Revista Brasileira de Ciência do Solo

Division - Soil In Space and Time | Commission - Soil Survey and Classification

Espodossolos of Brazil: A review of structure and composition of classes

Andressa Rosas de Menezes[(1)*], **Ademir Fontana**[(2)] and **Lúcia Helena Cunha dos Anjos**[(3)]

[(1)] Instituto Brasileiro de Geografia e Estatística e Fundo de População das Nações Unidas, Rio de Janeiro, Rio de Janeiro, Brasil.
[(2)] Empresa Brasileira de Pesquisa Agropecuária, Embrapa Gado de Corte, Campo Grande, Mato Grosso do Sul, Brasil.
[(3)] Universidade Federal Rural do Rio de Janeiro, Departamento de Solos, Seropédica, Rio de Janeiro, Brasil.

ABSTRACT: Soil taxonomic systems seek to express pedogenic processes in their classes by choosing attributes or differential characteristics to identify classes at different categorical or hierarchical levels. Due to the advancement of knowledge, classification systems are periodically revised and/or expanded, and this may happen based on the evaluation of the database of these attributes or characteristics for a given class. In this context, the analysis of a broad set of Espodossolos (the equivalent of Spodosols or Podzols) from different pedoenvironments in Brazil is considered relevant to support the improvement of the categorization of this order in the Brazilian Soil Classification System – SiBCS. This study aimed to classify the profiles in the database and, based on their distribution, propose the restructuring of the Espodossolos classes up to the fourth categorical level in the SiBCS. Data from profiles with spodic horizons and the Espodossolos available in the literature, including surveys since 1960, were compiled in an electronic spreadsheet, displaying the morphological, physical, and chemical attributes. In the current edition of SiBCS, there are limitations in clearly separating the Espodossolos at the order and suborder levels due to the definitions adopted for the diagnostic attributes and the control section of the spodic B horizon. From the data base of compiled profiles, at the great group level, the soils are mostly identified in the Órticos class, in the subgroup as espessarênicos, arênicos and típicos, with few profiles or absence of profiles in the êutricos, êutricos arênicos and carbonáticos classes. Based on this assessment, it is proposed, for the order level, the reduction of the control section of the spodic B horizon to start within 2.00 m of depth; for the suborder, a criterion based on the organic carbon contents separating two classes: Humilúvicos and Háplicos. In the great group, based on the criterion of starting depth of spodic B horizon: Hiperespessos, Espessos and Órticos; and in the subgroup to adopt the classes of tiônicos, organossólicos, húmicos, saprolíticos, dúricos, fragipânicos, abrúpticos, hidromórficos, espessarênicos and típicos.

Keywords: hierarchical classification, spodic horizons, taxonomic system.

*** Corresponding author:**
E-mail: andressa.rosas@hotmail.com

Received: June 25, 2024
Approved: December 03, 2024

How to cite: Menezes AR, Fontana A, Anjos LHC. Espodossolos of Brazil: A review of structure and composition of classes. Rev Bras Cienc Solo. 2025;49:e0240117.
https://doi.org/10.36783/18069657rbcs20240117

Editors: José Miguel Reichert and José Coelho de Araújo Filho.

INTRODUCTION

In the different soil classification systems, the taxonomic structure includes diagnostic attributes and differential characteristics organized in categorical levels. Due to the differences in concepts and precepts, each system uses the information or data available to define the structure, as well as the selection of criteria at each categorical level based on those components that allow greater distinction between classes and that are easy to obtain. In the case of morphogenetic systems, such as the Brazilian Soil Classification System (SiBCS), the criteria related to pedogenesis are placed at the higher hierarchical levels, and the ones related to use and management at lower levels, especially in subgroups, families, and series (Resende et al., 2012).

The Espodossolos (the equivalent of Spodosols or Podzols) order and all classes at lower hierarchical levels are identified in different soil classification systems, both those considered international, such as Soil Taxonomy (Soil Survey Staff, 2022) and World Reference Base for Soil Resources (IUSS Working Group WRB, 2022), and those considered national such as The Australian Soil Classification (Isbell, 2021), Soil Classification – a Taxonomic System for South Africa (Soil Classification Working Group, 1991), The Canadian System of Soil Classification (Soil Classification Working Group, 1998), *Référentiel pédologique* (Baize and Girard, 2008); and Russian Soil Classification (Shishov et al., 1998).

In the SiBCS, the order of Espodossolos "comprises soils constituted by mineral material, presenting the diagnostic spodic B horizon immediately below the E, A or histic horizon within 2.00 m from the surface or 4.00 m, if the sum of the A and E horizons or the histic and E horizons exceeds 2.00 m in depth" (Santos et al., 2018). At the suborder level, comprise the type of spodic horizon that occurs in isolation or overlapping other types of horizons (spodic or non-spodic). At the great group level, they are divided according to drainage and depth of onset of the spodic horizon. At the subgroup level, they are classified by the presence of certain diagnostic horizons (histic and fragipan), thickness and texture of the surface and eluvial horizons (espessarênicos and arênicos), and presence of distinct chemical attributes (êutricos, and carbonáticos). Those without any of the previous differential characteristics, such as other diagnostic horizons, diagnostic properties, or extraordinary attributes, are called typical (Santos et al., 2018).

Notably, with the advancement of knowledge, periodically, every classification system undergoes review and/or expansion, which can be due to the evaluation of large databases containing differential attributes or characteristics relevant to define the classes, or the improvement of the categorization of soil classes to express new individuals identified in a given pedoenvironment.

In the current edition of SiBCS (Santos et al., 2018), there are limitations in identifying soils at the level of the order of Espodossolos, due to predominant morphological criteria that are not entirely clear, and the control section to verify the occurrence of the spodic B horizon. In the suborder, there are limitations to define the types of Espodossolos, based on the color criteria to separate humified organic matter from Fe and Al oxides, regarding the predominant component in the podzolization process. At the great group level, there is a discrepancy in the distribution of profiles classified as Espodossolos, which, according to the criteria used in the SiBCS, are mostly identified in the Órticos classes. In the subgroup, the profiles are distributed as espessarênicos, arênicos, and típicos, with the absence or rare occurrence of the êutricos, êutricos arênicos and carbonáticos classes, which questions the validity of the latter criteria to separate these subgroups in the Brazilian territory.

In this sense, based on a broad database prepared with Espodossolos profiles from different Brazilian pedoenvironments, the objective of this study was to classify the profiles in the database and, based on their distribution, propose the restructuring of the Espodossolos classes up to the fourth categorical level in the SiBCS.

MATERIALS AND METHODS

Preparation of a data collection on soils with spodic B horizons

From bibliographic research in scientific articles, pedological surveys, soil classification and correlation field guides, thesis and dissertations, 189 profiles were selected, which were formerly classified as Espodossolos, according to different versions of the Brazilian Soil Classification System - SiBCS, or equivalent classes in the mapping units of soil surveys prior to the publication of the SiBCS first edition in 1999.

Profiles selection required to have the following complete information necessarily: i) organic carbon (C_{org}) content of all horizons of the soil profile; ii) initial and final depth of the spodic B horizon; and iii) morphological characterization. Profiles whose samples were collected by augers were disregarded.

Data related to the profiles were compiled in an electronic spreadsheet containing the general description of the environment, and morphological, physical and chemical attributes. The analysis of the consistency of the morphology data was performed to verify the coherence of the subsurface horizon identification according to the spodic B criteria, aiming to eliminate eventual buried A, O or H horizons that could lead to errors in the interpretation of the C_{org} contents. In addition, it was verified the possibility of C_{org} variation with depth in the profile due to other processes, such as the deposition of sediments in the fluvic character.

Overall, the method to determine the C_{org} in the literature compiled for this study was the wet route, which consists of oxidation with potassium dichromate (Fontana and Campos, 2017). The horizon nomenclature was adjusted according to the designations established by Santos et al. (2015), considering the large number of studies conducted before this publication. However, the original morphological description was preserved. After that, the selected profiles were reclassified according to the current edition of SiBCS (Santos et al., 2018). Thus, the original number of profiles was reduced to 154, totaling 385 spodic horizons with complete data that were used to evaluate and prepare the proposals.

Proposal for categorization of Espodossolos classes

All profiles were classified up to the fourth categorical level (subgroup) using the SiBCS criteria (Santos et al., 2018), and the distribution of the identified profiles in the taxonomic classes was evaluated quantitatively.

The main changes proposed are, at the order level, to reduce the upper control section of the spodic B horizon, based on the significantly small occurrence of profiles in the database with the depth according to the current definition and at the suborder level, to adopt limit values for the C_{org} content as a criterion, which makes the identification less susceptible to discrepancies associated with subjectivity in defining the types of spodic B horizons, currently mainly based on color. On the great group level, the inclusion of a thickness criterion and review of the depth of occurrence of spodic B horizon and, on the subgroup level, the other diagnostic horizons, diagnostic properties, or extraordinary attributes (presented below in the Results and Discussion section).

RESULTS AND DISCUSSION

Profiles distribution in current Espodossolos classes at SiBCS (Santos et al., 2018)

In total, there are 154 Espodossolos profiles, classified according to SiBCS current edition (Santos et al., 2018). Out of this total, there are 66 profiles of the suborder Humilúvicos, 19 profiles of the suborder Ferrilúvicos, and 69 profiles of the suborder Ferri-humilúvicos

(Figure 1). This unequal quantitative distribution of the suborders is due to the limitations inherent in the definitions of the SiBCS, as presented by Menezes et al. (2025):

i. There is no differentiation between the Bh(m) and Bhs(m) horizons by morphology and the contents of amorphous oxides of Al (Al_o) and Fe (Fe_o);

ii. Many authors attribute the suffixes to the horizons Bhs(m) and Bs(m) without performing analysis with selective extraction of pedogenetic oxides in the spodic horizons and in the immediately overlying horizon to identify accumulation, since only 38 % of the horizons evaluated in the database presented this data;

iii. There is no differentiation between the C_{org} contents of the Bs(m) horizons and the Bhs(m) horizons, so there are Bhs(m) horizons that received the subscript "h" due to the dark color, expressed by the chroma value less than or equal to 3, but have only 1.2 g kg^{-1} of C_{org}; and

iv. There are authors who identify horizons of accumulation of pedogenetic oxides, Bs(m) and Bhs(m), with 0.0 % Al_o + 0.5 Fe_o, in disagreement with their respective SiBCS definitions (Santos et al., 2018).

At the great group level, 85 % of the profiles in the database are classified as Órticos, 12 % as Hidromórficos, and only 3 % in the Hidro-Hiperespessos and Hiperespessos classes (Figure 1). Based on the data, it can be seen that the separation by differential attributes at this categorical level is ineffective, since most of the profiles are concentrated in the Órticos class, which is defined as - "soils that do not meet the criteria of the other classes" (Santos et al., 2018).

Furthermore, it should be mentioned that the small number of profiles of the Hidro-Hiperespessos and Hiperespessos classes is not directly associated with the low expression of these soils in Brazilian territory, but in a certain way, it reflects the difficulties inherent in opening trenches of more than 2.00 m in depth, often carried out manually, under substantially sandy soils with a loose consistency when dry, in which the lateral cuts of the trench are extremely susceptible to collapse, and this may even set the pedologist at risk.

At the subgroup level, the number of profiles in the database, classified in each class according to the current edition of the SiBCS, is as follows: 43 espessarênicos; 63 arênicos; 13 dúricos; 1 fragipânico; 6 organossólicos; 1 êutrico; 1 êutrico arênico; and 26 típicos (Figure 1). Among the soils classified as espessarênicos and arênicos, 11 profiles also present a dúrico character within 1.00 m of the surface, while two profiles classified as arênicos can also be classified as fragipânicos.

Among the set of profiles evaluated in the database, there are no Espodossolos classified at the subgroup level as carbonáticos. Furthermore, it is contradictory to the concept of podzolization process, the presence of carbonates, as well as high pH(H_2O) values, high values of the sum of bases, base saturation, and sodium saturation (Menezes et al., 2022).

As for the êutricos arênicos and êutrico subgroups, only two profiles described in the literature meet the criteria for these classes. By definition, these soils must have a sum of bases greater than or equal to 2.0 $cmol_c$ kg^{-1} combined with a pH(H_2O) greater than or equal to 5.7 in most horizons up to 1.00 m from the soil surface (Santos et al., 2018). However, these pH(H_2O)values and sum of bases are outside the central characteristics of the spodic B horizons described in Brazil and, in a way, the êutrico character contradicts the premises of the pedogenetic process of podzolization (De Coninck, 1980; Gustafsson et al., 1995; Schaetzl, 2002; Menezes et al., 2022). Thus, it would be more appropriate to the general concept of pedogenesis as base for the SiBCS, to identify these soils in other classes and highlight a possible intermediate characteristic given the expression of some morphology similar to that of soils classified as Espodossolos.

Proposal for categorization of Espodossolos classes in SiBCS

The proposal presented here for categorizing the Espodossolos is based on the assumption of selecting clear criteria with less overlap to identify the classes, as well as the reduction of the control section in which these criteria should be observed. At the order level, it is important to define limits for attributes relevant to the identification of the spodic B horizons (Menezes et al., 2025), which prevents the classification of soils without expressive podzolization process in harmony with a system that is based on pedogenesis.

Additionally, at the suborder level, it is proposed the use of the C_{org} content as a criterion to express the strength of the illuviation of the organic matter in the podzolization process. This criterion allows for lesser subjectivity in identifying suborders of Espodossolos and, at the same time, emphasizes the potential storage of organic carbon in some soils of this order. It is noteworthy that the definition of spodic B horizons, in the current version of SiBCS, lacks quantitative criteria related to the dominant illuvial compounds. Subsequently, at the great group level, the inclusion of criteria for definition and assertive measurement, such as thickness and the upper limit of control section for occurrence of the spodic B horizon; while, at the subgroup level, other diagnostic horizons, diagnostic properties or extraordinary attributes of occurrence in the database are presented, most of them already in the SiBCS.

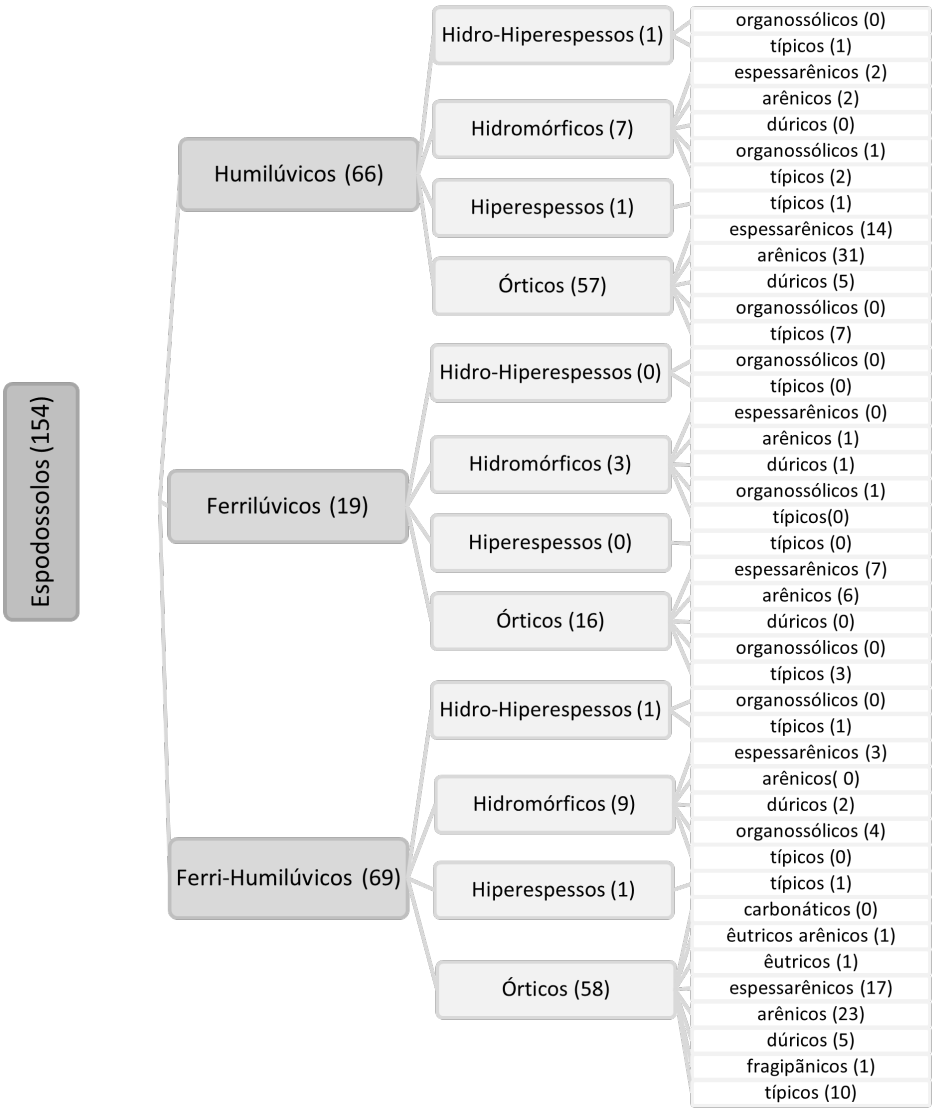

Figure 1. Profiles distribution of the Espodossolos up to the 4th categorical level, with the names of classes in Portuguese, according to the SiBCS (Santos et al., 2018).

a) Definition of the control section for the 1st categorical level (Order)

At the time of database preparation, only four profiles were found in the literature with spodic B horizons ranging from 2.00 to 4.00 m, and no complete profile was found starting after this lower limit (Figure 2). In this sense, the spodic B horizon starting at 2.00 m of depth is proposed as a control section of the order. This value is also applied in other soil classification systems, such as Soil Taxonomy (Soil Survey Staff, 2022) and WRB (IUSS Working Group WRB, 2022), and this change also allows harmonization with global soil data repositories.

To define the new control section, logistical difficulties associated with the possible collapse of walls and the risks of burial in a soil with a predominantly sandy texture in horizons A and E (Menezes et al., 2018) were also considered.

For areas with a potential occurrence of Espodossolos, currently identified by the common name “giants”, the possible presence of a spodic B horizon at greater depth can be reported in the observation item or in the description of the mapping unit. Conditional to the sampling with an auger, followed by laboratory analyses, it is possible to record the presence of spodic properties at a lower hierarchical level (family) of the SiBCS. This is parallel to what is done for any and all relevant differential characteristics in other classes, thus reporting at the proper level a characteristic that could be relevant for C_{org} storage potential or limiting in geotechnical terms even though it is placed in another soil order.

b) Definition of the 2nd categorical level (Suborder)

At this level, it is emphasized the expressive accumulation of humified organic matter by translocation - eluviation/illuvation, by the pedogenetic process of podzolization (complexation/cheluviation), according to the definition of the diagnostic spodic B horizon: “mineral nature presenting illuvial accumulation of humified organic matter (soluble alkaline fractions) combined with aluminum, which may or may not contain iron” (Santos et al., 2018).

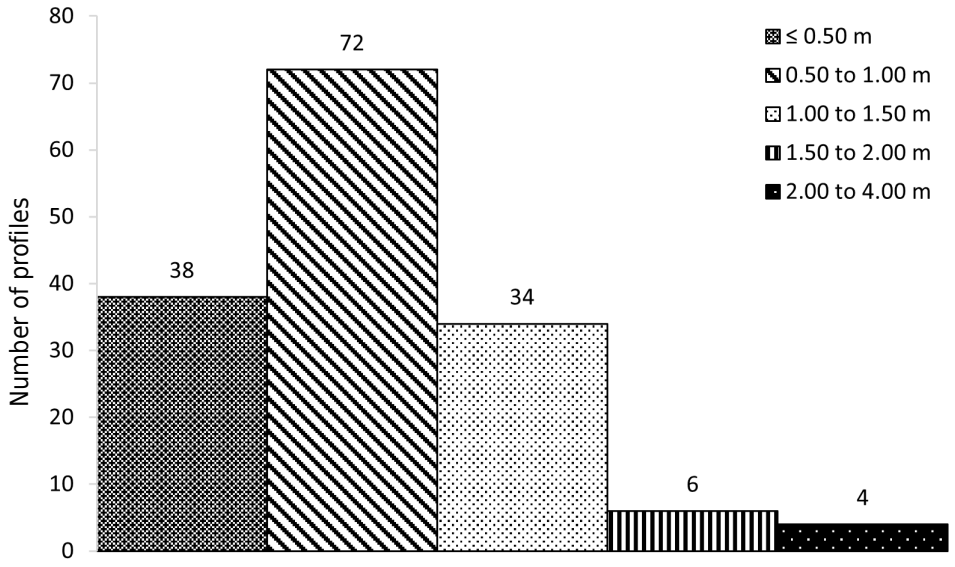

Figura 2. Profiles distribution by initial depths of the spodic B horizons of Espodossolos classified according to the original database and SiBCS (Santos et al., 2018).

To give a name to the suborder, the prefix HUMI is preserved as an indication of the accumulation of highly transformed and/or humified organic matter, considering it has several chemical elements in its composition besides organic carbon. The suffix LÚVICO is an indication of the illuviation process that characterizes the podzolization and leads to the accumulation of organic and/or mineral compounds in the spodic B horizon.

Given the median C_{org} contents of the spodic B horizons, especially the horizons with C_{org} contents ≥5.0 g kg^{-1} (mode) (Table 1) and the limits defined for the spodic B types (Menezes et al., 2025), two classes are proposed at the suborder level:

- **Humilúvicos:** Soils with spodic B horizon* presenting C_{org} content ≥15.0 g kg^{-1}**;

**The spodic B horizons evaluated are those above a lithological discontinuity or polygenetic profile (i.e., profile and more superficial horizons, which disregard buried horizons).*

***Control section for this criterion: in at least 0.20 m thickness of one or more spodic B horizon. The value is the absolute C_{org} content of each horizon.*

The value of thickness was obtained after the evaluation of the data from all spodic B horizons thickness as median and/or mode as observed in table 2.

- **Háplicos:** Other soils with a diagnostic spodic horizon B.

Thus, the classes of Espodossolos are simplified at the suborder level, removing from the SiBCS the current subjectivity due to the difficulty in identifying the types of spodic horizons.

c) Definition of the 3rd categorical level (Great Group)

At this level, the upper depth of the spodic B horizon was chosen to separate the classes (Figure 2; Table 2), with three great groups being proposed:

- **Hiperespessos**: soils with a spodic B horizon starting at a depth ≥1.00 m;
- **Espessos**: soils with a spodic B horizon starting at a depth between 0.50 and 1.00 m;
- **Órticos**: other soils.

Despite the great variability of morphological attributes of horizons in the Espodossolos, commonly with transitions from the spodic B horizons to the overlying ones showing discontinuous or broken topography, it is possible to identify the dominant depth if a wider horizontal section of observation of the profiles is surveyed, as recommended in the manuals for soil description for these soils.

Table 1. Descriptive statistics of C_{org} contents of the spodic B horizons types and all spodic horizons in the database according to the current SiBCS (Santos et al., 2018)

Statistics	Bs(m)	Bh(m)	Bhs(m)	All spodic horizons (C_{org} ≥5.0 g kg^{-1})
	g kg^{-1}			
Mean	7.5	19.8	19.0	19.8
Median	6.7	15.1	14.5	15.0
Mode	6.1	5.0	5.0	5.0
Standard deviation	4.9	15.0	17.1	15.2
Minimum	0.2	0.5	1.2	5.0
Maximum	19.0	70.0	99.2	99.2
Count	93	127	165	310

Table 2. Descriptive statistics of thickness and upper depth of the spodic B horizons, and lower depth of horizons with sandy texture of database profiles

Statistics	Thickness of spodic B horizons with C_{org} ≥15.0 g kg^{-1}*	Upper depth of spodic B horizons	Lower depth of sandy horizons
	m		
Mean	0.26	1.00	0.90
Median	0.21	0.90	0.80
Mode	0.20	0.90	0.20
Standard deviation	0.19	0.52	0.70
Minimum	0.03	0.11	0.02
Maximum	1.15	4.00	5.40
Count	118	393	805

* The value of C_{org} were defined as a minimum for a spodic Bsh horizons in Menezes et al. (2025).

d) Definition of the 4th categorical level (Subgroup)

At this level, soils are identified by differential characteristics or attributes still related to genesis, but with greater relevance to express potential or limitation for soil use and management (plant nutrition, depth, physical impediment, acidity, texture, mineralogical composition, etc.). The subgroup classes are based on other diagnostic horizons, diagnostic properties or extraordinary attributes, absence of these, or soils identified as intermediate to other orders or suborders.

To compose the typical subgroup, the results from the study of Menezes et al. (2018) about the distribution and occurrence of Espodossolos in Brazilian pedoenvironments, including *restingas* (Atlantic Forest), *muçunungas* (Coastal Tablelands), high-altitude fields (*Cerrado* – Brazilian savanna and Atlantic Forest), *savannas* (Pantanal) and *campinaranas* (Amazon), were used as basis. The authors highlight that these soils are mostly formed under sandy sediments or from the alteration of felsic rocks, such as quartzite or sandstone, with the predominance of the sand fraction and, therefore, commonly present a sandy texture up to the first 1.00 m of the profile depth (Table 2). Based on this observation, the class *arênicos*, as defined in the current version of SiBCS, is the typical class and a subgroup to represent a characteristic which is predominant is expendable.

The suggested classes and their sequence in the taxonomic keys are:

- **tiônicos:** soils with one or more sulfuric horizons or sulfide materials from the soil surface to a depth of 1.50 m;
- **organossólicos:** soils with a histic horizon that does not meet the thickness criteria for the Organossolos order;
- **húmicos:** soils with a humic A horizon;
- **saprolíticos:** soils with one or more Cr horizons or layers from the soil surface to a depth of 1.00 m;
- **dúricos:** soils with a duric characteristic (placic, ortstein, and duripã) in one or more horizons or layers from the soil surface to a depth of 1.00 m;
- **fragipânicos:** soils with fragipã in one or more horizons or layers from its surface to a depth of 1.00 m;
- **abrúpticos:** soils with abrupt textural change within 1.00 m depth;
- **hidromórficos:** soils that remain saturated with water in one or more horizons or layers from the soil surface to a depth of 1.00 m for some time in most years (or are

artificially drained), which may be expressed in the form of mottled, variegated and/or areas of accumulation of iron and/or manganese oxides (due to the reduction and oxidation of iron and/or manganese);

- **espessarênicos:** soils with a sandy texture from their surface to a depth of at least 1.00 m; and
- **típicos:** other soils that are not included in the previous classes.

Considering the adjustments at all categorical levels, with the decrease in the depth of the control section at the order level, the Espodossolos in the database previously classified in the Hidro-Hiperespessos or Hiperespessos great groups are now classified as Neossolos Quartzarênicos, due to their predominant sandy texture and the absence of a spodic B horizon within 2.00 m depth of the soil surface. These soils can be identified as intermediate to the Espodossolos at the subgroup level, if the spodic B horizon is located at greater depth, similar to the WRB (IUSS Working Group WRB, 2022).

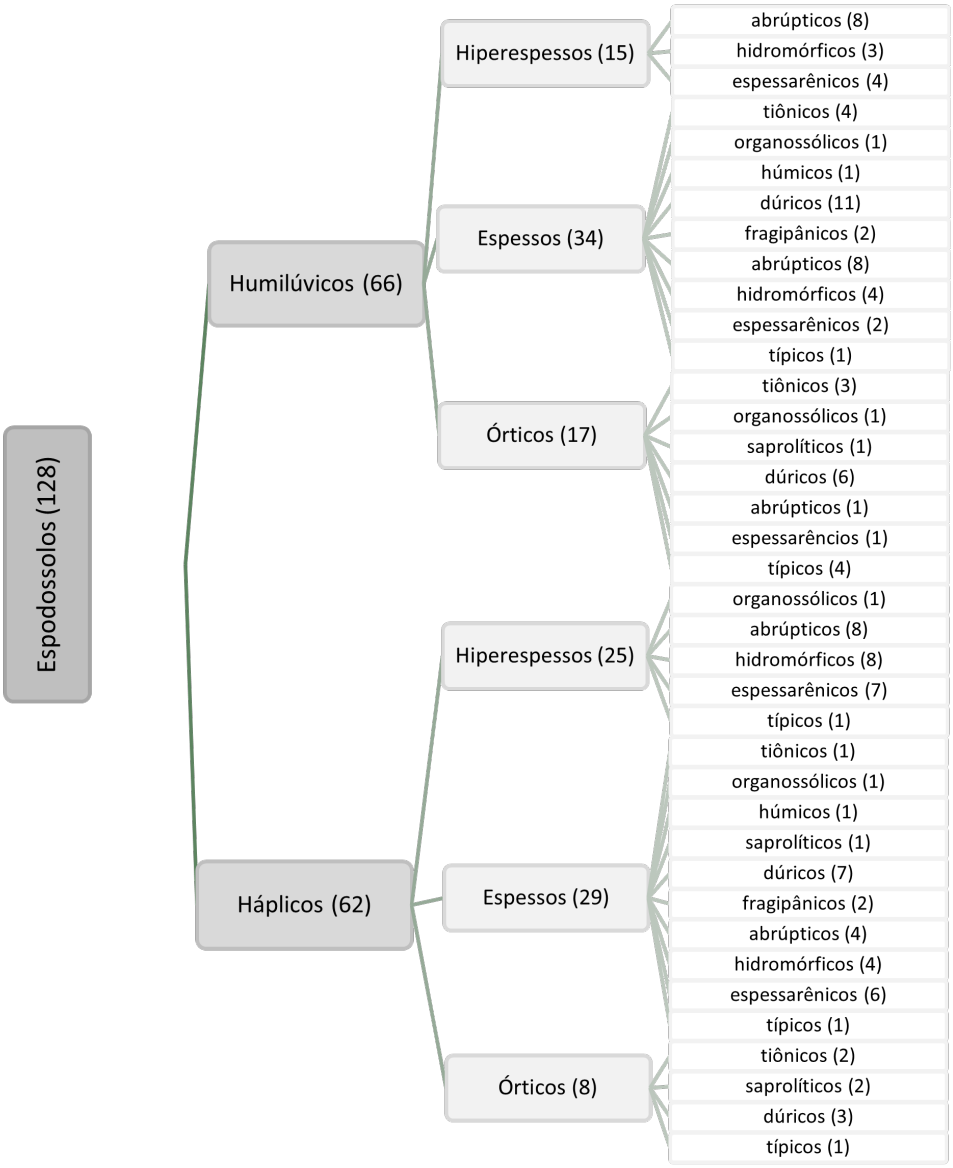

Figure 3. Profiles distribution of the Espodossolos up to 4th categorical level, with the names of classes in Portuguese, according to the proposal in this study.

Considering the proposed definition of spodic B, soils whose B horizons have C_{org} contents <5.0 g kg^{-1}, pH(H_2O) >5.9, and thickness ≥0.10 m would be classified in other classes of the SiBCS and, when pertinent, in subgroups intermediate to Espodossolos, for example: Neossolo Quartzarênico Órtico espodossólico. Soils with spodic B horizons coinciding with the plânico B horizon from the SiBCS (Santos et al., 2018), such as the profiles located in the Pantanal region of Baixa Nhecolândia (Cardoso et al., 2012; Schiavo et al., 2012) that present a sodic or solodic character, should be classified as Planossolos Nátricos and Planossolos Háplicos, considering a taxonomic precedence of the Planossolos over the Espodossolos. In these soils, the use of the intermediate character for the Espodossolos in the fourth level must be evaluated on a case-by-case basis, based on the concept that defines a podzolization process.

At the suborder level, the highlight of the illuviation process of organic matter is a reference to the pedogenesis of the spodic B horizons, which implies the translocation of complexes formed by humified organic matter and aluminum, with or without iron, as specified in the SiBCS and other taxonomic systems. Due to the difficulty of evaluating the elements Al and Fe in the spodic B horizons, in the current routine of soil analysis in Brazilian laboratories, the attribute of greatest ease of determination prevails, in this case, the C_{org}. This criterion does not prevent the detailed characterization of Al and Fe in studies on pedogenesis of Espodossolos, to understand the processes and the changes that occurred and still occur in their pedoenvironments.

At the great group level, the upper depth of the spodic B horizon was preserved as a criterion of greatest certainty and ease of measurement, compared to the assessment of hydromorphic conditions that are highly variable with seasons and years and with a poor relationship with morphological attributes such as color, mainly in soils of sandy texture.

At the subgroup level, the dúricos, organossólicos, fragipânicos, espessarênicos and típicos classes of the current version of SiBCS were maintained. The carbonáticos, êutricos arênicos, arênicos and êutricos classes were excluded for the reasons already mentioned regarding the podzolization process, which is already established by their absence in the database. The tiônicos, saprolíticos, hidromórficos, húmicos and abrúpticos subgroups were included, since they occurred in the database and these classes highlight the environments in which these soils are formed, as presented by Menezes et al. (2018).

In numerical terms, out of 154 profiles in the database, the proposal excludes only 26 profiles (17 %) from the order of Espodossolos as they do not meet the criteria of limiting values of pH(H_2O), C_{org} or depth of beginning of the spodic B horizon (2 profiles) (Figure 3). At the suborder level, the distribution according to the proposal is now equitable, where 66 profiles (52 %) have a minimum thickness of 0.20 m of the spodic B horizons and C_{org} contents ≥15.0 g kg^{-1}, being classified as Humilúvicos; and 62 profiles (48 %) do not meet these criteria and are identified as Háplicos. For the great group level, by reducing the limits of the depth of onset of the spodic B horizon, a normal distribution of the profiles in the database is now observed. The subgroup level now has coherence with relevant criteria in terms of potential or limitations for the use and management of Espodossolos.

CONCLUSIONS

The criteria currently adopted by the Brazilian Soil Classification System (Santos et al., 2018) for identifying the Espodossolos classes has limitations at the order level owing to the control section for the upper boundary of the spodic B horizon of 4.00 m. In the suborders there are limitations on the identification of types of spodic B horizons due to the absence of a direct relationship with morphology (color) that could allow their clear distinction. At the great group level, there is a discrepancy in the number of profiles in the database, with an absolute predominance of Órticos, showing that the choice of criterion is not adequate. For the subgroup, the greatest occurrence of the espessarênicos,

arênicos and típicos classes, with few or no soils identified as êutricos, êutricos arênicos and carbonáticos, argument that these criteria are not relevant to represent the Brazilian Espodossolos.

The proposal includes, at the order level, the reduction of the control section of the upper boundary of the spodic B horizon from 4.00 to 2.00 m; at the suborder level, the use of limits of C_{org} content in the spodic B horizon as a criterion for distinguishing between Humilúvicos and Háplicos. At the great group level, it is proposed to change the depth of the beginning of the spodic B horizon and subdivide the classes into Hiperespessos, Espessos and Órticos. As for the subgroup, the classes according the definitions of tiônios, organossólicos, húmicos, saprolíticos, dúricos, fragipânicos, abrúpticos, hidromórficos, espessarênicos and típicos.

DATA AVAILABILITY

The data will be provided upon request.

FUNDING

To the CNPq for the first author's master's scholarship, to PPGA-CS/UFRRJ, and to Embrapa Solos, FAPERJ and CAPES for financial support.

AUTHOR CONTRIBUTIONS

Conceptualization: Ademir Fontana (equal), Andressa Rosas de Menezes (equal) and Lúcia Helena Cunha dos Anjos (equal).

Data curation: Ademir Fontana (supporting) and Andressa Rosas de Menezes (lead).

Formal analysis: Ademir Fontana (equal) and Andressa Rosas de Menezes (equal).

Investigation: Ademir Fontana (equal) and Andressa Rosas de Menezes (equal).

Methodology: Ademir Fontana (equal) and Andressa Rosas de Menezes (equal).

Project administration: Ademir Fontana (lead).

Supervision: Ademir Fontana (lead) and Lúcia Helena Cunha dos Anjos (supporting).

Validation: Ademir Fontana (equal), Andressa Rosas de Menezes (equal) and Lúcia Helena Cunha dos Anjos (equal).

Visualization: Ademir Fontana (equal), Andressa Rosas de Menezes (equal) and Lúcia Helena Cunha dos Anjos (equal).

Writing – original draft: Ademir Fontana (equal), Andressa Rosas de Menezes (equal) and Lúcia Helena Cunha dos Anjos (equal).

Writing – review & editing: Ademir Fontana (equal), Andressa Rosas de Menezes (equal) and Lúcia Helena Cunha dos Anjos (equal).

REFERENCES

Baize D, Girard MC. Référentiel pédologique. Versailles, France: Éditions Quæ; 2008.

Cardoso EL, Crispim SMA, Carvalho Filho A, Lumbreras JF, Motta PEF, Araújo A, Fernandes AHBM, Jacomine PKT, Fernandes FA, Coelho MR, Calderano SB, Schinsato E, Soares MTS. Guia

de excursão de estudos de solos no Pantanal e Cerrados do estado do Mato Grosso do Sul. Corumbá: Embrapa Pantanal, Rio de Janeiro: Embrapa Solos; 2012.

De Coninck F. Major mechanisms in formation of spodic horizons. Geoderma. 1980;24:101-28. https://doi.org/10.1016/0016-7061(80)90038-5

Fontana A, Campos DVB. Carbono orgânico. In: Teixeira PC, Donagemma GK, Fontana A, Teixeira WG, editors. Manual de métodos de análise de solo. 3. ed. rev. e ampl. Brasília, DF: Embrapa; 2017. p. 360-7.

Gustafsson JP, Bhattacharya P, Bain DC, Fraser AR, Mchardy WJ. Podzolisation mechanisms and the synthesis of imogolite in northern Scandinavia. Geoderma. 1995;66:167-84. https://doi.org/10.1016/0016-7061(95)00005-9

Isbell RF. National committee on soil and terrain. The Australian soil classification. 3rd ed. Melbourne: CSIRO Publishing; 2021.

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 (IUSS); 2022. Available from: https://www.isric.org/sites/default/files/WRB_fourth_edition_2022-12-18.pdf.

Lumbreras JF, Carvalho Filho A, Calderano Filho B, Santos RD. Levantamento pedológico, vulnerabilidade e potencialidade ao uso das terras: quadrícula de Silva Jardim e Rio das Ostras, estado do Rio de Janeiro. Rio de Janeiro: Embrapa Solos; 2001. (Boletim de Pesquisa e Desenvolvimento, 23).

Menezes AR, Fontana A, Anjos LHC. *Espodossolos* in Brazil: A review of the criteria and conceptualization of the spodic B horizon. Rev Bras Cienc Solo. 2025;49:e0240116. https://doi.org/10.36783/18069657rbcs20240116

Menezes AR, Fontana A, Anjos LHC, Pereira MG, Schiavo JA. Soils with dark subsurface horizons in saline basins in the Brazilian Pantanal. Rev Bras Cienc Solo. 2022;46:e0210088. https://doi.org/10.36783/18069657rbcs20210088

Menezes AR, Fontana A, Anjos LHC. Spodosols in Brazil: distribution, characteristics and diagnostic attributes of spodic horizons. S Afr J Plant Soil. 2018;35:241-50. https://doi.org/10.1080/02571862.2017.1410734

Resende M, Curi N, Oliveira JB, Ker JC. Princípio da classificação dos solos. In: Ker JC, Curi N, Schaefer CEGR, Vidal-Torrado P, editors. Pedologia: Fundamentos. Viçosa, MG: Sociedade Brasileira de Ciência do Solo; 2012. p. 21-46.

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 RD, Lemos RC, 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.

Schaetzl RJ. A Spodosol-Entisol transition in northern Michigan. Soil Sci Soc Am J. 2002;66:1272-84. https://doi.org/10.2136/sssaj2002.1272

Schiavo JA, Dias Neto AH, Pereira MG, Rosset JS, Secretti M, Pessenda LCR. Characterization and classification of soils in the Taquari river basin - Pantanal region, state of Mato Grosso do Sul, Brazil. Rev Bras Cienc Solo. 2012;36:697-708. https://doi.org/10.1590/s0100-06832012000300002

Shishov LL, Tonkonogov VD, Lebedeva II. Russian soil classification. Mowcow: Academy of Agricultural Science; 1998.

Soil Classification Working Group. The Canadian system of soil classification. 3rd ed. Ottawa: NRC Research Press; 1998. Available from: https://sis.agr.gc.ca/cansis/publications/manuals/1998-cssc-ed3/index.html.

Soil Classification Working Group. Soil classification: A taxonomic system for South Africa. 2nd ed. Department of Agricultural Development, 1991. (Memoirs on Agricultural Natural Resources of South Africa No. 15).

Soil Survey Staff. Keys to soil taxonomy. 13th ed. Washington, DC: United States Department of Agriculture, Natural Resources Conservation Service; 2022.