9-529-2017

Moraes MT, Debiasi H, Carlesso R, Franchini JC, Silva VR, Luz FB. Soil physical quality on tillage and cropping systems after two decades in the subtropical region of Brazil. Soil Till Res. 2016;155:351-62. https://doi.org/10.1016/j.still.2015.07.015

Moura EG. Avaliação das qualidades físicas dos solos de duas transecções na baixada ocidental Maranhense [dissertation]. Botucatu: Universidade Estadual Paulista; 1991.

Mundim DA, Bonomo R, Pires FR, Souza JM. Atributos físico-hídricos e químicos do solo sob aplicação de vinhaça. Energ Agric. 2018;33:321-9. https://doi.org/10.17224/EnergAgric.2018v33n4p321-329

Nacif PGS, Rezende JO, Fontes LEF, Costa LM, Costa OV. Efeitos da subsolagem em propriedades físico-hídricas de um Latossolo Amarelo Distrocoeso do Estado da Bahia. Magistra. 2008;20:186-92.

Nacinovic MGG. Avaliação de erosão hídrica superficial em parcelas experimentais [thesis]. Rio de Janeiro: Universidade Federal do Rio de Janeiro; 2013.

Oliveira AE. Modelagem de infiltração de água no solo com modelo Green-AMPT [dissertation]. Santa Maria: Universidade Federal de Santa Maria; 2015.

Oliveira CA. Atributos do solo do bioma cerrado sob diferentes usos e manejo [dissertation]. Goiânia: Universidade Federal de Goiás; 2009.

Oliveira FA. Impacto do pastejo na condutividade hidráulica de Latossolos sob pastagens e cerrado nativo [monograph]. Brasília, DF: Universidade de Brasília; 2005.

Oliveira GV, Lima RA, Santos EL, Ceccatto SK, Soriani R, Conte O, Balbinot Junior AA, Franchini JC, Debiasi H. Infiltração estável de água no solo influenciada pelo manejo e o sentido de semeadura. In: Resumos expandidos da XIV Jornada Acadêmica da Embrapa Soja; 2019 Jul 23-24; Londrina, Paraná, Brazil. Londrina: Embrapa Soja; 2019. p. 146-52. Available from: https://www.alice.cnptia.embrapa.br/alice/bitstream/doc/1114519/1/p146.pdf.

Oliveira Junior RC, Rodrigues TE, Valente MA, Silva JML. Caracterização físico-hídrica de quatro perfis de solos da região da Transamazônica, trecho Altamira-Itaituba. Belém: Embrapa CPATU; 1998. (Boletim de pesquisa, 206).

Oliveira Junior RC, Valente MA, Rodrigues TE, Silva JML. Caracterização físico-hídrica de cinco perfis de solos do nordeste Paraense. Belém: Embrapa Amazônia Oriental; 1997. (Boletim de pesquisa, 177).

Oliveira Junior RC, Valente MA, Rodrigues TE. Caraterização físico-hídrica de solos do sudeste Paraense. Belém: Embrapa Amazônia Oriental; 1999. (Boletim de Pesquisa, 20). Available from: http://www.infoteca.cnptia.embrapa.br/infoteca/handle/doc/.

Oliveira LA, Gonçalves RM, Martins FP. Contraste de condutividade hidráulica em solos de texturas arenosa e argilosa encontrados nos tributários da margem esquerda do rio Tijuco, município de Ituiutaba, estado de Minas Gerais, Brasil. Caminhos Geogr. 2010;11:230-43. https://doi.org/10.14393/RCG113316139

Ortiz PFS, Rolim MM, Silva JLB, Tavares UE, Cavalcanti RQ. Infiltração de água em Ultisol com diferentes tempos de produção de cana-de-açúcar no semiárido brasileiro. Agropec Cient Semiárido. 2020;16:107-13. https://doi.org/10.30969/acsa.v16i2.1131

Ottoni MV, Ottoni Filho TB, Lopes-Assad MLRC, Rotunno Filho OC. Pedotransfer functions for saturated hydraulic conductivity using a database with temperate and tropical climate soils. J Hydrol. 2019;575:1345-58. https://doi.org/10.1016/j.jhydrol.2019.05.050

Ottoni MV, Ottoni Filho TB, Schaap MG, Lopes-Assad MLRC, Rotunno Filho OC. Hydrophysical Database for Brazilian Soils (HYBRAS) and pedotransfer functions for water retention. Vadose Zone J. 2018;17:170095. https://doi.org/10.2136/vzj2017.05.0095

Pachepsky Y, Park Y. Saturated hydraulic conductivity of U.S. soils grouped according to textural class and bulk density. Soil Sci Soc Am J. 2015;79:1094-100. https://doi.org/10.2136/sssaj2015.02.0067

Paiva AQ, Souza LS, Ribeiro AC, Costa LM. Propriedades físico-hídricas de solos de uma topossequência de tabuleiro do estado da Bahia. Pesq Agropec Bras. 2000;35:2295-302. https://doi.org/10.1590/S0100-204X2000001100023

Panachuki E. Infiltração de água no solo e erosão hídrica, sob chuva simulada, em sistema de integração agricultura-pecuária [dissertation]. Dourados: Universidade Federal do Mato Grosso do Sul; 2003.

Panachuki E, Bertol I, Alves Sobrinho T, Oliveira PTS, Rodrigues DBB. Perdas de solo e de água e infiltração de água em Latossolo Vermelho sob sistemas de manejo. Rev Bras Cienc Solo. 2011;35:1777-85. https://doi.org/10.1590/S0100-06832011000500032

Pavei DS, Monteiro FN, Menezes RS, Valim WC, Rodrigues SA, Salton JC, Panachuki E. Infiltração e atributos físicos de Latossolo em sistemas agropecuários convencionais e conservacionistas. In: Anais do 13º Encontro Nacional de Engenharia de Sedimentos, I Partículas nas Américas; 2018 Sep 24-28; Vitória, Espírito Santo, Brazil. Vitória: Abrhidro; 2018.

Pedron FA, Fink JR, Rodrigues MF, Azevedo AC. Condutividade e retenção de água em Neossolos e Saprolitos derivados de arenito. Rev Bras Cienc Solo. 2011;35:1253-62. https://doi.org/10.1590/S0100-06832011000400018

Pequeno PLL. Funções de pedotransferência para estimativa de retenção de água em solos da mesorregião do agreste Paraibano [thesis]. João Pessoa: Universidade Federal da Paraíba; 2016.

Perreault S, El Alem A, Chokmani K, Cambouris AN. Development of pedotransfer functions to predict soil physical properties in southern Quebec (Canada). Agronomy. 2022;12:526. https://doi.org/10.3390/agronomy12020526

Polizeli KMVC, Silva AP, Tormena CA, Leão TP. Long-term effects of no-tillage on dynamic soil physical properties in a Rhodic Ferrasol in Paraná, Brazil. Soil Till Res. 2009;103:158-64. https://doi.org/10.1016/j.still.2008.10.014

Portugal AF. Geoambientes de terra firme e várzea da Região do Juruá, noroeste do Acre [thesis]. Viçosa, MG: Universidade Federal de Viçosa; 2009.

Pott CA. Determinação da velocidade de infiltração básica de água no solo por meio de infiltrômetros de aspersão, de pressão e de tensão, em três solos do estado de São Paulo [dissertation]. Campinas: Instituto Agronômico; 2001.

Pruski FF, Silva DD, Teixeira AF, Cecílio RA, Silva JMA, Griebeler NP. Hidros - Dimensionamento de sistemas hidroagrícolas. Viçosa, MG: Editora UFV; 2006.

Pruski FF, Vendrame V, Oliveira EF, Balbino LC, Ferreira PA, Werlang L, Carvalho LT. Infiltração da água num Latossolo Roxo. Pesq Agropec Bras. 1997;32:77-84.

Rahmati M, Weihermüller L, Vanderborght J, Pachepsky YA, Mao L, Sadeghi SH, Moosavi N, Kheirfam H, et al. Development and analysis of the Soil Water Infiltration Global database. Earth Syst Sci Data. 2018;10:1237-63. https://doi.org/10.5194/essd-10-1237-2018

Ramos RC. Atributos físicos do solo cultivado com plantas de cobertura sob dois regimes hídricos [dissertation]. São Mateus: Universidade Federal do Espírito Santo; 2018.

Rauber LR, Reinert DJ, Gubiani PI, Fachi SM. Steady infiltration rate: Relation to antecedent soil moisture, soil permeability, and measurement method and period. Rev Bras Cienc Solo. 2024;48:e0240007. https://doi.org/10.36783/18069657rbcs20240007

Rawls WJ, Brakensiek DL, Saxton K. Estimation of soil water properties. T ASAE. 1982;25:1316-20. https://doi.org/10.13031/2013.33720

Resende M. Pedologia. Viçosa, MG: Universidade Federal de Viçosa; 1982.

Reynolds WD, Elrick DE. A method for simultaneous in situ measurement in the vadose zone of field-saturated hydraulic conductivity, sorptivity and the conductivity-pressure head relationship. Ground Water Monit R. 1986;6:84-95. https://doi.org/10.1111/j.1745-6592.1986.tb01229.x

Ribeiro KD, Menezes SM, Mesquita MGBF, Sampaio FMT. Propriedades físicas do solo, influenciadas pela distribuição de poros, de seis classes de solos da região de Lavras – MG. Cienc Agrotec. 2007;31:1167-75. https://doi.org/10.1590/S1413-70542007000400033

Rodrigues TE, Oliveira Junior RC, Silva JML, Valente MA, Capeche CL. Caracterização físico hídrica dos principais solos da Amazônia legal: I - Estado do Pará. Acordo EMBRAPA-SNLCS e FAO. Belém: Embrapa/SNLCS-FAO; 1991. (Relatório técnico).

Rojas CAL. Alterações físico-hídricas de um Podzólico em função do manejo de solo [dissertation]. Porto Alegre: Universidade Federal do Rio Grande do Sul; 1998.

Sales LEO, Carneiro MAC, Severiano EC, Oliveira GC, Ferreira MM. Qualidade física de um Neossolo Quartzarênico submetido a diferentes sistemas de uso agrícola. Cienc Agrotec. 2010;34:667-74. https://doi.org/10.1590/S1413-70542010000300020

Sales LEO, Ferreira MM, Oliveira MS, Curi N. Estimativa da velocidade de infiltração básica do solo. Pesq Agropec Bras. 1999;34:2091-5. https://doi.org/10.1590/S0100-204X1999001100016

Santana MB, Souza LS, Souza LD, Fontes LEF. Atributos físicos do solo e distribuição do sistema radicular de citros como indicadores de horizontes coesos em dois solos de tabuleiros costeiros do estado da Bahia. Rev Bras Cienc Solo. 2006;30:1-12. https://doi.org/10.1590/S0100-06832006000100001

Santos DP, Schossler TR, Santos IL, Melo NB, Nobrega JCA, Santos GG. Physical-hydric attributes in Latossolo Amarelo under systems of use in the cerrado/caatinga ecotone areas in Piauí state, Brazil. An Acad Bras Cienc. 2021;93:e20190667. https://doi.org/10.1590/0001-3765202120190667

Santos GG, Marchão RL, Silva EM, Silveira PM, Becquer T. Qualidade física do solo sob sistemas de integração lavoura-pecuária. Pesq Agropec Bras. 2011;46:1339-48. https://doi.org/10.1590/S0100-204X2011001000030

Santos HG, Jacomine PKT, Anjos LHC, Oliveira VA, Lumbreras JF, Coelho MR, Almeida JA, Araújo Filho JC, Oliveira JB, Cunha TJF. Sistema brasileiro de classificação de solos. 5. ed. rev. ampl. Brasília, DF: Embrapa; 2018.

Santos PB. Serviços ecossistêmicos em diferentes sistemas de preparo do solo e espaçamentos para cultura da cana-de-açúcar no cerrado do estado de São Paulo [dissertation]. Niterói: Universidade Federal Fluminense; 2020.

Santos RD, Santos HG, Ker JC, Anjos LHC, Shimizu SH. Manual de descrição e coleta de solo no campo. 7 ed. rev. ampl. Viçosa, MG: Sociedade Brasileira de Ciência do Solo; 2015.

Scheffler R, Neill C, Krusche AV, Elsenbeer H. Soil hydraulic response to land-use change associated with the recent soybean expansion at the Amazon agricultural frontier. Agr Ecosyst Environ. 2011;144:281-9. https://doi.org/10.1016/j.agee.2011.08.016

Schossler TR, Marchão RL, Santos IL dos, Santos DP, Nóbrega JCA, Santos GG. Soil physical quality in agricultural systems on the cerrado of Piauí state, Brazil. An Acad Bras Cienc. 2018;90:3975-89. https://doi.org/10.1590/0001-3765201820180681

Scorza Junior RP, Silva JP. Potencial de contaminação da água subterrânea por pesticidas na Bacia do rio Dourados, MS. Pesticidas: R Ecotoxicol Meio Ambiente. 2007;17:87-106. https://doi.org/10.5380/pes.v17i0.10666

Silva AJN, Ribeiro MR. Caracterização de Latossolo Amarelo sob cultivo contínuo de cana-de-açúcar no estado de Alagoas: atributos morfológicos e físicos. Rev Bras Cienc Solo. 1997;21:677-84. https://doi.org/10.1590/S0100-06831997000400019

Silva AP. Influência da forma e posição da encosta nas características do solo e na regeneração natural de espécies florestais em áreas de pastagens abandonadas [dissertation]. Seropédica: Universidade Federal Rural do Rio de Janeiro; 2011.

Silva EC. Atributos físicos de um Latossolo em sistemas de produção agropecuária [dissertation]. Dourados: Universidade Federal da Grande Dourados; 2016.

Silva EM, Azevedo JA, Rauber JC, Reatto A. Caracterização físico-hídrica e hidráulica de solo do bioma cerrado submetidos a diferentes sistemas de preparo. Planaltina, DF: Embrapa Cerrados; 2003 (Boletim de Pesquisa e Desenvolvimento, 101).

Silva GC. Sustentabilidade estrutural de Latossolos cultivados com cana-de-açúcar do estado de Goiás [thesis]. Goiânia: Universidade Federal de Goiás; 2021.

Silva GJ, Valadão Júnior DD, Bianchini A, Azevedo EC, Maia JCS. Variação de atributos físico-hídricos em Latossolo Vermelho-Amarelo do cerrado Mato-Grossense sob diferentes formas de uso. Rev Bras Cienc Solo. 2008;32:2135-43. https://doi.org/10.1590/S0100-06832008000500034

Silva GM, Buso WHD, Oliveira LFC, Nascimento JL. Caracterização físico-hídrica de um Latossolo Vermelho Perférrico submetido a dois sistemas de manejo do solo. Pesq Agropec Trop. 2001;31:127-31.

Silva JRL, Montenegro AAA, Santos TEM. Caracterização física e hidráulica de solos em bacias experimentais do semiárido brasileiro, sob manejo conservacionista. Rev Bras Eng Agr Amb. 2012;16:27-36. https://doi.org/10.1590/S1415-43662012000100004

Silva MAS, Mafra AL, Albuquerque JA, Bayer C, Mielniczuk J. Atributos físicos do solo relacionados ao armazenamento de água em um Argissolo Vermelho sob diferentes sistemas de preparo. Cienc Rural. 2005;35:544-52. https://doi.org/10.1590/S0103-84782005000300009

Silva PLF, Oliveira FP, Tavares DD, Nóbrega CC, Amaral AJ. Water availability in a Planosol under integrated croplivestock-forestry system in the agreste region of Paraiba, Brazil. Rev Caatinga. 2019;32:449-57. https://doi.org/10.1590/1983-21252019v32n218rc

Soares WA, Silva SR, Lima JRS. Land-use change effect on the hydro-dynamic characteristics of soil in the Brazilian semi-arid region. Rev Ambient Água. 2020;15:23-68. https://doi.org/10.4136/ambi-agua.2368

Soil Science Division Staff. Soil survey manual. 18th ed. Washington DC: United States Department of Agriculture, Natural Resources Conservation Service; 2017.

Sondatécnica. Estudos de levantamentos pedológicos e hidrológicos. In: Projeto de irrigação e drenagem da cana-de-açúcar na região Norte-Fluminense. Rio de Janeiro; 1983.

Sone JS, Oliveira PTS, Zamboni PAP, Vieira NOM, Carvalho GA, Macedo MCM, Araujo AR, Montagner DB, Alves Sobrinho T. Effects of long-term crop-livestock-forestry systems on soil erosion and water Infiltration in a Brazilian Cerrado site. Sustainability. 2019;11:5339. https://doi.org/10.3390/su11195339

Sone JS, Oliveira PTS, Euclides VPB, Montagner DP, Araujo AR, Zamboni PAP, Vieira NOM, Carvalho GA, Alves Sobrinho T. Effects of nitrogen fertilisation and stocking rates on soil erosion and water infiltration in a Brazilian Cerrado farm. Agr Ecosyst Environ. 2020;304:107159. https://doi.org/10.1016/j.agee.2020.107159

Souza JM, Bonomo R, Pires FR, Bonomo DZ. Curva de retenção de água e condutividade hidráulica do solo em lavoura de café conilon submetida à subsolagem. Coffee Sci. 2014;9:226-36.

Souza JS, Almeida IK, Carvalho GA, Alves Sobrinho T, Bacchi CGV. Influence of soil properties and environmental characteristics in water infiltration in urban areas. Geociências. 2019;38:1029-38. https://doi.org/10.5016/geociencias.v38i4.13032

Souza LS, Souza LD. Caracterização físico-hídrica de solos da área do Centro Nacional de Pesquisa de Mandioca e Fruticultura Tropical. Cruz das Almas: Embrapa Mandioca e Fruticultura Tropical; 2001 (Boletim de Pesquisa e Desenvolvimento, 20)

Souza ZM, Leite JA, Beutler AN. Comportamento de atributos físicos de um Latossolo Amarelo sob agroecossistemas do Amazonas. Eng Agric. 2004;24:654-62. https://doi.org/10.1590/S0100-69162004000300017

Sperandio HV, Cecílio RA. Atributos físicos do solo em área sob colheita florestal semimecanizada no estado do Espírito Santo. Rev Cienc. Agric. 2017;15:69-74. https://doi.org/10.28998/rca.v15i2.3390

Suzuki LEAS, Lima CLR, Reinert DJ, Reichert JM, Pillon GN. Condição estrutural de um Argissolo no Rio Grande do Sul, em floresta nativa, em pastagem cultivada e em povoamento com eucalipto. Cienc Florest. 2012;22:833-43. https://doi.org/10.5902/198050987564

Szabó B, Weynants M, Weber TK. Updated European hydraulic pedotransfer functions with communicated uncertainties in the predicted variables (euptfv2). Geosci Model Dev. 2021;14:151-75. https://doi.org/10.5194/gmd-14-151-2021

Teixeira WG, Lima HN, Pinto WHA, Souza KW, Shinzato E, Schroth G. O manejo do solo nas várzeas da Amazônia. In: Bertol I; Maria IC; Souza LS, editors. Manejo e conservação do solo e da água. Viçosa, MG: Sociedade Brasileira de Ciência do Solo; 2019. p. 701-28.

Teixeira WG, Ottoni MV, Armindo RA, Martins ALS, Lumbreras JF, Calegari A, Silva MB, Ferreira RV, Shinzato E. Estimativas e avaliação da velocidade de infiltração e da condutividade hidráulica saturada em solos do estado do Maranhão. In: Silva MB, editor. Guia de campo da XIII Reunião Brasileira de Classificação e Correlação de Solos: RCC do Maranhão. Brasília, DF: Embrapa; 2020.

Teixeira WG. Land use effects on soil physical and hydraulic properties of a clayey ferralsol in the Central Amazon [thesis]. Bayreuth: Universitat Bayreuth; 2001.

Teixeira WG, Schroth G, Marques JD, Huwe B. Unsaturated soil hydraulic conductivity in the Central Amazon: field evaluations. In: Teixeira W, Ceddia M, Ottoni M, Donnagema G, editors. Application of soil physics in environmental analyses: measuring, modelling and data integration. Suiça: Springer International Publishing; 2014. p. 283-305. https://doi.org/10.1007/978-3-319-06013-2_13

Tenfen JR. Infiltração de água e atributos físicos de um Latossolo Vermelho sob sistemas de manejo [dissertation]. Dourados: Universidade Federal da Grande Dourados; 2014.

Thomas SK, Conta JF, Severson ED, Galbraith JM. Measuring saturated hydraulic conductivity in soil. Virginia: Communications and Marketing, College of Agriculture and Life Sciences, Virginia Tech; 2016. (Publication CSES-141P.)

Toma RS. Evolução do funcionamento físico-hídrico do solo em diferentes sistemas de manejo em áreas de agricultura familiar na região do vale do Ribeira, SP [thesis]. Piracicaba: Universidade de São Paulo; 2012.

Tomasella J, Hodnett MG. Soil hydraulic properties and van Genuchten parameters for an Oxisol under pasture in central Amazonia. In: Gash JHC, Nobre CA, Roberts JM, Victoria RL, Baldocchi D, editors. Amazonian deforestation and climate. Chichester: John Wiley & Sons; 1996. p. 101-24.

Tomasini BA, Vitorino ACT, Garbiate MV, Souza CMA, Alves Sobrinho T. Infiltração de água no solo em áreas cultivadas com cana-de-açúcar sob diferentes sistemas de colheita e modelos de ajustes de equações de infiltração. Eng Agríc. 2010;30:1060-70. https://doi.org/10.1590/S0100-69162010000600007

United States Department of Agriculture - USDA. Soil survey manual: Soil Survey Division Staff. Washington DC: United States Department of Agriculture, Natural Resources Conservation Service; 2017. (Agriculture Handbook No. 18).

Uyeda CA. Influência da aplicação de vinhaça na condutividade hidráulica do solo saturado e no escoamento superficial [thesis]. Piracicaba: Universidade de São Paulo; 2009.

Valadão FCA, Maas KDB, Weber OLS, Valadão Junior DD, Silva TJ. Variação nos atributos do solo em sistemas de manejo com adição de cama de frango. Rev Bras Cienc Solo. 2011;35:2073-82. https://doi.org/10.1590/S0100-06832011000600022

Vilarinho MKC, Nascimento JC, Silva TJA, Isquierdo EP, Caldeira DAS, Oliveira CP. Velocidade de infiltração básica de um Plintossolo Pétrico situado em áreas de pastagem e cerrado. Rev Bras Agric Irrig. 2019;7:17-26. https://doi.org/10.7127/RBAI.V13N2001042

Vitorino ACT, Ferreira MM, Curi N, Lima JM, Silva MLN, Motta PEF. Mineralogia, química e estabilidade de agregados do tamanho de silte de solos da região Sudeste do Brasil. Pesq Agropec Bras. 2003;38:133-41. https://doi.org/10.1590/S0100-204X2003000100018

Warrick AW. Soil physics companion. Boca Raton: CRC Press; 2001.

Weynants M, Montanarella L, Tóth G, Strauss P, Feichtinger F, Cornelis W, et al. European HYdropedological Data Inventory (EU-HYDI). Luxembourg: Publications Office of the European Union; 2013.

Yuen KK. The two-sample trimmed *t* for unequal population variances. Biometrika. 1974;61:165-70. https://doi.org/10.1093/biomet/61.1.165

Zhang Y, Schaap MG. Estimation of saturated hydraulic conductivity with pedotransfer functions: A review. J Hydrol. 2019;575:1011-30. https://doi.org/10.1016/j.jhydrol.2019.05.05