Technical Paper 29

RELATION BETWEEN THE SOIL UNITS OF THE FAO-UNESCO SOIL MAP OF THE WORLD LEGEND AND THE SOIL CLASSES USED IN BRAZILIAN SURVEYS

João Bertoldo de Oliveira & Maurits van den Berg

ISRIC

INTERNATIONAL SOIL REFERENCE AND INFORMATION CENTRE

RELATION BETWEEN THE SOIL UNITS OF THE FAO-UNESCO SOIL MAP OF THE WORLD LEGEND AND THE SOIL CLASSES USED IN BRAZILIAN SURVEYS

João Bertoldo de Oliveira & Maurits van den Berg

1996

CIP-GEGEVENS KONINKLIJKE BIBLIOTHEEK, DEN HAAG

Oliveira, João Bertoldo de

Relation between the soil units of the FAO-UNESCO soil map
of the world legend and the soil classes used in
Brazilian surveys / João Bertoldo de Oliveira & Maurits
van den Berg. - Wageningen :International Soil Reference
and Information Centre. -(Technical paper /
International Soil Reference and Information Centre, ISSN
0923-3792 ; 29)
Met lit. opg.
ISBN 90-6672-068-9
Trefw.: bodemclassificatie / bodemkunde ; Brazilië.

International Soil Reference and Information Centre (ISRIC)
P.O. Box 353
6700 AJ Wageningen, The Netherlands
Phone : +31 317 471711
Fax : +31 317 471700
E-mail : SOIL@ISRIC.NL

Table of Contents

ABSTRACT

1 Introduction 1

2 Comparison of Recommended Analytical Methods 3

3 Master Horizons 7

4 Diagnostic Horizons and Diagnostic Properties 9

5 Major Soil Groupings and Soil Units *vs*. General Classes 15
5.1 Histosols 15
5.2 Anthrosols 16
5.3 Leptosols 16
5.4 Vertisols 17
5.5 Fluvisols 18
5.6 Solonchaks 19
5.7 Gleysols 20
5.8 Andosols 21
5.9 Arenosols 21
5.10 Regosols 23
5.11 Podzols 23
5.12 Plinthosols 24
5.13 Ferralsols 25
5.14 Planosols 27
5.15 Solonetz 27
5.16 Greyzems 28
5.17 Chernozems & Kastanozems 28
5.18 Phaeozems 29
5.19 Podzoluvisols 30
5.20 Gypsisols 30
5.21 Calcisols 31
5.22 Nitisols 31
5.23 Alisols 35
5.24 Acrisols 36
5.25 Luvisols 36
5.26 Lixisols 37
5.27 Cambisols 38

6 Discussion 41

7 Conclusions 43

Bibliography 45

Appendix 1 The Highest Taxonomic Levels of the Soil Classification System in Use in Brazil 49

Appendix 2 English x Portuguese x English Vocabulary of Terms of the Brazilian System of Soil Classification 55

RELATION BETWEEN THE SOIL UNITS OF THE FAO-UNESCO SOIL MAP OF THE WORLD LEGEND AND THE SOIL CLASSES USED IN BRAZILIAN SURVEYS[1]

João Bertoldo de Oliveira[2] & Maurits van den Berg[3]

ABSTRACT

This paper presents a correlation between the soil units of the Revised Legend of the FAO-Unesco Soil Map of the World (FAO Legend) and the soil classes used in Brazilian surveys, with special attention to discrepancies and incompatibilities between the systems and weaknesses that may be considered for future revisions. The paper also compares horizon definitions and analytical methods used or recommended by the two systems. Where possible, a reference to at least one description of each of the Soil Units identified in Brazil is provided.

Published profile descriptions were encountered in the consulted literature for 23 of the 28 Major Soil Groupings of the FAO Legend. Three Major Soil Groupings (Andosols, Gypsisols, Greyzems) do probably not exist in Brazil. Podzoluvisols probably occur, but no descriptions could be found with sufficient detail to identify them unambiguously. Fimic Anthrosols have been identified in Brazil as "Indian Black Earth" and "Archaeological Black Earth", but are not (yet) considered as such in the classification system. Examples for 87 of the 131 Soil Units that belong to the 24 identified Major Soil Groupings are given. Gelic and probably also andic and gypsic Soil Units do not exist in Brazil. Some other soil units could not be identified because the consulted soil descriptions and analytical data were not sufficient to discriminate between e.g. some soil units of Podzols. Other Soil Units have very small occurrences, and therefore only appear as inclusions on available soil maps, without a detailed description (e.g. Umbric Regosols and Cambic Arenosols).

The central concept of most Major Soil Groupings of the FAO Legend corresponds well with General Classes of the "Brazilian Soil Classification". However, many discrepancies appear with a more detailed analysis.

It was concluded that the correlations between the "Brazilian System of Soil Classification" and the FAO Legend are strong enough to be used for the translation of the legend of Brazilian maps to small scale (say <1 : 1 000 000) maps, with the FAO Legend, if used for educational purposes. For scientific purposes or technology transfer and maps with larger scale, the correlations between the systems are too weak for simple "translation". This will require additional support by comparisons of profile descriptions, correlation between analytical methods and in some cases even additional fieldwork.

The main drawbacks of the system of soil classification in use in Brazil are the lack of clear definitions and the fact that it has no official status. This leads to locally varying applications. In general, the FAO Legend seems well applicable to Brazilian conditions, but modifications are suggested for some important groupings like Nitisols and Ferralsols. Less restrictive definitions are suggested for the ferralic B horizon and gleyic properties. The recognition of Ferralic Arenosols seems unpractical and of little relevance.

---

1 Text based on lecture notes by the first author used in the Post-Graduate Course "Soil Classification" at the University of São Paulo (USP/ESALQ).

2 Visiting professor of the State University of São Paulo (UNICAMP) and of the University of São Paulo (USP).

3 Lecturer Soil Science, Eduardo Mondlane University, Maputo, Mozambique.

1 INTRODUCTION

The FAO-Unesco Soil Map of the World results from a recommendation of the 7th International Congress of Soil Science, held in Madison, Wisconsin (USA), in 1960; with the following objectives:

- make a first appraisal of the world's soil resources;
- supply a scientific base for the transfer of experience between areas with similar environments;
- promote the establishment of a generally accepted soil classification and nomenclature;
- establish a common framework for more detailed investigations in developing areas;
- serve as a basic document for educational, research and development activities;
- strengthen international contacts in the field of soil science;

The development of the map, at scale 1 : 5 000 000, and its legend started in 1961. In 1971 the first map - South America - was published, and in 1981 the last two, of a total of nineteen.

New classification concepts and better understanding of soil conditions resulting from a lot of new information arising from extensive soil surveys, especially in developing countries, urged for a revision of the legend. The Revised Legend of the Soil Map of the World was published in 1988 as a joint effort of FAO, Unesco and ISRIC (FAO, 1988), supported by intensive international exchange of ideas. A reprint with corrections was issued in 1994 (ISRIC, 1994).

It is stated in the Revised Legend that although the Legend was (and is) not meant to substitute national systems of soil classification, it aims at being a common denominator between various systems, so that comparisons can be made. It is also a tool for soil survey and land evaluation in countries which have not adopted a specific system of soil classification.

Considering the above, we believe that it is important, and in line with the objectives of the Soil Map of the World project, to correlate the Soil Units of the Legend with the soil classes used in national soil surveys. The results of such correlations can be used to feed global databases which are in development; for comparative pedologic studies and for agrotechnology transfer. The latter is of special importance in the case of Brazil, as there exists a large field for exchange of agrotechnologic and pedologic information with other countries in the tropics, notably the PALOP[1] countries.

A potential pitfall for correlation of soil classification systems is that similarity of nomenclature may tempt to oversimplification. The Revised Legend states (Chapter III, 2nd paragraph): "... It should therefore be stressed that the uniformity aimed at in the preparation of the Soil Map of the World will be reached only if the names are used in accordance with the definitions which have been agreed upon, possibly at the cost of restricting the meaning which they have acquired locally". Therefore we feel that a sound correlation exercise should deal with the entire process of classification, including identification of master horizons, laboratory analysis and the proper application of the classification rules.

---

[1]PALOP: Países Africanos de Língua Oficial Português, i.e. African countries with Portuguese as official language.

The principal objective of this paper is to make a correlation between the Soil Units of the Revised Legend of the Soil Map of the World (FAO, 1990) and the soil classes used in Brazilian soil surveys. Special attention will be given to discrepancies and incompatibilities between the systems and inconsistencies of the systems, that may be considered in future revisions. It is aimed to provide a reference to at least one example of a published description of each of the Soil Units identified in Brazil.

Systematic soil surveys started relatively recently in Brazil. In 1954 the first national institute for soil survey was created. In those days the classification used was based on the American soil classification systems of Baldwin et al., (1938) and Thorp & Smith (1949). Since the beginning of the sixties, criteria of the Seventh Approximation were incorporated (Bennema & Camargo, 1964) and later also of Soil Taxonomy (Soil Survey Staff, 1975) and the Legend of the FAO-Unesco Soil Map of the World (FAO-Unesco, 1974) . Still, there exists neither an up-to-date "Brazilian Soil Taxonomy", nor an official text which relates and defines all classes of soils in a classification system. In the past decade several drafts of such a system and discussion papers on these drafts have been published by EMBRAPA/SNLCS[1].

In order to make the text more readable, the term "Brazilian System (of Soil Classification)" will be used instead of the more correct "Soil classification as used in Brazilian soil surveys". References to the "Revised Legend of the Soil Map of the World (FAO, 1990)" will be abbreviated by "the FAO Legend".

The "Brazilian System" has a morphogenetic base. Its organization is centred on characteristics that express evidence of pedogenetic processes, using morphological, physical, chemical and mineralogical criteria (Camargo et al., 1987). It can be considered as a referential system, because there is no clearly established hierarchy. The soils of each class are divided in lower categorical levels by adding adjectives, for example Eutrophic medium/clayey textured Red-Yellow Podzolic Soils with low clay activity, moderate A horizon; or carbonatic Reddish Brunizem. The 37 classes that are identified at the highest categorical level are distributed among 16 groupings, listed in Appendix 1. Appendix 2 presents a list of the most important terms used in the "Brazilian System of Soil Classification" in English and Portuguese.

The main references used for the present text are "Classes gerais de solos do Brasil. Guia auxiliar para a sua identificação" (Oliveira et al., 1992); and "Soil classification as used in Brazilian soil surveys" (Camargo et al., 1987), that have combined a number of EMBRAPA/SNLCS publications in a systematic way. Besides several other papers published by EMBRAPA were used. The paper of Camargo et al. (1987) also presents a tentative correlation between the Brazilian System and the first edition of the FAO Legend (FAO-Unesco, 1974) and the USDA Soil Taxonomy (Soil Survey Staff, 1975). This correlation is at the Major Soil Grouping Level for the 16 groupings presented in Appendix 1 and partially at the Soil Unit level for the Latosols.

[1]EMBRAPA: Empresa Brasileira de Pesquisa Agropecuária. SNLCS: Serviço Nacional de Levantamento, Comissão de Solos.

2 COMPARISON OF RECOMMENDED ANALYTICAL METHODS

An aspect that complicates an objective correlation of soil classification systems is that the recommended analytical methods for determination of (diagnostic) chemical and physical properties are not always the same. The use of different methods may lead to the introduction of systematic differences in analytical results, which affect the meaning of critical values that are used for class limits. A summary of the most important methods recommended by EMBRAPA/SNLCS for classification purposes are listed below (adapted from International ..., 1988). The codes between brackets refer to the identifiers of the "Manual de métodos de análise de solo" (EMBRAPA, 1979).

Fractions > 2 mm (gravel and stones) and < 2 mm (fine earth) - air-dried samples, wood rolling to break clods and sieving through a rounded hole 2 mm sieve; % volume by volumetric measurement of fraction coarser than 2 mm (Meth 1,2,2); % weight determined by weighting the given fractions (Meth. 1,2,1).

Particle size distribution - determined in the <2 mm fraction dispersed in water with NaOH or occasionally calgon, high speed stirring, sedimentation; clay determined by modified hydrometer method (Vettori & Pierantoni, 1968), sands by sieving and silt by difference; no pretreatment to destroy organic matter (Meth. 1,16,2).

Water dispersable clay - same as above, but without the use of dispersing agent (Meth. 1,17,2).

Flocculated clay ratio - calculated as 100% x (total clay - water dispersable clay)/total clay; Meth 1,18).

Bulk density - determined on undisturbed core samples by volumetric ring (Kopecky) method (Meth. 1,11,1) or paraffin-coated clods (Meth. 1,11,3), when applicable reported on base of ovendry weight.

Particle density - volumetric flask and ethyl alcohol (Meth. 1,12U).

Porosity - calculated from bulk density and particle density (Meth 1,13).

Water content 1/3 bar - determined on presaturated disturbed samples of <2 mm fraction by centrifuging at 2,400 rpm during 30 minutes (Meth. 1,8).

pH H_2O and 1N KCl - measured potentiometrically by glass electrode in a 1:2.5 soil:water and soil:1N KCl suspension respectively; contact not less than 30 minutes; stirring immediately before reading (Meth. 2,1,1 and 2,1,2).

Extractable bases - Ca^{2+} and Mg^{2+} extracted with 1N KCl and titrated with EDTA (Meth. 2,9 and 2,10); K^+ and Na^+ extracted with 0.05N HCl + 0.025N H_2SO_4, and determined by flame photometer (Meth. 2,12 and 2,13).

Sum of bases - calculated as sum of Ca^{2+}, Mg^{2+}, K^+ and Na^+ determined as above (Meth. 2,14).

Extractable acidity - Al^{3+} extracted with 1N KCl; acidity titrated with 0.025N NaOH and bromthymol blue as indicator (Meth. 2,8); $Al^{3+}+H^+$ extracted with 1N $Ca(OAc)_2$ at pH 7.0; titration of acidity with 0.0606N NaOH and phenolphthalein as indicator (Meth 2,15); H^+ calculated by difference from above determinations (Meth. 2,16).

CEC - sum of cations at pH 7.0 - calculated by summing extractable bases and $Ca(OAc)_2$ extractable acidity as described above (Meth. 2,17).

Base saturation - ratio between sum of bases and CEC as described above, reported as % of CEC (Meth. 2,18).

Aluminium saturation - ratio between Al^{3+} extracted with 1N KCl and sum of bases + Al^{3+}; reported as %.

Available P - extracted with 0.05N HCl + 0.025N H_2SO_4 and determined colorimetrically (Meth. 2,6).

Organic carbon - wet combustion with 0.4N $K_2Cr_2O_7$ and titration with 0.1N $FeSO_4$ (Meth. 2,2).

Total nitrogen - Kjeldahl - digestion with acid mixture, destilation and titration of NH_3 with 0.01N HCl (Meth. 2,4,1).

Sulphuric attack - boiling of fine earth fraction with H_2SO_4 1:1. Fe, Al, Ti, Mn and P are extracted. Iron and aluminium are determined complexometrically by titration and reported as Fe_2O_3 and Al_2O_3 (Meth. 2,24 and 2,25). Titanium, manganese and phosphorous are determined colorimetrically using ascorbic acid, reported as TiO_2, MnO_2 and P_2O_5 (Meth. 2,26, 2,27, 2,28). Silicon is extracted from the residue of the sulphuric attack with NaOH 0.8% and determined colorimetrically, reported as SiO_2 (Meth. 2,23,3).

SiO_2/Al_2O_3, SiO_2/R_2O_3, Al_2O_3/Fe_2O_3 ratios (R=Al+Fe) - calculation on molecular basis, derived from the determinations described above (Meth. 2,29 and 2,30).

CBD extractable iron - determined by atomic absorption spectrophotometry, reported as Fe_2O_3.

Some of these methods are quite different from the ones recommended for use by the FAO Legend. Olmos & Paolinelli (1982) compared some results obtained with the analytical methods recommended by the USDA Soil Conservation Service (approximately the same as those recommended by the FAO Legend) and the methods recommended by EMBRAPA (1979). The results are summarized in Table 2.1. Although the representativeness of the values in Table 2.1 is not clear, it will be clear that using values determined by a certain method to classify a soil according to a system for which a different method was recommended is extremely risky. Note that the method of determination of particle size distribution may become crucial for the identification of a Ferralic B horizon.

Table 2.1 Correlation between values of diagnostic soil characteristics determined according to laboratory methods recommended by the Soil Conservation Service and SNLCS/EMBRAPA. Source: Olmos & Paolinelli (1982)

	Soil Conservation Service	SNLCS	
Organic carbon (%)	8	5.3	
	12	8	
	15	10	
	16	10.5	
	18	12	
Base saturation (pH 7, %)	50	65	
	37	50	
	25	35	
Exchangeable sodium percentage	15	20	
	6	8	
Cation exchange capacity (cmol(+).kg^{-1})		After deduction for organic matter	no deduction for organic matter
	16	6.5	10
	24	13	17
	32	17	20
	42	24	27

Not all Brazilian labs use the methods recommended by EMBRAPA mentioned above. E.g., for particle size distribution, the Agronomic Institute of Campinas, São Paulo (IAC) uses the pipette method and slow dispersion (Camargo et al., 1986). The same institute uses the resin exchange method for the assessment of available P.

It is shown in Chapter 4 that some, but not all, of the correlations found by Olmos & Paolinelli (1982) have been taken into account by the definitions of diagnostic properties of the "Brazilian System", to improve matching.

3 MASTER HORIZONS

Soil classification is not possible without a proper field description. Soil horizons must be identified, to be used as reference units for description and lab analysis. The names, or better codes, with which soil horizons are indicated reflect the ideas of the surveyor with respect to the dominant soil forming processes that are responsible for its present day conditions. Although these indications are rather subjective, they form an important guideline for the classification of the soil, even in morphometric systems.

The guidelines for identifying and coding of master horizons of the Brazilian Soil Survey and Conservation Service (EMBRAPA, 1988a) are quite similar to those of the Guidelines for Soil Profile Description (FAO, 1977), included in Appendix 1 of the FAO Legend. However, there are some discrepancies, that can lead to confusion.

The master horizons, A, B, C etc., are practically the same in both systems, except for a F horizon, which is used in Brazil to indicate a petroplinthite horizon. The combination of letters to indicate transitional horizons and the use of figure suffixes to subdivide master horizons and figure prefixes to indicate lithological discontinuities are identical. However, there are many differences in the use of letter suffixes, used to indicate the types of soil forming processes that are most expressively reflected in the horizon. A comparison of letter suffixes by FAO (1977) and EMBRAPA (1988a) is given in Table 3.1.

Table 3.1 Comparison of letter suffixes for master horizons used by FAO (1977) and EMBRAPA (1988a).

	FAO, 1977	EMBRAPA, 1988a
b	buried or bisequal soil horizon	buried soil horizon
c	accumulation in concretionary form	accumulation in concretionary form
d	—	strongly decomposed organic material (to be used in combination with O or H)
e	—	darkening of ped faces by organic matter which is not associated with sesquioxides
f	—	plinthite
g	mottling, reflecting variations in oxidation and reduction	strong gleying
h	accumulation of organic matter in mineral horizons (to be used in combination with A or B)	illuvial accumulation of organic matter (to be used in combination with B)
i	occurrence of permafrost	used with B horizon; incipient; only slightly altered in comparison with C horizon or parent material
j	occurrence of jarosite	thiomorphism
k	accumulation of calcium carbonate	k: presence of calcium carbonates, excl. secondary accumulation
		$\bar{k}$: secondary enrichment of calcium carbonate
m	strongly cemented, consolidated or indurated	extremely cemented
n	accumulation of sodium	accumulation of sodium
o	—	o: weakly decomposed organic material (to be used in combination with O or H)
		od, do: organic material in an intermediate stage of decomposition
p	disturbed by ploughing or other tillage practices	disturbed by ploughing or other tillage practices
q	accumulation of silica	accumulation of silica
r	strong reduction as a result of groundwater influence	saprolith, rotten rock; used in combination with C
s	accumulation of sesquioxides[1]	used with B horizon; illuvial accumulation of sesquioxides plus organic matter
t	accumulation of clay	accumulation of clay
u	unspecified	anthropogenic modifications and accumulations
v	—	vertic properties
w	used with B horizon; alteration in situ as reflected by clay content, colour, structure	used with B horizon; strongly weathered, generally accompanied by residual accumulation of sesquioxides.
x	occurrence of a fragipan	apparently cemented, but softens when moist (e.g. fragipan)
y	accumulation of gypsum	accumulation of gypsum
z	accumulation of salts more soluble than gypsum	accumulation of salts more soluble than gypsum

[1] It is often overlooked that the 3rd edition of the FAO Guidelines for Soil Description (FAO-ISRIC, 1990) restricts the suffix *s* to illuvial accumulation of sesquioxides. The suffix *o* was introduced for residual accumulation of sesquioxides.

4 DIAGNOSTIC HORIZONS AND DIAGNOSTIC PROPERTIES

Both the FAO Legend and the "Brazilian System" use the concepts of diagnostic horizons and diagnostic properties as key characteristics for classification. As the systems have developed in parallel, with mutual influences, the definitions are quite similar and show also many similarities with the USDA Soil Taxonomy (Soil Survey Staff, 1975). Most names of the "Brazilian System" are different and derived from local nomenclature. A comparison of diagnostic horizons of the two systems is given in Table 4.1. Table 4.2 gives a more detailed comparison between the Argic B horizon of the FAO Legend and the textural B of the "Brazilian System" and Table 4.3 compares the Ferralic B horizon of the FAO Legend with the Latosolic B horizon of the "Brazilian System". The Revised Legend is not completely clear with respect to the need to deduct the influence of organic matter on CEC for the identification of a Ferralic B horizon or ferralic properties. It is stated in Chapter IV, 3rd paragraph, that "the CEC used as criterion of diagnostic horizons and properties, is essentially meant to reflect the nature of the mineral component of the exchange complex. ...Where low clay activity is a diagnostic property, it may be desirable to deduct CEC linked to organic matter...". According to Van Baren, ISRIC (personal communication), these lines are meant for those cases that the CEC requirement is over a boundary but correction may take the CEC value under the boundary. However, these statements are often overlooked, or understood as something which is not (yet) formally implemented in the Legend. The definitions of Ferralic B horizon and ferralic properties do not explicitly mention the need for correction of CEC for organic matter.

A list of diagnostic properties used by the "Brazilian System" is given in Table 4.4. Several of the definitions of diagnostic properties use the same criteria as corresponding properties of the FAO Legend and of Soil Taxonomy (Soil Survey Staff, 1975), e.g. saline vs. salic properties, sulphidric materials vs. sulfidic materials. Other definitions use different critical values, which were introduced on purpose in the "Brazilian System", to account for the use of different analytical methods (see Table 2.1). This is the case for e.g. the definition of organic soil materials. Some other definitions are apparently the same, but differ because of different analytical methods. E.g., Table 2.1 shows that the critical value of 50% base saturation, used by the "Brazilian System" to separate "eutrophic" and "dystrophic" classes and to discriminate between chernozemic and prominent A horizons (Table 4.1), is in fact not the same critical value of 50% base saturation used by the FAO Legend to define eutric and dystric soil units, and to discriminate between e.g. Acrisols and Lixisols and mollic and umbric A horizons.

Table 4.1 Correlation of diagnostic horizons as defined by the FAO Legend (FAO, 1990) and the soil classification system in use in Brazil (SNLCS, according to Camargo et al., 1987). The most appropriate master horizon codes are placed between brackets behind the names of the diagnostic horizons.

Concept	**FAO Legend**	**Brazil/SNLCS**	remarks for Brazil/SNLCS
Organic horizon	Histic H horizon (H)	Turphose horizon (H)	no maximum thickness defined
"Man made" surface horizon	Fimic A horizon (Ap)	Anthropic A horizon (Au)	equivalent
Thick dark mineral surface horizon with high organic matter content and high base saturation	Mollic A horizon (Ah)	Chernozemic A horizon (A)	equivalent
Thick dark mineral surface horizon with high organic matter content and low base saturation	Umbric A horizon (Ah)	Prominent A horizon or Humic A horizon (A)	Humic A is stronger developed than Prominent A, but limits are not quantified
Weakly developed surface horizon	Ochric A horizon (Ah)	Moderate A horizon or Weak A horizon (A)	weak A horizon has <0.58% org. C; colour value moist >5 and is structureless or weakly structured
Eluvial horizon	Albic E horizon (E)	Albic horizon (E)	equivalent
Subsurface horizon with clay accumulation	Argic B horizon (Bt)	Textural B horizon (Bt)	see Table 4.2
Subsurface horizon with clay accumulation and high sodium saturation	Natric B horizon (Btn)	Natric B horizon (Btn)	equivalent
Subsurface horizon with illuviation of organic matter with iron or aluminum.	Spodic B horizon (Bhs)	Spodic B horizon (Bh, Bs, Bhs)	equivalent
Strongly weathered subsurface horizon	Ferralic B horizon (Bws)	Latosolic B horizon (Bw)	see Table 4.3
Subsurface horizon with weakly expressed pedogenetic alterations.	Cambic B horizon (Bw)	Incipient B horizon (Bi)	equivalent but excluding Gley and Plinthite horizon
Horizon enriched with plinthite	— (Bgs, Cgs)	Plinthic horizon (Bf, Cf, F)	≥15% plinthite by volume; ≥15cm thick;
Horizon characterized by moisture excess	— (Cg, Cr)	Gley horizon (Cg)	≥15cm thick; ≥20% with hue "bluer" than 10Y and chroma ≤2; saturated with water for some period each year if not artificially drained.
Horizon with secondary accumulation of calcium carbonate	(Petro)calcic (Cmk, Ck)	(Petro)calcic horizon (Cmk̄ , Ck̄)	equivalent
Horizon with secondary accumulation of gypsum	(Petro)gypsic horizon (Cmy, Cy)	(Petro)gypsic horizon (Cmy, Cy)	equivalent
Horizon with secondary accumulation of soluble salts	— (Cz)	Salic horizon (Cz)	≥15 cm thick; >2% secundary enrichment of soluble salts; thickness * %salt ≥60
Very acid horizon with jarosite mottles	Sulfuric horizon (Cj)	Sulfuric horizon (Cj)	equivalent

Table 4.2 Comparison of diagnostic criteria for subsurface horizons with clay accumulation according to the FAO Legend (FAO, 1990), and the soil classification system in use in Brazil (SNLCS, according to Camargo et al., 1987).

	FAO Legend	**BRAZIL/SNLCS**
Name	argic B horizon	textural B horizon
Texture	sandy loam or finer and clay content >8%	—
Vertical clay differen- tiation	if clay content of overlying horizon <15% then ≥3% more clay than over- lying horizon	if clay content of overlying horizon <15% then ratio of clay content {(textural B)/(overlying hor)} > 1.8
	if clay content of overlying horizon 15-40% then ratio of clay content {(argic B)/(overlying hor)} ≥1.2	if clay content of overlying horizon 15-40% then ratio of clay content {(Textural B)/(overlying hor)} ≥ 1.7
	if clay% overlying horizon >40% then ≥8% more clay than overlying horizon	if clay content of overlying horizon >40% then ratio of clay content {(Textural B)/(overlying hor)} > 1.5
		the requirements above are waived if the B horizon has blocky or prismatic structure and clay skins exceed few and weak
Minimum vertical distance for clay increase:	30 cm if clay skins are evident; else 15cm	—
Thickness:	>15cm and > 1/10th of the sum of all overlying horizons	if base below 150cm then thickness ≥15cm else: if texture sandy: ≥15cm if texture loamy or finer: ≥7.5cm and at least 1/10th of overlying horizons
Thickness of overlying horizons	>5cm if transition is abrupt. Else >18cm	-
Others	set of properties that characterize ferralic B horizon is not allowed	the above cited requirements for vertical clay differentiation are waived if the B horizon has blocky or prismatic structure with shiny (waxy) ped faces to a degree that exceeds weak and few

Table 4.3 Comparison of diagnostic criteria for strongly weathered subsurface horizons according to the FAO Legend (FAO, 1990), and the soil classification system in use in Brazil (SNLCS, according to Camargo et al., 1987).

	FAO Legend	**Brazil/SNLCS**
Name	ferralic B horizon	latosolic B horizon
Texture	sandy loam or finer and ≥8% clay in fine earth	sandy loam or finer
Thickness	≥30 cm	≥50 cm
Cation exch. capacity	≤16 cmol/kg clay <u>or</u> ECEC ≤12 cmol/kg clay	<13 cmol/kg clay after deduction of the contribution of organic matter
Weatherable minerals	<10% in 50-200μm fraction	<4% in 50μm-2mm fraction
Silt/clay ratio	≤0.2	<0.7
Water dispersable clay	<10%	<10%
Rock structure	<5% by volume	<5% by volume
Others	—	SiO_2/Al_2O_3 of clay fraction < 2.2; lack the set of properties which characterize the textural B horizon

Table 4.4 Diagnostic properties used by the "Brazilian System of Soil Classification", according to EMBRAPA (1988b).

	diagnostic property	definition
Activity of clay	high clay activity (Ta)	CEC ≥24 cmol(+).kg^{-1} in B*) horizon
	low clay activity (Tb)	CEC <24 cmol(+).kg^{-1} in B*) horizon
Base status	eutrophic	base saturation in B*) horizon ≥50% of CEC (pH(7))
	dystrophic	base saturation in B*) horizon <50% of CEC (pH(7))
	allic	Al saturation in B*) horizon ≥50% of ECEC, and 1 N KCl extractable AL >0.3 cmol(+).kg^{-1}
Type of soil material	organic soil material	organic carbon (C%) ≥12% (by weight) if clay content ≥60%; C% ≥8% if no clay present; or intermediary values for 0≤clay% ≤60.
	mineral soil material	if soil material is not organic
Carbonates	carbonatic	$CaCO_3$ content ≥15%, but without a calcic horizon
	with carbonates	5% ≤ $CaCO_3$ content < 15%
Sodium saturation	sodic	sodium saturation >20% in the B horizon (if present) or in the C horizon;
	solodic	sodium saturation >8% and <20% in the B horizon (if present) or in the C horizon;
Salinity	saline	EC of saturation extract >4 mS.cm^{-1} at 25°C in some part of the soil
	lithic contact	transition of soil to hard coerent rock, which is so resistant that it is impracticle to be cut with spade or hoe when moist.
	lithoid contact	transition of soil to rock, which is weakly resistant and can be cut with spade or hoe
Weathering status	Ki index	molecular ratio SiO_2/Al_2O_3. Different critical values exist for different General classes.
	easily weatherable minerals	primary minerals which are slightly or moderately resistant to weathering, such as olivine, feldspates, hornblends and pyroxenes
Abrupt textural change	abruptic	accentuated increase of clay content from A or E to B horizon; similar definition as FAO Legend, but change must occur within 8 cm and not 5 cm.
Plinthite	plinthite	same definition as FAO Legend
	petroplinthite	irreversibly hardened plinthite
Vertic properties	slickensides, gilgai, cracks	same definition as FAO Legend
Sulfidic materials	sulphidric materials	same definition as FAO Legend

*) or C horizon for AC soils or A for AR soils.

5 MAJOR SOIL GROUPINGS AND SOIL UNITS VS. GENERAL CLASSES

Each section of this Chapter discusses a Major Soil Grouping of the FAO Legend and its Soil Units. Each section starts with the definition of the Major Soil Grouping (in italics), followed by a discussion of the degree of correlation with General Classes of the "Brazilian System" . Subsequently the Soil Units of the respective Major Soil Grouping are discussed one by one. It was attempted to refer to at least one example of a published description of a "representative" Brazilian soil profile for each Soil Unit.

Only Chapter X: "Key to Major Soil Groupings and Soil Units" of the FAO Legend was used for correlation. No additional use was made of Chapter VI of the same publication: "The Soil Units and Major Soil Groupings", because there exist some discrepancies between these two chapters.

5.1 HISTOSOLS

Soils having a H horizon or an O horizon, of 40 cm or more (60 cm or more if the organic material consists mainly of sphagnum or moss or has a bulk density of less than 0.1 $Mg.m^{-3}$) either extending down from the surface or taken cumulatively within the upper 80 cm of the soil; the thickness of the H or O horizon may be less if it rests on rocks or on fragmental material of which the interstices are filled with organic matter.

The closest equivalent in the "Brazilian System" is the "Organic Soils" ("Solos Orgânicos"). However, there are several differences: (1) the Brazilian system has no specific rules for ombrogenic peats (with organic material that consists mainly of sphagnum or moss and that have very low bulk density), which seems not relevant, as such soils probably do not occur in Brazil; (2) the "Brazilian System" does not waive the depth limits for organic soil material that rests directly on rocks or fragmentary material (see Folic Histosols, below). The latter is a weak point in the FAO Legend, because no lower limit for the soil thickness is defined.

At lower hierarchical levels, the "Brazilian System" does not use the degree of decomposition of the organic soil material as a diagnostic property. Therefore, it is not possible to make a clear correlation of the Organic Soils with the Histosols at the Soil Unit level.

Gelic Histosol - There are no climatic conditions in Brazil that permit the occurrence of these soils.

Thionic Histosols - Organic Thiomorphic Soils.
Example: Profile GB-56, (EMBRAPA, 1980). This profile was classified as an Organic Saline Thiomorphic Soil.

Folic Histosols - The "Brazilian System" does not recognize a class of well drained Organic Soils. These soils are uncommon in Brazil and only a very few profiles have been identified in the cool mountainous regions of the southern states: Rio Grande do Sul, Santa Catarina and Paraná.
Example: Profile RS-113 (Brasil, 1973b). This profile was classified as Eutrophic Lithosol with a turphose horizon.

Fibric Histosols - Organic Soils.
Example: Profile GB-46 (EMBRAPA, 1980).

Terric Histosols - Organic Soils.
Example: Profile IAC-1341 (Sakai & Lepsch, 1987).

5.2 ANTHROSOLS

Soils in which human activities have resulted in a profound modification or burial of the original soil horizons, through removal or disturbance of surface horizons, cuts and fills, secular additions of organic materials, long-continued irrigation, etc.

This Major Soil Grouping was not recognized in the first edition of the Legend of the Soil Map of the World (FAO-Unesco, 1974).

In Brazil, soils that would be classified as Fimic Anthrosols were described by Sombroek (1966) and Kern & Kämpf (1989), and denominated as respectively Indian Black Earth ("Terra Preta de Índio") and Archaeologic Black Earth ("Terra Preta Arqueológica"). However, these soils are not recognized as separate classes in the "Brazilian System".

Urbic Anthrosols occur in Brazil, in and near demographic concentrations, but these soils are not considered soils by the "Brazilian System".

5.3 LEPTOSOLS

Soils which are limited in depth by continuous hard rock or highly calcareous material (calcium carbonate equivalent of more than 40 percent) or a continuous cemented layer within 30 cm of the surface, or having less than 20 percent of fine earth over a depth of 75 cm from the surface; diagnostic horizons may be present, in particular a mollic, umbric or ochric A horizon, a cambic B horizon, or a calcic or petrocalcic horizon, or a duripan or petroferric phase with an indurated layer within 30 cm of the surface.

The "Brazilian System" recognizes three General Classes that correspond partly with Leptosols: Rendzinas, Litholic Soils ("Solos Litólicos") and Lithosols ("Litossolos"). Rendzinas are soils formed in highly calcareous material (which is not quantitatively defined in the "Brazilian System"), which have a chernozemic A horizon. Litholic soils have a broader definition than Leptosols: they have an A-R, A-C-R or A-Bw-C-R[1] horizon sequence with the R layer at less than 50 cm depth. Lithosols have an A horizon, directly overlying continuous hard rock. The Pedology Section of the Agronomic Institute of Campinas (IAC) has arbitrated a maximum limit of 20 cm for the thickness of the solum of Lithosols. This General Class was only introduced

[1]If not stated otherwise, horizon symbols of FAO system are used.

in the beginning of the 1970's, when mappings at scales larger than 1:500 000 started. Many soil surveys consider the Lithosols still as part of the Litholic Soils because the usually strong variability of soil depth makes their delineation difficult.

Lithic Leptosols - Lithosols. Note that Lithic Leptosols have a solum with a thickness of not more than 10 cm, whereas Brazilian Lithosols may be up to 20 cm thick. Example: Profile CE-89 (Brasil, 1973a).

Gelic Leptosols - There are no climatic conditions in Brazil to permit the occurrence of such soils.

Rendzic Leptosols - Rendzinas. Note that Rendzic Leptosols may not present an A horizon with a thickness that exceeds 30 cm. The "Brazilian System" does not apply this restriction to the Rendzinas.
Examples: Profile RN-57 (Brasil, 1971b); and Figure 49 of Oliveira et al. (1992).

Mollic Leptosols - Litholic Soils (or Lithosols) with a chernozemic A horizon.
Example: Profile MS-52 (Brasil, 1971a); and Figure 52 of Oliveira et al. (1992).

Umbric Leptosols - Litholic Soils (or Lithosols) with a prominent or humic A horizon.
Examples: Profile SC-70 (Santa Catarina, 1973); and Figure 51 of Oliveira et al. (1992).

Dystric Leptosols - Dystrophic Litholic Soils (or Lithosols) with a moderate or weak A horizon.
Examples: Profile SP-82 (Brasil, 1960); and Figure 50 of Oliveira et al. (1992).

Eutric Leptosols - Eutrophic Litholic Soils (or Lithosols) with a moderate or weak A horizon.
Example: Profile MS-68 (Brasil, 1971a).

5.4 VERTISOLS

Soils having, after de upper 18 cm have been mixed, 30 percent or more clay in all horizons to a depth of at least 50 cm; developing cracks from the soil surface downward, which at some period in most years (unless the soil is irrigated) are at least 1 cm wide to a depth of 50 cm; having intersecting slickensides or wedge-shaped or parallelepiped structural aggregates at some depth between 25 and 100 cm from the surface, with or without gilgai.

The concept of the general class Vertisols ("Vertissolos") of the "Brazilian System" is the same as that of the FAO Legend. The "Brazilian System" is more restrictive with respect to the clay content requirement (clay >30% in entire soil profile), but no quantitative width and depth requirements for cracks are specified.

Gypsic Vertisols - Gypsic Vertisols. These soils are not known to occur in Brazil. There is notice of soils with "clayey gypsiferous material" as parent material, e.g. Profile PE-74 (Brasil, 1972b). However, it is not clear whether this profile presents a true gypsic horizon, because no analytical data regarding $CaSO_4$ content are given, and no morphological evidence of secondary gypsum enrichment is mentioned.

Calcic Vertisols - Calcic Vertisols, Carbonatic Vertisols. The "Brazilian System" does not present consistent guidelines with respect to the nomenclature of soils with a calcic horizon (Table 4.1) and soils which are "carbonatic" or "with carbonates" (Table 4.4). As a result,

in Brazil, Vertisols with a calcic horizon are often classified as Carbonatic Vertisols. Note also that the "Brazilian System" does not define the depth requirements for the occurrence of high $CaCO_3$ content; hence soils with a calcic horizon or carbonatic properties deeper than 125 cm (e.g. Profile MS-96; Brasil, 1971a) are still considered Carbonatic Vertisols or Calcic Vertisols.
Example: Profile BA-257 (EMBRAPA, 1977-1979).

Dystric Vertisols - Dystrophic Vertisols. Vertisols with base saturation $<50\%$ are not reported in the consulted literature for Brazil. If they occur it will probably be in small areas. Even at world level they are a minority among the Vertisols (Driessen & Dudal, 1991).

Eutric Vertisols - Eutrophic Vertisols. These are by far the most common Vertisols in Brazil. Other classes of the "Brazilian System" that belong to the Eutric Vertisols of the FAO Legend are the Carbonatic Vertisols, with $>15\%$ $CaCO_3$ equivalent, but lacking a calcic horizon or with a calcic horizon at >125 cm depth; the Solodic Vertisols, with exchangeable Na^+ (ESP) between 8 and 20% of the CEC; and the Shallow Vertisols.
Examples: Profile CE-92 (Brasil, 1973a) and Figure 47 of Oliveira et al. (1992).

5.5 FLUVISOLS

Soils showing fluvic properties and having no diagnostic horizons other than an ochric, a mollic or an umbric A horizon, or a histic H horizon, or a sulfuric horizon, or sulfidic material within 125 cm of the surface, or salic properties.

The central concept of Fluvisols: soils formed in recent alluvial deposits, corresponds best with the Alluvial Soils ("Solos Aluvionais") of the "Brazilian System". However, there are some important differences: In the "Brazilian System", saline soils and soils with a gley horizon within 50 cm of the surface are keyed out as respectively Solonchaks and Gley Soils before the Alluvial Soils. Hence, the Brazilian Alluvial Soils are most typically found on active river levees and along intermittent rivers. Most Fluvisols of large active floodplains are classified as Gley Soils according to the "Brazilian System". The saline Fluvisols are classified in Brazil as Solonchaks. See Section 5.7 for further discussion of Gley Soils.

Thionic Fluvisols - Thionic Humic Gley Soils and Thionic Low Humic Gley Soils, lacking other subsurface diagnostic horizons except a sulphuric horizon within 125 cm from the surface. Thionic Fluvisols with salic properties are classified as Solonchaks according to the "Brazilian System".
Example: Profile PRJ-16, (EMBRAPA, 1978); and Figure 46 of Oliveira et al. (1992).

Salic Fluvisols - Solonchaks (with fluvic properties), Undifferentiated Coastal Saline Soils (see Section 5.6 for further discussion of these soils).
Example Profile GB-45: (EMBRAPA, 1980); and Figure 33 of Oliveira et al. (1992).

Mollic Fluvisols - Alluvial Soils with chernozemic A horizon or Eutrophic Humic Gley Soils. There are very few descriptions of these soils in Brazil.
Example: Profile RN-21 (Brasil, 1971b).

Calcaric Fluvisols - These soils are not reported in the consulted literature for Brazil. They may occur in small areas.

Umbric Fluvisols - Alluvial Soils with prominent A horizon or Dystrophic Humic Gley Soils.
Example: Profile Furnas-26 (Brasil, 1962).

Dystric Fluvisols - Dystrophic Alluvial Soils with moderate (or weak) A horizon or Dystrophic Low Humic Gley Soils.
Example: Profile BA-287 (EMBRAPA, 1977-1979).

Eutric Fluvisols - Eutrophic Alluvial Soils with moderate (or weak) A horizon or Eutrophic Low Humic Gley Soils.
Example: Profile CE-107 (Brasil,1973a).

5.6 SOLONCHAKS

Soils, which do not show fluvic properties, having salic properties and having no diagnostic horizons other than an A horizon, a histic H horizon, a cambic B horizon, a calcic or a gypsic horizon.

The "Brazilian System" recognizes two General Classes that have salinity as there major property: (1) The Undifferentiated Coastal Saline Soils ("Solos Salinos Costeiros Indiscriminados"), developed on semi-aquatic terrain, usually mangrove land; and (2) the Solonchaks, developed on terrestrial or semi-terrestrial terrain.

The definition of the Solonchaks of the "Brazilian System" is: "Mineral soils, mostly hydromorphic, either with a salic horizon, or which are saline in the C horizon following the A horizon, occurring in a terrestrial or semi-terrestrial environment". Apparently this is similar to the definition in the FAO Legend, but many Solonchaks of one system will be classified differently by the other because: (1) the definition of the "Brazilian System" does not specify depth requirements for the occurrence of salinity; (2) the diagnostic property "saline" of the "Brazilian System" (Table 4.4) is much less restrictive than the "salic properties" of the FAO Legend; (3) Solonchaks key out in the "Brazilian System" before Alluvial Soils; hence they include most of the soils that are classified as Salic Fluvisols according to the FAO Legend (except the aquatic ones). Almost all saline soils in Brazil occur in young alluvial plains. The "Brazilian System of Soil Classification" does not provide (yet) for saline soils with an incipient B horizon.

Gelic Solonchaks - There are no climatic conditions in Brazil to permit the occurrence of such soils.

Gleyic Solonchaks - Solonchaks or Solonetzic-Solonchaks. These soils occur in the coastal area or in alluvial plains showing gleyic properties within 100 cm from the surface. The Gleyic Solonchaks are the most common Solonchaks in Brazil. Most of them occur in wet alluvial plains.
Example: Profile CE-100 (Brasil, 1973a).

Mollic Solonchaks - Solonchaks with a chernozemic A horizon are common in Brazil. However, most of these soils are hydromorphic and therefore keyed out as Gleyic Solonchaks.

Gypsic and Calcic Solonchaks - We do not know of the occurrence of these soils in Brazil.

Sodic Solonchaks - Solonetzic-Solonchaks. These soils are uncommon in Brazil, because almost all saline soils in Brazil are developed in very wet conditions and therefore related to the Salic Fluvisols or to the Gleyic Solonchaks that are keyed out before the Sodic Solonchaks. An example of such a Gleyic Solonchak with sodic properties is Profile CE-100 (Brasil, 1973a).

Haplic Solonchaks - We do not know of the occurrence of these soils in Brazil.

5.7 GLEYSOLS

Soils formed from unconsolidated materials, exclusive of coarse textured materials and alluvial deposits which show fluvic properties, showing gleyic properties within 50 cm of the surface; having no diagnostic horizons other than an A horizon, a histic H horizon, a cambic B horizon, a calcic or a Gypsic horizon; lacking the characteristics which are diagnostic for Vertisols or Arenosols; lacking salic properties; lacking plinthite within 125 cm of the surface.

The "Brazilian System" recognizes two General Classes that together accommodate most Gleysols of the FAO Legend: (1) Humic Gley Soils ("Gleis Húmicos") and (2) Low Humic Gley Soils ("Gleis Pouco Húmicos"). The Humic Gleys have a turphose horizon, a chernozemic A horizon or a prominent A horizon. The Low Humic Gleys have a moderate A horizon. It was already mentioned in Section 5.5 that the Gley Soils of the "Brazilian System" also include Fluvisols that present a gley horizon within 50 cm from the surface.

Gelic Gleysols - There are no climatic conditions in Brazil to permit the occurrence of such soils.

Thionic Gleysols - Thiomorphic (Low) Humic Gley Soils. Note that most Thiomorphic (Low) Humic Gley Soils in Brazil are related to recent alluvial-marine sediments, presenting fluvic properties and are therefore mostly classified as Thionic Fluvisols according to the FAO Legend.

Andic Gleysols - These soils are not known to occur in Brazil.

Mollic Gleysols - Humic Gley Soils with chernozemic A horizon or Eutrophic Humic Gley Soils with turphose horizon. These are uncommon soils in Brazil.
Example: Profile MS-105 (Brasil, 1971a).

Umbric Gleysols - Dystrophic (or Allic) Humic Gley Soils with prominent A horizon or Dystrophic (or Allic) Humic Gley Soils with turphose horizon. These are common soils in Brazil.
Example: Profile BA-40 (EMBRAPA, 1976).

Calcic Gleysols - Calcic Humic Gley Soils or Carbonatic Humic Gley Soils (see remarks Calcic Vertisols, section 5.4). These are uncommon soils in Brazil.
Example: MS-63 (Brasil, 1971a).

Dystric Gleysols - Dystrophic (or Allic) Humic Gley Soils and Dystrophic (or Allic) Low Humic Gley Soils. These are common soils in Brazil.
Example: Profile "point" 758 (Sakai & Lepsch, 1987).

Eutric Gleysols - Eutrophic Low Humic Gley Soils
Example: Profile GB-29 (EMBRAPA, 1980).

5.8 ANDOSOLS

Soils showing andic properties to a depth of 35 cm or more from the surface and having a mollic or an umbric A horizon possibly overlying a cambic B horizon, or an ochric A horizon and a cambic B horizon; having no other diagnostic horizons; lacking gleyic properties within 50 cm of the surface; lacking the characteristics which are diagnostic for Vertisols; lacking salic properties.

The concept of Andosols refers to soils formed in recent volcanic deposits, which are characterized by soil materials with andic properties, i.e. with low bulk density, large content of acid oxalate extractable aluminium and iron and large phosphate retention capacity among others. As there is no recent volcanism in Brazil, such soils are not accounted for in the "Brazilian System".

Paradoxically, some of the most strongly weathered soils in Brazil have some characteristics in common with Andosols: the "Latosols Una variant" (Geric Ferralsols according to the FAO Legend) have high phosphate retention capacity (approximately 2 μg $P.g^{-1}$ soil; Casagrande, 1993), bulk density of about 0.9 $Mg.m^{-3}$ and some of them present oxalate extractable Fe of 0,2% against values around 0,05%, in other Ferralsols (Al-oxalate was 0.8% vs. 0.2% in other Ferralsols). None of these soils satisfy all analytical diagnostic criteria for their classification as Andosols.

Some Red-Yellow Podzolic Soils in Acre State (extreme Northwest of Brazil) present relatively high contents of volcanic glass (Gama et al., 1992), probably originating from the volcanic zones of the Andes. However, these authors did not present sufficient data to identify the soils as Andosols.

Some authors reported cracking and hardening on drying - suggesting higher clay activity than actually observed - combined with thixotropy in the lower part of B horizons of some Brazilian Brown Cambisols, Structured Brown Earths and Brown Latosols (Rodrigues, 1984; Palmieri, 1986). They attributed these phenomena to the presence of amorphous compounds (allophane) or haloysite. Bennema & Camargo (1964) recognized some similarity of these soils with Andisols. However, Ker & Resende (1990), concluded that none of the soil materials meet the requirements for andic properties, based on data on phosphate adsorption, amorphous Al compounds, and absence of volcanic glass in the coarse fraction.

5.9 ARENOSOLS

Soils which are coarser than sandy loam to a depth of at least 100 cm of the surface, having less than 35 per cent of rock fragments or other coarse fragments in all subhorizons within 100 cm of the surface, exclusive of materials which show fluvic or andic properties; having no diagnostic horizons other than an ochric A horizon or an albic E horizon.

Most Arenosols of the FAO Legend are classified as Quartz Sands ("Areias Quartzosas") according to the "Brazilian System". Quartz Sands, however, by definition, may only present small amounts of weatherable minerals (a tentative limit was set at 4%). Sandy soils with >4%

of weatherable minerals and no clear horizon differentiation are classified as Regosols ("Regossolos") according to the "Brazilian System".

Another difference between the Arenosols of the FAO Legend and the Quartz Sands of the "Brazilian System" is that the control section for texture requirements of the FAO Legend extends from 0 to 100 cm; whereas EMBRAPA/SNLCS has not defined a control section. Note also that Arenosols with some diagnostic B horizon below 125 cm of the surface are classified according to that horizon and excluded from the Quartz Sands.

Gleyic Arenosols - Hydromorphic Quartz Sands or Hydromorphic Marine Quartz Sands. Example of the latter: Profile GB-49 (EMBRAPA, 1980).

Albic Arenosols - Quartz Sands. The albic horizon is not considered a diagnostic attribute to discriminate between Quartz Sands in the "Brazilian System". Most Albic Arenosols are not classified as Quartz Sands in the "Brazilian System", which takes account of the illuvial horizon below the E, but e.g. as Red-Yellow Podzolic Soils with very thick A+E horizons overlying a textural B horizon (e.g. profile BA-100, EMBRAPA, 1977-1979, with A + E > 150 cm) and Giant Podzols as in profile GB-50 (A + E = 400 cm; EMBRAPA, 1980).

Calcaric Arenosols - We do not know of the occurrence of these soils in Brazil. If they occur they would be classified as Sandy Textured Calcaric Regosols.

Luvic Arenosols - Podzolic Quartz Sands. There are few descriptions of such soils in Brazil. Example: Profile IAC-1239 (Oliveira & Prado, 1984).

Ferralic Arenosols - Quartz Sands and Sandy Regosols with low cation exchange capacity. These are the most common Arenosols of Brazil. The ferralic properties are not used as diagnostic criteria to discriminate among different Quartz Sands in the "Brazilian System of Soil Classification", because they are considered unpractical and not very important for soil management.
Examples: BA-327 (EMBRAPA 1977-1979) and Figures 55 and 56 of Oliveira et al. (1992). An example of a Ferralic Arenosol which is classified as Sandy Regosol by the "Brazilian System", is profile BA-318 (EMBRAPA, 1977-1979). The B horizon of this soil has 6% clay and 6% silt; contains 10% of fieldspars and presents a CEC of just 1,7 cmol(+). kg (-1).

Cambic Arenosols - Cambic Quartz Sands and Sandy Regosols. These are uncommon soils in Brazil.

Haplic Arenosols - This Soil Unit comprises the remaining Quartz Sands and Sandy Regosols with high activity clay. These are uncommon in Brazil. The requirements for Cambic Arenosols over Haplic Arenosols (some colour differentiation) are so weak, that we cannot grasp the importance for the FAO Legend of distinguishing these two Soil Units.
Example: Profile PE-97 (Brasil, 1972a).

5.10 REGOSOLS

Soils from unconsolidated materials, exclusive of materials that are coarse textured and more than 100 cm deep or show fluvic properties, having no diagnostic horizons other than an ochric or umbric A horizon; lacking gleyic properties within 50 cm of the surface; lacking the characteristics which are diagnostic for Vertisols or Andosols; lacking salic properties; lacking soft powdery lime.

The central concept of Regosols of the FAO Legend corresponds with Regosols ("Regossolos") of the "Brazilian System". The most important difference, mentioned already for the Arenosols, is that sandy soils with more than 4% weatherable minerals are classified as Regosols according to the "Brazilian System" and as Arenosols according to the FAO Legend. In fact these sandy Regosols are the most common Regosols in Brazil. This division of sandy soils is considered important by Brazilian soil scientists, particularly for low input agriculture, which is common in North East Brazil, where sandy Regosols occur most frequently. We have not found any reference to Regosols with clayey texture.

Note that many incipient coarse textured soils that are a product of physical weathering of hard rock, (e.g. in dry climates) are excluded from the Arenols of the FAO Legend, because they have more than 35% of rock fragments. These soils will be classified as Regosols according to the key of the Legend. The definition in Chapter VI of the Legend does not mention this possibility.

Gelic Regosols - There are no climatic conditions in Brazil to permit the occurrence of such soils.

Umbric Regosols - Medium textured Dystrophic Regosols with a prominent A horizon. These soils occur in the cooler mountainous regions in South East Brazil, but we do not have a reference to any profile description.

Gypsiric and Calcaric Regosols - We do not know of the occurrence of such soils in Brazil. Especially the Gypsiric Regosols do probably not occur.

Dystric Regosols - Medium textured Dystrophic Regosols or Medium textured Allic Regosols both with a moderate or weak A horizon.
Example: Profile CE-123 (Brasil, 1973a).

Eutric Regosols - Medium textured Eutrophic Regosols with a moderate or weak A horizon. These soils are very common in the dry regions of North East Brazil.
Example: Profile PA-61 (Brasil, 1972b).

5.11 PODZOLS

Soils having a spodic B horizon.

The Major Soil Grouping "Podzols" of the FAO Legend corresponds with the General Classes Podzols ("Podzóis"), Parapodzols ("Parapodzóis") and Hydromorphic Podzols ("Podzóis Hidromórficos") of the "Brazilian System". There are no provisions for subdivision of these General Classes. Note that the "Brazilian System" does not specify a lower depth requirement for the top of the spodic B horizon of these soils. Hence, soils with a thick albic E horizon, succeeded by a spodic B which upper limit occurs below 125 cm from the surface, are classified as Podzols according to the "Brazilian System". The FAO Legend classifies these soils as Albic Arenosols.

Gelic Podzols - There are no climatic conditions in Brazil to permit the occurrence of such soils.

Gleyic Podzols - Hydromorphic Podzols.
Example: Profile SP-73 (Brasil, 1960).

Carbic Podzols - Podzols (Humic). Probably these soils occur in Brazil, but we do not have any description.

Ferric Podzols - Podzols (Ferric). Probably these soils occur in Brazil, but we do not have any description.

Cambic Podzols - Parapodzol. The Parapodzols identified in the coastal plains of Paraná are probably Cambic Podzols according to the FAO Legend.
We do not have a reference to any profile description.

Haplic Podzols - Podzol (Humic-Ferric).
These are the most common Podzols in Brazil.
Examples: Profile BA-224 (EMBRAPA, 1977-1979) and Figure 20 of Oliveira et al. (1992).

5.12 PLINTHOSOLS

Soils having 25 percent or more plinthite by volume in a horizon which is at least 15 cm thick within 50 cm of the surface or within a depth of 125 cm when underlying an albic E horizon or a horizon which shows gleyic or stagnic properties within 100 cm of the surface.

The Major Soil Grouping Plinthosols was introduced in the Revised FAO Legend of 1988, not in the least through the influence of Brazilian soil scientists. In Brazil, until recently, such soils were named Ground Water Laterite Soils ("Laterita Hidromórfica"). Today they are divided among two General Classes: Plinthosols ("Plintossolos") and Petric Plinthosols ("Plintossolos Pétricos"). The latter are recognized at the phase level of the FAO Legend.

The definition of Plinthosols of the "Brazilian System" is slightly different from that of the FAO Legend: Soils with a plinthite horizon ($\geq$15cm thick; $\geq$15% plinthite by volume) at less than 40 cm from the surface, or deeper if underlying an E horizon, a mottled (hydromorphic) horizon or a petroplinthite horizon.

Albic Plinthosols - Eutrophic or Dystrophic or Allic Plinthosols. The albic horizon is not used in Brazil as a diagnostic criterion among Plinthosols.
Examples: Figure 42 of Oliveira et al. (1992) and Profile MS-38 (Brasil, 1971a). The latter soil was originally identified as Ground Water Laterite Soil.

Humic Plinthosols - Dystrophic or Allic Plinthosols with prominent A horizon, or Dystrophic (or Allic) Plinthosols with humic A or turphose horizon.
Example: Profile TM 44 (EMBRAPA, 1982). This soil was originally identified as Ground Water Laterite Soil.

Dystric Plinthosols - Dystrophic (or Allic) Plinthosols with moderate or weak A horizon.
Examples: Figure 42 of Oliveira et al. (1992) and Profile 18 (EMBRAPA, 1975a). The latter soil was originally identified as Ground Water Laterite Soil.

Eutric Plinthosols - Eutrophic Plinthosols with a moderate or weak A horizon.
Example: Profile MA-8 (EMBRAPA, 1984).

5.13 FERRALSOLS

Soils having a ferralic B horizon.

The central concept of Ferralsols is: strongly weathered soils, with little vertical differentiation, very few primary minerals and with "low activity clay minerals" such as kaolinite and Al and Fe (oxi)hydroxides.

Strongly weathered soils with low activity clays are the most common soils in Brazil. Therefore, it is not surprising that the definition and subdivision of such soils is much better worked out than those of other General Classes; even more so, because the "Brazilian System" is still in development.

The most important strongly weathered soils of the "Brazilian System" are the Latosols ("Latossolos"), Structured Dusky Red and Brown Earths ("Terra Roxa Estruturada" and "Terra Bruna Estruturada") and Podzolic Soils ("Podzólicos") as shown in Appendix I (groupings 1,2 and 3). Podzolic Soils may have low or high clay activity. Note that criteria used by the "Brazilian System" include colour, Fe_2O_3 content, TiO_2 content and CEC of the clay fraction, corrected for the influence of organic matter.

The concept of the Latosols of the "Brazilian System" is similar to that of the Ferralsols of the FAO Legend. However, some small differences in the definitions cause a relation that, in practice, is far from 1 to 1.

The Ferralsols are keyed out in the FAO Legend before soils which have both low clay activity and a B horizon with (illuvial) clay accumulation, such as the Lixisols and the Acrisols (see sections 5.25, 5.27), because the definition of the ferralic B horizon admits both an increase of the clay content and the presence of clay skins. In the "Brazilian System", the textural B horizon has precedence over the Latosolic B (see Tables 4.2 and 4.3), as was also the case in the original version of the FAO Legend (FAO-Unesco, 1974). The "Brazilian System", classifies Ferralsols with considerable vertical clay differentiation as Podzolic Soils with Low activity clay, and not as Latosols.

However, in practice this will often not apply, because the definition of the ferralic B horizon, which constitutes the diagnostic horizon of Ferralsols, demands, in addition to a small CEC, a silt/clay ratio < 0.2 and a water dispersable clay content $< 10\%$. These criteria are often not satisfied in soils that present a textural B horizon.

The reverse situation may occur even more frequently: soils that are excluded from the Ferralsols because of a too large silt/clay ratio or water dispersable clay content, but which are still considered Latosols. In fact, many Brazilian soil scientists consider the requirements with respect to water dispersable clay content and silt/clay ratio used by the FAO Legend much too restrictive, because they exclude many "genuine" Latosols from the Ferralsols. Even some extremely weathered Latosols can present a large amount of water dispersable clay in the B horizon due to the phenomenon of reversion of charge, as for example in profile IAC-1250 (Oliveira & Prado, 1987) or a silt/clay ratio slightly higher than 0.2 in profile ISSW-BR 1 (International..., 1978). According to the FAO Legend such soils should be classified as Cambisols (Chapter 5.28) or as Acrisols or Lixisols, if the criteria for an argic B horizon are met (which are less restrictive than the criteria for a textural B of the "Brazilian System"; Table 4.2).

In the following discussion of Soil Units, only Latosols are considered to correspond with Ferralsols. It should be clear from the above that in many cases Podzolic Soils with Low activity clay or Structured Dusky Red Earths may be an alternative if there is a considerable clay differentiation.

Plinthic Ferralsols - All the Latosols ("Latossolos") that present plinthite within 125 cm of the surface layer. The adjective "plíntico" is put behind the name of such soils.
Example: Profile IAC-1451 (Oliveira, 1995), which is a plinthic Latosol Una variant.

Geric Ferralsols - The geric properties, i.e. properties indicating extremely weathering, which are diagnostic for these soils, have not (yet) been formalized as a diagnostic criterion in the "Brazilian System", but some pedologists are using the concept in their soil surveys. The IAC (Campinas, São Paulo State) has indicated such soils by the adjective "Acric", e.g. Acric Red-Yellow Latosols, Acric Dark-Red Latosols. Most Ferriferous Latosols, which by definition have >36 % Fe_2O_3, also belong to the Geric Ferralsols.
Examples: Profile IAC-1350 (Oliveira & Prado, 1987) and figure 5, Oliveira et al. (1992).

Humic Ferralsols - The other Latosols with a humic - or a thick chernozemic - A horizon. In Brazil, most Humic Ferralsols with a chernozemic A horizon are soils which originally presented a humic A horizon that was transformed to a chernozemic A by liming.
Examples: Profile SP-67. (BRASIL, 1960) and Figures 6 and 9 of Oliveira et al. (1992).
Some Brazilian Latosols present a humic A horizon with a thickness of upto 200 cm. Such soils cannot be classified properly according to the FAO Legend, which states that "Diagnostic horizons and diagnostic properties are assumed to have their upper limit within 125 cm of the surface...". An example of such a soil is Profile SP 68 (Brasil, 1960), with an A horizon of 200 cm thickness, and a CEC$>$16 cmol(+).kg^{-1} clay, if no correction for organic matter is made.

Rhodic Ferralsols - Dusky Red Latosols, Dark-Red Latosols and the redder part of the Red-Yellow Latosols and the Latosols Una Variant, without plinthite and lacking geric properties and showing a moderate or weak A horizon. They may be allic, eutrophic or dystrophic. These soils are abundant in Southern Brazil.
Examples: Profile IAC-1360 (Oliveira & Prado, 1987) and Figure 7 of Oliveira et al. (1992).

Xanthic Ferralsols - Typically Yellow Latosols, but also some Brown Latosols and the yellower part of the Red-Yellow Latosols and of the Latosols Una variant, all of them without plinthite and lacking geric properties but showing a moderate or a weak A horizon.
Examples: Profile BA-57 (EMBRAPA, 1977-1979) and Figure 10 of Oliveira et al. (1992).

Haplic Ferralsols - The remaining Red-Yellow Latosols, Brown Latosols and Latosols Una variant.
Examples: Profile BA-18 (EMBRAPA, 1977-1979) and Figures 11 and 12 of Oliveira et al. (1992).

5.14 PLANOSOLS

Soils having an E horizon showing stagnic properties at least in part of the horizon, and abruptly overlying a slowly permeable horizon within 125 cm of the surface, and lacking a natric or a spodic B horizon.

The Planosols of the FAO Legend are virtually the same as the Planosols ("Planossolos") of the "Brazilian System". A conceptual difference between the two systems is that in the "Brazilian System" the "slowly permeable horizon" must present a textural B horizon (Chapter 4) which is separated from the overlying horizon by an "abrupt textural change", which presents a fractured boundary when dry. The overlying horizon is usually an E horizon, but an A horizon is also allowed. According to the FAO Legend, the abrupt change to the slowly permeable horizon may also be due to a lithologic discontinuity, or a fragipan, but always underlying an E horizon.

"FAO Planosols" with a textural B horizon that do not present an abrupt textural change, and/or lack the strong structure or fractured upper boundary which are required for "Brazilian Planosols", are usually classified as Hydromorphic Grey soils ("Solos Hidromórficos Cinzentos") according to the "Brazilian System".

Gelic Planosols - The climatic conditions in Brazil do not permit the occurrence of such soils.

Mollic Planosols - Planosols with chernozemic A horizon or with an eutrophic H horizon. These soils are generally eutrophic. They are uncommon in Brazil.
Example: Profile RS-11 (Brasil, 1973b).

Umbric Planosols - Planosols with prominent A horizon or with humic A horizon or H horizon. These soils are usually dystrophic.
Example: Profile RS-110 (Brasil, 1973b).

Dystric Planosols - Dystrophic Planosols with a moderate or weak A horizon.
Example: Profile GB-60 (EMBRAPA, 1980).

Eutric Planosols - Eutrophic Planosols with moderate or weak A horizon.
Examples: Profile BA-149 (EMBRAPA, 1977-1979) and Figures 28 and 29 of OLIVEIRA ET AL. (1992).

5.15 SOLONETZ

Soils having a natric B horizon.

All Brazilian Solonetz known sofar present evidence of solodization and are therefore accommodated in a General Class called Solodized Solonetz ("Solonetz Solodizados"). The definition of the Solodized Solonetz is almost the same as that of the Solonetz of the FAO Legend. The "Brazilian System" has as an additional requirement that the textural and structural differences between the natric B horizon and the overlying horizon must be "contrasting" (without exact specification), but this is typical for all soils with a natric B horizon. Another difference between the definitions is that the "Brazilian System" does not recognize (yet?) Solodized Solonetz with a chernozemic A horizon. This has no serious consequences for the Brazilian situation, because soils classified according to FAO as Mollic Solonetz are very rare in Brazil.

Gleyic Solonetz - Solodized-Solonetz, imperfectly drained phase. Note that the "Brazilian System" does not recognize a "gleyic" class.
Almost all Brazilian Solonetz were described as having an imperfect or somewhat poor drainage. It is difficult to check from profile descriptions whether the criteria for gleyic properties are met, because the chemical evidences for reduction are only recently being applied in Brazil. The colour requirements for gleyic properties are usually just not met. These requirements (neutral, bluish or greenish colours) are considered very restrictive.

Stagnic Solonetz - Stagnic properties are not considered in the "Brazilian System of Soil Classification" and Stagnic Solonetz would simply be classified as Solodized-Solonetz by the "Brazilian System". Such soils, that show evidence of reducing conditions in the top of the B horizon, are common in the "Pantanal" of Mato Grosso and in some alluvial plains in the regions with an ustic moisture regime.
Example: Profile 24- Jequitinhonha (Brasil, 1970)

Mollic Solonetz - These soils are very rare in Brazil. At the moment, no General Class is defined to accommodate soils with both a natric B and a chernozemic A horizon. Example: RS-12 (Brasil, 1973b). This soil is an intergrade with Gleyic Solonetz.

Gypsic Solonetz - We do not know of the occurrence of these soils in Brazil.

Calcic Solonetz - Calcic/Carbonatic Solodized Solonetz. These are uncommon soils in Brazil. See section 5.4 (Calcic Vertisols) for remark on the Calcic horizon in the "Brazilian System of Soil Classification".
Example: Profile BA-273 (EMBRAPA, 1977-1979). This soil was simply classified as Solodized Solonetz, in spite of having a well developed calcic horizon at the surface.

Haplic Solonetz - Solodized-Solonetz and Saline Solodized-Solonetz. These are the most common Solonetz in Brazil. Most of them have a weak A horizon. The Saline Solodized-Solonetz is an intergrade with Solonchaks.
Examples: Profile BA-262 (EMBRAPA, 1977-1979) and Figure 30 of Oliveira et al. (1992); Example of a Saline Solodized-Solonetz: Profile RJ 17 (EMBRAPA, 1978).

5.16 GREYZEMS

Soils having a mollic A horizon with a moist chroma of 2 or less to a depth of at least 15 cm and showing uncoated silt and sand grains on structural ped surfaces; having an argic B horizon; lacking the characteristics which are diagnostic for Planosols.

These soils are practically confined to the cold regions of Northern Europe and Asia. Some soils in Southern Brazil have been related to Greyzems (Brasil, 1973b), but some of these do not present the required characteristics of the mollic A horizon and none of them presents uncoated silt and sand grains on structural ped surfaces.

5.17 CHERNOZEMS & KASTANOZEMS

Soils having a mollic A horizon with a moist chroma of 2 or less (Chernozems) or more than 2 (Kastanozems) to a depth of at least 15cm; having a calcic or petrocalcic horizon or concentrations of soft powdery lime (Kastanozems: or a Gypsic horizon) within 125 cm of the surface; lacking a natric B horizon; lacking the characteristics which are diagnostic for

Vertisols, Planosols or Andosols; lacking salic properties; lacking gleyic properties within 50 cm of the surface when no argic B horizon is present; lacking uncoated silt and sand grains on structural ped surfaces.

The climatic conditions in Brazil are not appropriate for the formation of significant areas covered with soils presenting a combination of a mollic A horizon and a calcic horizon or soft powdery lime. That is why there is not a separate class for such soils in the "Brazilian System". Soils that were identified as Calcic Brunizems, like the one of Figure 21 of Oliveira et al. (1992), and some Rendzinas with strongly calcareous material ($CaCO_3$ > 40% below 30 cm), like profile RJ-10 (EMBRAPA, 1978), are probably Calcic Chernozems.

5.18 PHAEOZEMS

Soils having a mollic A horizon; lacking a calcic horizon, a gypsic horizon and concentrations of soft powdery lime; having a base saturation (by NH_4OAc) which is 50 percent or more throughout the upper 125 cm of the soil; lacking a ferralic B horizon; lacking a natric B horizon; lacking the characteristics which are diagnostic for Vertisols, Planosols or Andosols[1]; lacking salic properties; lacking gleyic properties within 50 cm of the surface when no argic B horizon is present; lacking uncoated silt and sand grains on structural ped surfaces when the mollic A horizon has a moist chroma of 2 or less to a depth of at least 15 cm.

This Major Soil Grouping matches the General Classes of Reddish Brunizems ("Brunizéns Avermelhados") and Brunizems ("Brunizéns") of the "Brazilian System". The Brunizems have a cambic B horizon or a textural B horizon. The Reddish Brunizems must present a textural B horizon which has a more vivid reddish colour than the Brunizems (colour chroma ≤3; value ≤4; hue most commonly 10YR or 7.5YR). Rendzinas (of the "Brazilian System") with a mollic A horizon with a thickness > 30 cm are also classified as Phaeozems.

Note that the definitions of Brunizems and Reddish Brunizems do not exclude the presence of a calcic horizon (the FAO Legend classifies such soils as Kastanozems or Chernozems, c.f. section 5.17), but do exclude soils with low activity clays. The Brazilian classification of Phaeozems with low activity clays depends strongly on other diagnostic properties, which are discussed below.

Gleyic Phaeozems - Hydromorphic Brunizems.
Example: RS-158 (Brasil, 1973b).

Stagnic Phaeozems - We do not know of any description of such soil in Brazil. They may occur.

Luvic Phaeozems - With high activity clays: Brunizems (with an argic B horizon) or Reddish Brunizems. The latter are the most common Phaeozems in Brazil. With low activity clays: Structured Red (or Brown) Earth with chernozemic A horizon; Eutrophic Red Yellow (or Dark Red) Podzolic with chernozemic A (see Table 5.1).
Examples: Reddish Brunizems: IAC-1345 (Oliveira & prado, 1987) and Figure 22 of Oliveira et al. (1992); Structured Red Earth: Profile II RCC SP (EMBRAPA, 1983) and Figure 13 of Oliveira et al. (1992).

---

[1]According to the definition in Chapter VI of the Revised Legend, Phaeozems should also lack the characteristics which are diagnostic for Nitisols. However, in Chapter X, Phaeozems are keyed out before Nitisols. According to a personal communication of Dr. F. Nachtergaele (FAO, Rome) the definition of Chapter X should be applied.

Calcaric Phaeozems - We do not know of any description of such soils that do not belong to the Rendzinas of the Brazilian System, but they may exist. These would be the Brunizems and Reddish Brunizems without calcic horizon or soft powdery lime within 125 cm of the surface, but showing strong effervescence with HCl at least from 20 to 50 cm of the surface.

Haplic Phaeozems - With high activity clays: Brunizems (with a cambic B horizon); With low clay activity: Cambisols Tb[1] with Chernozemic A horizon. These soils are not common in Brazil.
Example: Profile MG-42 (EMBRAPA, 1982).

5.19 PODZOLUVISOLS

Soils having an argic B horizon showing an irregular or broken upper boundary resulting from deep tonguing of the E into the B horizon, or from the formation of discrete nodules larger than 2 cm, the exteriors of which are enriched and weakly cemented or indurated with iron and having redder hues and stronger chromas than the interiors; lacking a mollic A horizon.

We do not know of the occurrence of these soils in Brazil. Some soils classified according to the "Brazilian System" as Planosols ("Planossolos") may be related to the Gleyic Podzoluvisols and some Planosolic Red-Yellow Podzolic Soils to the Stagnic Podzoluvisols.

5.20 GYPSISOLS

Soils having a gypsic or a petrogypsic horizon, or both, within 125 cm of the surface; having no diagnostic horizons other than an ochric A horizon, a cambic B horizon, an argic B horizon permeated with gypsum or calcium carbonate, a calcic or a petrocalcic horizon; lacking the characteristics which are diagnostic for Vertisols or Planosols; lacking salic properties; lacking gleyic properties within 100 cm of the surface.

We do not know anything about the occurrence of these soils in Brazil. Some profiles (e.g. PE-74; Brasil, 1972a) were reported to have gypsic parent material, but the lack of data on $CaSO_4$ content and remarks on morphological evidences do not allow the identification of a gypsic horizon in these soils.

[1]Tb: with low clay activity; see Table 4.4

5.21 CALCISOLS

Soils having one or more of the following: a calcic horizon, a petrocalcic horizon or concentrations of soft powdery lime within 125 cm of the surface; having no diagnostic horizons, other than an ochric A horizon, a cambic B horizon or an argic B horizon which is calcareous; lacking the characteristics which are diagnostic for Vertisols or Planosols; lacking salic properties; lacking gleyic properties within 100 cm of the surface;

Although there are large occurrences of Calcisols in North East Brazil, the "Brazilian System" does not have a General Class that corresponds with Calcisols. Therefore, correlation becomes difficult. The indication of the presence of a calcic horizon, by the adjective "calcic" is only used for a few General Classes, e.g. Calcic Brunizems and Calcic Vertisols. The criteria for using this adjective are not clearly defined (see Section 5.4). In some General Classes the "Brazilian System" makes no distinction between the presence of a calcic horizon and calcareous material; e.g. Carbonatic-Eutric Cambisols and Carbonatic Non-Calcic Brown Soils. Another problem for correlation is that the "Brazilian System" does not recognize any equivalent for "soft powdery lime".

Petric Calcisols - The authors believe that these soils do not occur in Brazil.

Luvic Calcisols - Carbonatic Non-Calcic Brown Soils. Note that this name is a *contradictio in terminus*, inherited from the classification of Baldwin & Thorp. Carbonatic Non Calcic Brown Soils may present a calcic horizon, but this class also comprises soils with primary carbonates.
Example: Profile BA-178 (EMBRAPA, 1977-1979).

Haplic Calcisols - Carbonatic-Eutrophic Cambisols. Carbonatic-Eutrophic Cambisols may present a calcic horizon, but this class also comprises soils with primary carbonates.
Example: Profile BA-234 (EMBRAPA, 1977-1979).

5.22 NITISOLS

Soils having an argic B horizon, showing a clay distribution which does not show a relative decrease from its maximum of more than 20 percent within 150 cm of the surface; showing gradual to diffuse horizon boundaries between A and B horizons; having nitic properties in some subhorizon within 125 cm of the surface; lacking the tonguing which is diagnostic for Podzoluvisols; lacking ferric or vertic properties; lacking plinthite within 125 cm of the surface.

Although some of the soils discussed in the former sections may present an argic B horizon (e.g. Luvic Phaeozems); the FAO Legend considers other diagnostic properties of dominant importance for their accommodation in Major Soil Groupings. The five Major Soil Groupings Nitisols, Acrisols, Alisols, Lixisols and Luvisols have as their major common characteristic an argic B horizon. The criteria used for subdivision between and among these soils are quite different from those used by the "Brazilian System" for soils with a textural B horizon. The major rules for division and subdivision according to both systems are given in Table 5.1. Table 5.2 shows the subdivision of Podzolic Soils and Structured Earths according to the "Brazilian System". These Tables show that the main discriminators for soils with an argic horizon of the FAO Legend are the presence of a mollic (Brazil: chernozemic) A horizon, nitic properties, base saturation and clay activity. The Brazilian system does not use the base saturation of the B horizon to discriminate among soils with low activity clays at a high level. The presence of the Brazilian equivalent of "nitic properties" is not considered for soils with high activity clay. A more important discriminator of the "Brazilian System" is colour (and herewith related Fe content and Fe/Ti ratio), as shown in Table 5.2.

The Major Soil Grouping Nitisols corresponds typically with the "Structured Dusky Red Earths" ("Terra Roxa Estruturada") and "Structured Brown Earths" ("Terra Bruna Estruturada") of the "Brazilian System". However, there are some important differences, as shown in Appendix I and Table 5.1: (1) the "nitic properties" are not used as diagnostic in the "Brazilian System", which uses different criteria to define the typical morphology of "Structured Earths" (see Appendix I); (2) the "Structured Earths" have by definition low activity clay; (3) the "Structured Earths" may have any type of A horizon, except turphose, in combination with any base status class, whereas Nitisols may not present a combination of a mollic A horizon and a base saturation of >50% in the B horizon, because such soils are classified as Phaeozems, Kastanozems or Chernozems (the latter two are very rare in Brazil); (4) most important: many of the most productive Brazilian Structured Dusky Red Earths present a horizon which shows the set of properties that characterize the ferrallic B horizon below the argic B horizon. The FAO Legend classifies these soils as Ferralsols because these key out before the Nitisols (see Chapter 6, Discussion).

In the following text the Nitisols are principally compared with Structured Dusky Red and Brown Earths. Table 5.1 shows that the "Brazilian System" classifies Nitisols with high clay activity as Brunizems or Rubrozems. Some Nitisols with low activity clays that do not satisfy the requirements of Structured Dusky Red or Brown Earths must be classified as Dark Red or Red-Yellow Podzolics.

Humic Nitisols - Typically "Structured Dusky Red Earths" or "Structured Brown Earths" with a chernozemic A horizon or a prominent A horizon or a humic A horizon. These soils have low clay activity and may be eutrophic (except if a chernozemic A is present), but are usually dystrophic or allic. Humic Nitisols with high clay activity and low base saturation are classified as Rubrozems.
Example: Profile ISCW-BR 25 (EMBRAPA, 1978).

Rhodic Nitisols - Typically "Structured Dusky Red Earths" with moderate A horizon. These soils may be eutrophic, dystrophic or allic. These are the most common Nitisols in Brazil.
Example: Profile ISCW-BR 6 (EMBRAPA, 1978).

Haplic Nitisols - Red-Yellow Podzolic Soils or Structured Brown Earths with a moderate A horizon. The latter are not common, because most Structured Brown Earths of the Brazilian System correspond with Humic Nitisols.
Example: Profile ISCW-BR 4 (EMBRAPA, 1978).

Table 5.1 Schematic taxonomic subdivision of soils with: A) an argic B horizon according to FAO Legend (FAO, 1990); B) textural B horizon according to the "Brazilian system of soil classification".

A		With nitic properties		without nitic properties	
CEC-clay cmol(+).kg-1	mollic A horizon	BS≥50% in entire B	BS<50% in at least part of B	BS≥50% in entire B	BS<50% in at least part of B
≥ 24 in at least part of the B horizon	yes	Phaeozem Castanozem Chernozem	Nitisol	Phaeozem Kastanozem Chernozem	Alisol
	no	Nitisol	Nitisol	Luvisol	Alisol
<24 in entire B horizon	yes	Phaeozem (Kastanozem) (Chernozem)	Nitisol	Phaeozem (Kastanozem) (Chernozem)	Acrisol
	no	Nitisol	Nitisol	Lixisol	Acrisol

B		With "nitic" properties		without "nitic" properties	
CEC cmol(+).kg-1	A horizon	BS≥50% in entire B	BS<50% in at least part of B	BS≥50% in entire B	BS<50% in at least part of B
≥ 24 in at least part of the B horizon	chernozemic	Reddish Brunizem (Brunizem)	Podzólicos Ta	Reddish Brunizem (Brunizem)	-
	humic prominent	-	Rubrozems (or Podzolic Ta)	-	Rubrozem (or Podzolic Ta)
	moderate weak	Podzolic Ta	(Podzolic Ta)	Non Calcic Brown Soils (Podzolic Ta)	Podzolic Ta
<24 in entire B horizon	chernozemic	Structured Dusky Red (and Brown) Earths; (Podzolics Tb)	Structured Dusky Red (and Brown) Earths; (Podzolics Tb)	Podzolic Tb	Podzolic Tb
	humic prominent	Structured Dusky Red (and Brown) Earths; (Podzolics Tb)	Structured Dusky Red (and Brown) Earths; (Podzolics Tb)	Podzolic Tb	Podzolic Tb
	moderate weak	Structured Dusky Red (and Brown) Earths; (Podzolics Tb)	Structured Dusky Red (and Brown) Earths; (Podzolics Tb)	Podzolic Tb	Podzolic Tb

N.B. (1) General Classes between brackets are uncommon in Brazil.
(2) Hydropmorphic soils are not included.
(3) CEC cmol(+).kg^{-1}clay for "Brazilian System" determined after deduction for organic matter.
(4) Ta, high clay activity; Tb, low clay activity. See Table 4.4.

Table 5.2 Criteria for subdivision of soils with a textural B horizon with low clay activity according to the soil classification in use in Brazil.

	Fe_2O_3 %	TiO_2 %	Ki	magnetic attraction	CEC clay $cmol(+).kg^{-1}$	Colour	Other criteria
Structured Dusky Red Earth	≥15	>1.5	0.9-2.3	weak - strong	<24	hue: 5YR or redder;	well developed blocky structure + waxy character; small textural gradient
Structured Brown Earth	>10	—	1.7-2.1	none	<24	hue: 5YR or yellower; value: 3-5; chroma: 3-6	well developed blocky structure + waxy character; small textural gradient
Dark Red Podzolic	≤15 ≥ 3.75+.0625 %cl	≤1.7	—	—		hue: 5YR or redder; value: < 5; chroma: < 7	—
Red Yellow Podzolic	≤11 < 3.75+.0625 %cl	—	—	none		red to strong brown	—
Gray Brown Podzolic		—	—	none	typically > 24;	dark brown to yellowish brown; change to polichromatic with depth	rather shallow; moderately drained; large difference between dry colour A and moist colour A (value increases 3 units)
Yellow Podzolic	≤7	—	≤2.2	—	<13	brown to olive brown; typically 10YR 5/6 - 10YR 5/8	base saturation <50%; apparently no waxy properties and with weak structure;
Greyish Podzolic		—	—	—	normally <24	greyish	moderately to imperfectly drained; but without gley horizon;

5.23 ALISOLS

Soils having an argic B horizon which has a cation exchange capacity equal to or more than 24 cmol(+).kg^{-1} clay and a base saturation (by NH_4OAc) of less than 50 percent in at least some part of the B horizon within 125 cm of the surface; lacking the E horizon abruptly overlying a slowly permeable horizon, the distribution pattern of the clay and the tonguing which are diagnostic for Planosols, Nitisols and Podzoluvisols respectively.

See also the general comments on soils with an argic B horizon in Section 5.22. Alisols correspond typically with Dystrophic and Allic Podzolic Soils with high clay activity and with Rubrozems of the "Brazilian System" (Table 5.1).

Plinthic Alisols - Dystrophic (or Allic) Plinthic Red-Yellow Podzolic Soils with high activity clay, Dystrophic (or Allic) Plinthic Dark-Red Podzolic Soils with high activity clay. These soils probably occur in Brazil, but we do not know of any published description.

Gleyic Alisols - These soils probably occur in Brazil, but we do not know of any published description. They would be classified as Dystrophic (or Allic) Grey Hydromorphic Soils with high activity clay or as Dystrophic (or Allic) Red-Yellow Podzolic Soils with high activity clay. The "Brazilian System" does not use adjectives like *gleyic* to indicate the hydromorphic conditions but the term "-poorly drained phase" is sometimes added. Note that most hydromorphic soils with a textural B horizon and high clay activity in Brazil are identified as Planosols.

Stagnic Alisols - We do not know of any description of these soils in Brazil, but they probably occur as Planosolic Red-Yellow Podzolic Soils with high clay activity - poorly drained phase; or Dystrophic (or Allic) Grey Hydromorphic Soils with high activity clay. Note that most Grey Hydromorphic Soils occur in wet alluvial plains and it is hard to find them without showing gleyic properties (which would classify them as Gleyic Alisols).

Humic Alisols - Rubrozems, Dystrophic (or Allic) Red-Yellow Podzolic Soils with high activity clay, Dystrophic (or Allic) Dark-Red Podzolic Soils with high activity clay, Dystrophic (or Allic) Grey Brown Podzolic Soils; the latter three with a humic or prominent A horizon. We do not know of any description of such soils with a thick chernozemic A horizon.
Examples: Profile ISCW-BR 15 (EMBRAPA, 1978) and Figure 23 of Oliveira et al. (1992).

Ferric Alisols - The ferric properties are not used as diagnostic attributes in the "Brazilian System". These soils are uncommon in Brazil.
Example: Profile PE-22 (Brasil, 1972a).

Haplic Alisols - Dystrophic (or Allic) Red-Yellow Podzolic Soils, or Dystrophic (or Allic) Dark-Red Podzolic Soils, both with high activity clay and moderate (ochric) or weak (ochric) A horizon. These are the most common Alisols in Brazil.
Example: Profile BA-130 (EMBRAPA, 1976).

5.24 ACRISOLS

Soils having an argic B horizon which has a cation exchange capacity of less than 24 cmol(+).kg^{-1} clay and a base saturation (by NH_4OAc) of less than 50 percent in at least some part of the B horizon within 125 cm of the surface; lacking the E horizon abruptly overlying a slowly permeable horizon, the distribution pattern of the clay and the tonguing which are diagnostic for Planosols, Nitisols and Podzoluvisols respectively.

See also the general comments on soils with an argic B horizon in Section 5.22. Most Acrisols correspond with Dystrophic (or Allic) Podzolic Soils with low activity clay (see Table 5.1) of the "Brazilian System". An exception are the Acrisols with gleyic properties in the argic B horizon. These soils are classified in the "Brazilian System" as Grey Hydromorphic Soils. At this moment it is difficult to estimate to which extent Acrisols of the FAO Legend may correspond with Latosols of the "Brazilian System" (see section 5.13).

Plinthic Acrisols - Dystrophic (or Allic) Plinthic Red-Yellow Podzolic Soils with low activity clay; Dystrophic (or Allic) Plinthic Dark-Red Podzolic Soils with low activity clay; Dystrophic (or Allic) Plinthic Grey Hydromorphic Soils; Dystrophic (or Allic) Plinthic Greyish Podzolic Soils; Plinthosols (of the Brazilian System) with less than 25% plinthite and a textural B horizon (see section 5.12). These soils are common mainly in the Northern and Northeastern regions of Brazil.
Examples: Profile PE-20 (Brasil, 1972a) and Figure 42 of Oliveira et al. (1992). The latter example was identified as Plinthosol according to the "Brazilian System of Soil Classification".

Gleyic Acrisols - Dystrophic (or Allic) Grey Hydromorphic Soils with low activity clay.
Example: Profile MA-7 (EMBRAPA, 1984).

Humic Acrisols - Dystrophic (or Allic) Red-Yellow (or Dark Red) Podzolic Soils with low activity clay and prominent or humic or chernozemic A horizon. These soils are common in the cooler regions of Southern Brazil.
Example: Profile PR-66 (EMBRAPA, 1984a) and Figure 19 of Oliveira et al. (1992).

Ferric Acrisols - Dystrophic (or Allic) Red-Yellow Podzolic Soils with low clay activity. Ferric properties are not used as diagnostic attributes in the "Brazilian System", although they are common in the Red-Yellow Podzolic Soils.
Example: Profile ISCW-BR 22 (International..., 1978).

Haplic Acrisols - Dystrophic (or Allic) Red-Yellow (or Dark Red) Podzolic Soils, low activity clay, moderate or weak A horizon; Dystrophic (or Allic) Yellow Podzolic Soils; Dystrophic (or Allic) Yellow, Red-Yellow or Dark Red Latosols. The Haplic Acrisols are the most common Acrisols in Brazil.
Examples: Profile IAC-1963 (Oliveira et al., 1982) and Figure 16 of Oliveira et al. (1992).

5.25 LUVISOLS

Soils having an argic B horizon which has a cation exchange capacity equal to or more than 24 cmol(+).kg^{-1} clay and a base saturation (by NH_4OAc) of 50 percent or more throughout the B horizon; lacking a mollic A horizon; lacking the E horizon abruptly overlying a slowly permeable horizon, the distribution pattern of the clay and the tonguing which are diagnostic for Planosols, Nitisols and Podzoluvisols respectively.

Table 5.1 shows that Luvisols correspond typically with Non Calcic Brown Soils, and Eutrophic Podzolics with high activity clay of the "Brazilian System". The Eutrophic Podzolics are typical for the humid regions, whereas the Non Calcic Brown Soils are mainly confined to (semi-)arid regions, with thorn shrub vegetation as reflected by the weakly developed massive A horizon and the higher CEC.

Gleyic Luvisols - Eutrophic Planosolic Red-Yellow Podzolic Soils with high activity clay - poorly drained phase. These soils probably occur in Brazil, but we do not know of any published description.

Stagnic Luvisols - Eutrophic Planosolic Red-Yellow Podzolic Soils with high activity clay - poorly drained phase; possibly Planosolic Non Calcic Brown Soils. These soils probably occur in Brazil, but we do not know of any published description.

Albic Luvisols - Non Calcic Brown Soils or Eutrophic Red-Yellow (or Grey Brown) Podzolic Soils with high activity clay. Note that the albic E horizon is not used as a diagnostic attribute to subdivide general classes of the "Brazilian System". Although E horizons are very common in Brazilian soils with an argic B horizon, they are seldomly strong enough to meet the criteria for the albic E horizon.
Examples: Profile PE-104 (Brasil, 1972a) and Figures 26 and 27 of Oliveira et al. (1992).

Vertic Luvisols - Vertic Non Calcic Brown Soils; Eutrophic Vertic Red-Yellow Podzolic Soils with high activity clay.
Example: Profile AL-45 (EMBRAPA, 1975b)

Calcic Luvisols - Carbonatic Non-Calcic Brown Soils. Note that this name is a *contradictio in terminus*, inherited from the classification of Baldwin & Thorp. Example: Profile BA-178 (Brasil, 1976).

Ferric Luvisols - See remarks for Ferric Acrisols (Section 5.24). We do not know of any description of soils in Brazil related to Ferric Luvisols, but these soils may occur.

Chromic Luvisols - The Chromic Luvisols accommodate some Eutrophic Dark-Red Podzolic Soils with high clay activity and with a moderate or weak A horizon, Eutrophic Red-Yellow Podzolic Soils with high activity clay and a moderate or weak A horizon and Non Calcic Brown Soils; all having a hue of 7.5 YR and a chroma of more than 4 or a hue redder than 7.5YR.
Example: Profile CE-150 (Brasil, 1973a) and Figure 24 of Oliveira et al. (1992).

Haplic Luvisols - The remaining Eutrophic Red-Yellow Podzolic Soils and Non Calcic Brown Soils and Eutrophic Greyish Brown Podzolic Soils. The latter are restricted to the highlands of the Southern States of Brazil.
Example: Profile AL-57 (EMBRAPA, 1975b).

5.26 LIXISOLS

Soils having an argic B horizon which has a cation exchange capacity of less than 24 cmol(+).kg^{-1} clay at least in some part of the B horizon and a base saturation (by NH_4OAc) of 50 percent or more throughout the B horizon; lacking a mollic A horizon; lacking the E horizon abruptly overlying a slowly permeable horizon, the distribution pattern of the clay and the tonguing which are diagnostic for Planosols, Nitisols and Podzoluvisols respectively.

Lixisols correspond typically with Eutrophic Podzolic Soils with low clay activity of the "Brazilian System" (see Tables 5.1 and 5.2). Lixisols that do not present clear clay skins or with a clay ratio from A to B horizon that is too small to satisfy the requirements of a textural B horizon (Table 4.2) will be classified as Latosols if CEC clay < 16 cmol(+).kg^{-1} clay (after deduction for organic matter) or else as Cambisols according to the "Brazilian System" (see general comments on soils with an argic B horizon in Section 5.22). For simplicity these possibilities are not worked out below, although it may apply to a large portion of the Lixisols.

Plinthic Lixisols - Eutrophic Plinthic Red-Yellow (or Dark-Red) Podzolic Soils with low activity clays.
Example: Profile CE-91 (Brasil, 1973a).

Gleyic Lixisols - No example of these soils could be found in the available literature. They probably exist and would be classified as Eutrophic Planosolic Red-Yellow Podzolic Soils - poorly drained phase. The consulted descriptions of such soils are not clear enough for the identification of gleyic or stagnic properties. The Grey Hydromorphic Soils ("Hidromórficos Cinzentos") known at present in Brazil are dystrophic or allic soils and therefore Acrisols instead of Lixisols.

Stagnic Lixisols - We do not know of any description of these soils in Brazil but these soils may occur. See remarks Gleyic Lixisols.

Albic Lixisols - The albic E horizon is not used as diagnostic attribute to separate classes of soils in lower categorical level in the "Brazilian System". Many of the Brazilian Lixisols present an E horizon which, however, is generally too weak to satisfy the criteria of the albic E horizon. Most Albic Lixisols correspond with the Eutrophic Red-Yellow Podzolic Soils with low activity clay; as long as they present the diagnostic albic E horizon.
Example: Profile IAC-1263 (Oliveira & Prado, 1984)

Ferric Lixisols - Eutrophic Red-Yellow (and Dark-Red) Podzolic Soils with low clay activity. "Ferric properties" are not used as diagnostic attributes in the "Brazilian System of Soil Classification" although they are common among the Podzolic Soils.
Example: Profile SE-23 (EMBRAPA, 1975c).

Haplic Lixisols - The remaining Eutrophic Red-Yellow (and Dark-Red) Podzolic Soils; with low clay activity; possibly Yellow Podzolic Soils and Greyish Podzolic Soils, but all these soils identified so far in Brazil are allic or dystrophic, and therefore related to Acrisols.
Example: Profile CE-48 (Brasil, 1973a) and Figures 15 and 17 of Oliveira et al. (1992).

5.27 CAMBISOLS

Soils having a cambic B horizon and no diagnostic horizons other than an ochric or an umbric A horizon or a mollic A horizon overlying a cambic B horizon with a base saturation (by NH_4OAc*) of less than 50 percent in at least some part of the B horizon; lacking salic properties; lacking the characteristics diagnostic for Vertisols or Andosols; lacking gleyic properties within 50 cm of the surface.*

The central concept of the Cambisols of the FAO Legend is the same as that of the Cambisols ("Cambissolos") of the "Brazilian System". However, the relation between the FAO Cambisols and the Brazilian Cambisols is not 1:1, because there are many, apparently slight, differences in horizon definitions and class limits. Note that the Brazilian Cambisols with low activity clays[1] may have both a chernozemic A horizon and be eutrophic in the B horizon. Such soils are classified as Phaeozems by the FAO Legend.

Gelic Cambisols - The climatic conditions in Brazil do not permit the occurrence of such soils.

Gleyic Cambisols - Cambisols -poorly drained phase. These soils can be eutrophic, dystrophic or allic and may have high or low activity clay.
Example: Profile GB-33 (EMBRAPA, 1980).

Vertic Cambisols - Vertic Cambisols.
Example: Profile BA-239 (EMBRAPA, 1977-1979).

Humic Cambisols - Dystrophic Cambisols with a prominent or chernozemic A horizon. These soils can present high or low activity clay.
Example: Profile RS-47 (Brasil, 1973b) and Figure 139 of Oliveira et al. (1992).

Calcaric Cambisols - Carbonatic Eutrophic Cambisols, normally with high activity clay. Note the redundancy in the nomenclature for these soils. The occurrence of these soils in Brazil is mainly restricted to the dry Northeastern region.
Example: Profile RN-35 (Brasil, 1971b).

Ferralic Cambisols - Cambisols with low activity clay and with a moderate or weak A horizon. These Cambisols, which can be considered transitional to Ferralsols, are very common in Brazil. As was discussed in Section 5.11, probably many Brazilian Latosols are keyed out as Ferralic Cambisols according to the FAO Legend.
Examples: Profile BA-229 (EMBRAPA, 1977-1979) and Figures 36, 37 and 38 of Oliveira et al. (1992).

Dystric Cambisols - Cambisols with high activity clay and with a moderate or weak A horizon. These are uncommon soils in Brazil.
Example: Profile SC-98 (MEC/MINTER, 1973).

Chromic Cambisols - The attributes used to identify "chromic" soils are not employed in the "Brazilian System". The Chromic Cambisols are the Eutrophic Cambisols showing a hue of 7.5 YR and a chroma of more than 4 or a hue redder than 7.5YR and having a moderate or weak A horizon and high activity clay.
Example: Profile BA-236 (EMBRAPA, 1977-1979).

Eutric Cambisols - These are the remaining Eutrophic Cambisols, having a moderate or weak A horizon and high activity clay.
Example: Profile RN-36 (Brasil, 1971b).

---

[1]Recall that the "Brazilian System" classifies soils with a chernozemic A horizon and an eutrophic cambic B horizon with high clay activity as Reddish Brunizems.

6 DISCUSSION

It was mentioned in Chapter 1 of this paper, that the results of correlation analysis between soil classification systems can potentially be used for purposes like comparative pedologic studies and agrotechnology transfer. Hence, it would be possible to translate a soil map with a legend based on the Brazilian system of soil classification to a map which is based on the FAO Legend. The quality of the result depends on the quality of the sources and on the degree of correlation.

The results of the former Chapters suggest that no unique answer can be given to the question whether the degree of correlation between the Brazilian system and the FAO Legend is strong enough to produce translated maps with acceptable quality standards. It was shown that the central concepts of most Major Soil Groupings, and even many Soil units, of the FAO Legend correspond well with General Classes of the "Brazilian System of Soil Classification". However, there are many factors that make a correlation at detailed level risky: not only class limit definitions, but also most analytical methods are different. For example, in the case of Latosols, probably the most common soil in Brazil, the central concept corresponds very well with that of the Ferralsols of the FAO Legend. However: (1) CEC is determined by different methods; (2) CEC limits are different; (3) the FAO Legend imposes severe restrictions with respect to silt/clay ratio and content of water dispersable clay and (4) considerable vertical texture differentiation is allowed by the FAO Legend, but not by the "Brazilian System". These "minor" differences may have such large consequences that most Brazilian Latosols may not be classified as Ferralsols and vice versa. On the other hand, translation from the Brazilian System to the FAO Legend, for educational purposes, at very small scale (say < 1 : 1 000 000) seems to be allowed without much further investigation. For mapping at larger scales, and for scientific or technology transfer purposes, additional research will be necessary. Such research must include: (1) detailed correlation, preferably in different laboratories and for different soil groups, between analytical methods used in Brazil and analytical methods recommended by FAO; (2) regional correlation between the two systems, using detailed profile data; and possibly (3) additional fieldwork. Such investigations should also take account of the evolution that Soil Classification has shown in the last decades. Many class limits were changed, some new classes were defined and others were merged. In the case of Brazil, some of the changes were not well documented, and there are also regional differences in the application of the system.

There are many reasons why different soil classification systems use different criteria. The FAO Legend is a system of worldwide consensus, a kind of largest common denominator, which aims comprehensiveness. The Brazilian system "just" aims to cover the most important soils of the Brazilian territory in such a way that major soils are separated from a pedologic as well as from an agronomic point of view. With respect to analytical methods, FAO generally recommends the internationally best accepted methods, whereas the Brazilian System sticks with methods that have proved to correlate well with plant behaviour in Brazilian conditions, and/or simple methods, that can be executed by most laboratories using basic equipment. Therefore, in general it can not be stated whether one system is better than the other.

Nevertheless, in some cases weaknesses of one of the analysed systems became clear. The major weaknesses of the Brazilian system are that many class limits are not rigidly defined and there does not exist a single official reference document which presents all definitions. The problem increases with increasing level of detail. Brazilian soil surveyors that work at scales of

1 : 100.000 or larger, commonly create new classes, with limits adapted to local conditions. It is therefore to be expected that similar soils will be classified differently by different pedologists. A concrete example is the lack of guidelines to classify soils which have a calcic horizon and those which present high contents of primary carbonates. As a result, e.g. Vertisols with a calcic horizon are sometimes classified as Carbonatic Vertisols and sometimes as Calcic Vertisols. Some names bear redundancies, like Carbonatic Eutrophic Cambisols, whereas other names bear contradictions (Carbonatic Non-Calcic Brown Soils). Such confusions turn the system unaccessible and uncomprehensible for non-pedologists. On the other hand, the rigid class limits of the FAO Legend can also be considered a limitation, because people from different regions often find that the limits are not appropriate for their particular conditions.

It was also shown that the "Brazilian System of Soil Classification" in general does not define depth requirements for the occurrence of diagnostic features; e.g. Vertisols with a calcic horizon or carbonatic properties deeper than 125 cm are still considered Carbonatic Vertisols or Calcic Vertisols. In some cases it can be considered an advantage from a pedologic point of view not to define minimum depth requirements, e.g for giant Podzols. However, It is not very practical from an agronomic standpoint and for the surveyor. In the case of carbonatic properties it doesn't seem very wise from a pedologic view either.

In the authors' opinion, the following aspects related to the FAO Legend are subject to improvement:

Nitisols: (1) According to the present definition, Nitisols may not present both a mollic A horizon and a base saturation of >50% in the B horizon, because such soils are keyed ou as Phaeozems. Eutric soils which present both nitic properties and a mollic A horizon are quite common in Brazil. In our opinion it should be considered to classify such soils as Mollic Nitisols by giving preference to the Nitisols over the Phaeozems, or as Nitic Phaeozems, by introducing a nitic soil unit to the Phaeozems.

Nitisols: (2) Many of the most productive Brazilian Structured Dusky Red Earths present also a horizon which shows the set of properties that characterize the ferrallic B horizon. These soils include the ones described by Sombroek and Siderius (1981) as Nitosols, but the FAO Legend classifies these soils as Ferralsols. If FAO staff intends to keep such soils as Nitisols, then Nitisols should be keyed out before the Ferralsols or the definition of the Ferralsols must be changed.

Ferralsols: The constraints with respect to the silt/clay ratio of a ferrallic B horizon are far too restrictive; a luvic soil unit should be introduced for Ferralsols with a distinct vertical clay differentiation; correction for organic matter in the CEC should be stated more explicitly, and soils with a very thick umbric A horizon over a ferralic B (below 125 cm) should be taken into account as Humic Ferralsols.

Ferralic Arenosols - Quartz Sands. The use of ferralic properties to discriminate among Arenosols seems of little relevance, while the identification of ferralic properties in sandy soils is ambiguous, because (1) determining CEC/clay is subject to large error, especially when no correction is made for organic matter and clay contents are often underestimated due to microaggregation; and (2) the criterion of 4 cmol(+).kg^{-1} soil may also be satisfied in very sandy soils with high activity clays. If the separation of strongly weathered sandy soils is considered important for pedologic reasons, perhaps the CEC criteria can be replaced by colour criteria (e.g. Rhodic Arenosols).

Gleyic soil units: The colour requirements for gleyic properties (neutral, bluish or greenish colours) are considered too restrictive.

7 CONCLUSIONS

For 23 of the 28 Major Soil Groupings of the Revised FAO Legend it is possible to refer to published profile descriptions. 87 of the 131 Soil Units that compose the 23 referred Major Soil Groupings are represented. Three Major Soil Groupings (Andosols, Greyzems and Gypsisols) do probably not exist in Brazil.

The central concept of most Major Soil Groupings of the FAO Legend corresponds well with "General Classes of the Brazilian Soil Classification". However, more detailed analyses show many discrepancies.

The correlations between the "Brazilian System of Soil Classification" and the FAO Legend presented here are strong enough to be used for the translation of the legend of Brazilian maps to maps with the FAO Legend in the case of small scale maps (say < 1 : 1 000 000), when used for educational purposes.

For larger scales and scientific purposes or technology transfer, the correlations between the systems are too weak for simple "map translations": Additional support like comparisons of profile descriptions, correlation between analytical methods and in some cases even additional fieldwork will be necessary.

The "system of soil classification in use in Brazil" shows some interesting aspects, especially with respect to the classification and subdivision of strongly weathered soils. However, the lack of clear definitions and its official presentation after so many years are a serious drawback.

In general the FAO Legend seems well applicable to Brazilian conditions. Modifications are suggested for some important groupings like Nitisols and Ferralsols. Less restrictive definitions are suggested for the ferralic B horizon and gleyic properties. The consideration of Ferralic Arenosols seems unpractical and of little relevance.

ACKNOWLEDGEMENTS

The authors wish to express their sincere thanks to Dr. José Antônio Jorge for the translation of the first draft version of this paper; to Dr. Paulo Klinger Tito Jacomine and Professor Doracy Ramos for their help with the localization of some examples; to Mr. Hans van Baren and Dr. Otto Spaargaren (ISRIC) for their review of the final draft and to Mr. Clovis Tristão of UNICAMP-FEAGRI for support with communication via E-mail.

BIBLIOGRAPHY

Baldwin, M., C.E. Kellogg & J. Thorp. **Soil Classification.** In Soils & Men, Yearbook of Agriculture 1938. United States Department of Agriculture, Washington D.C.: 979-1001.

Beenema, J., **Classification of Brazilian soils. Report to the Government of Brazil.** Rome, FAO, EPTA 2.197. 1966. 83p.

Bennema, J. & M.N. Camargo. **Segundo esboço parcial de classificação de solos brasileiros; subsidios a IV Reuniao Técnica de Classificação de Solos.** Rio de Janeiro, Ministério de Agricultura. Divisão de Pedologia e Fertilidade do Solo, 1964. 17p.

Brasil. Ministério da Agricultura. Centro Nacional de Ensino e Pesquisas Agronômicas. Comissão de Solos. **Levantamento de Reconhecimento de Solos do Estado de São Paulo.** Rio de Janeiro, Serviço Nacional de Pesquisas Agronômicas, 1960. 634p. (SNPA, Boletim 12).

Brasil. Ministério da Agricultura. Centro Nacional de Ensino e Pesquisas Agronômicas. Comissão de Solos. **Levantamento de reconhecimento dos solos da região sob influência do reservatório de Furnas.** Rio de Janeiro, Serviço Nacional de Pesquisas Agronômicas, 1962. 462p.

Brasil. Ministério da Agricultura. Equipe de Pedologia e Fertilidade do Solo. **Levantamento de reconhecimento dos solos da zona do Médio Jequitinhonha.- Minas Gerais.** Rio de Janeiro, 1970. 340p. (Boletim Técnico, 9).

Brasil. Ministério da Agricultura. Divisão de Pesquisa Pedológica, DNPEA. **Levantamento de reconhecimento dos Solos do Sul do Estado do Mato Grosso.** Rio de Janeiro, 1971a. 839p. (Boletim Técnico, 18).

Brasil. Ministério da Agricultura. Divisão de Pesquisa Pedológica, DNPEA. **Levantamento Exploratório-reconhecimento de solos do Estado do Rio Grande do Norte.** Recife, Convênio MA/DNPEA-SUDENE/DRN, MA/USAID/BRASIL, 1971b. 530p. (Boletim Técnico, 21).

Brasil. Ministério da Agricultura. Divisão de Pesquisa Pedológica, DNPEA. **Levantamento exploratório-reconhecimento de solos do Estado de Pernambuco.** Recife, Convênio MAS/DNPEA-SUDENE/DRN, MA/CONTAP/USAID/ETA, 1972a. v.II, 534p. (Boletim Técnico, 26).

Brasil. Ministério da Agricultura. Equipe de Pedologia e Fertilidade do Solo. **Levantamento exploratório-reconhecimento de solos do Estado da Paraíba.** Rio de Janeiro, Convênio MA/EPE/-SUDENE/DRN, MA/CONTAP/USAID/BRASIL. 1972b. 683p. (Boletim Técnico, 15).

Brasil. Ministério da Agricultura. Divisão de Pesquisa Pedológica, DNPEA. **Levantamento exploratório-reconhecimento de solos do Estado do Ceará.** Recife, Convênio MA/CONTAP/USAID/ETA, 1973a. v.1 e 2, 502p. (Boletim Técnico, 28).

Brasil. Ministério da Agricultura. Divisão de Pesquisa Pedológica, DNPEA. **Levantamneto de reconhecimento de solos do Estado do Rio Grande do Sul.** Recife, 1973b. 431p. (Boletim Técnico, 30).

Brasil. Ministério da Agricultura. Divisão de Pesquisa Pedológica, DNPEA. **Estudo expedito de solos do Estado do Paraná para fins de classificação e correlação.** Recife, Convênios MA/CONTAP/USAID/ETA, MA/DPP.CERENA, 1973c. 58p. (Boletim Técnico, 37).

Brasil. Ministério das Minas e Energia. Secretaria Geral. **Projeto RADAMBRASIL. Folha SC.19. Rio Branco. Geologia, geomorfologia, pedologia, vegetação, uso potencial da terra.** Rio de Janeiro, 1976. 452 p. (Levantamento de Recursos Naturais, 12).

Camargo, M.N., E. KLamt & J.H. Kauffman. **Soil classification as used in Brazilian Soil Surveys.** ISRIC, Wageningen, Annual Report, 1986 Published in 1987. *Portuguese version:* **Classificação de solos usada em levantamentos pedológicos no Brasil.** Boletim Informativo da SBCS, Campinas, 12(1):11-33, 1987.

Camargo, O.A. de, A.C. Moniz, J.A. Jorge & J.M.A.S. Valadares. **Métodos de análise química, mineralógica e física de solos do Instituto Agronômico de Campinas.** Instituto Agronômico, Campinas, SP, 1986. 94 p. (Boletim Técnico nº 106).

Casagrande, J.C. **Avaliação de um modelo de complexação de superfície para adsorção de fosfatos em solos ácricos do Norte Paulista.** Tese de Doutoramento. USP-ESALQ, 1993, 97pp.

Driessen, P.M. & R. Dudal (Eds.). **The Major Soils of the World. Lecture notes on their geography, formation, properties and use.** Agricultural University Wageningen, The Netherlands, and Katholieke Universiteit Leuven, Belgium, 1991, 310 pp.

EMBRAPA. Centro de Pesquisas Pedológicas. **Mapa esquemático dos solos das regiões Norte, Meio-Norte e Centro-Oeste do Brasil**: texto explicativo. Rio de Janeiro, 1975a. 553p. (Boletim Técnico, 17).

EMBRAPA. Centro de Pesquisas Pedológicas. **Levantamento exploratório-reconhecimento de solos do Estado de Alagoas.** Recife, 1975b. 531p. Convênios EMBRAPA/CPP-SUDENE/DRN, MA/CONTAP/USAID/ETA. (EMBRAPA, Boletim Técnico, 35).

EMBRAPA. Centro de Pesquisas Pedológicas. **Levantamento exploratório-reconhecimento de solos do Estado de Sergipe.** Recife, 1975c. 506p. (EMBRAPA/CCP. Boletim Técnico, 36-SUDENE/DRN, Série Recursos de Solos,6).

EMBRAPA. Serviço Nacional de Levantamento de Solos. Rio de Janeiro. **Levantamento exploratório-reconhecimento de solos da margem esquerda do rio São Francisco, Estado da Bahia.** Recife, Convênios EMBRAPA/SNLCS-SUDENE/DRN, MA/USAID/ETA, 1976. 404p.

EMBRAPA. Serviço Nacional de Levantamento e Conservação de Solos. Rio de Janeiro. **Levantamento exploratório-reconhecimento de solos da margem direita do rio São Francisco, Estado da Bahia.** Recife, Convênios EMBRAPA/SNLCS-SUDENE/DRN, MA/USAID/ETA, 1977-1979. v.1 e 2. 1.296p (Boletim Técnico, 52).

EMBRAPA. Serviço Nacional de Levantamento e Conservação de Solos, 1ª Reunião de Classificação, Correlação e Interpretação de Aptidão Agrícola de Solos. **Guia de excurção de estudos de solos no Estado do Rio de Janeiro.** 1978. 122p.

EMBRAPA. Serviço Nacional de Levantamento e Conservação de Solos. **Manual de métodos de análise de solo.** Rio de Janeiro. 1979.

EMBRAPA. Serviço Nacional de Levantamento e Conservação de Solos. **Levantamento semidetalhado e aptidão agrícola dos solos do município do Rio de Janeiro.** Rio de Janeiro. 1980. 389p. (Boletim Técnico, 66).

EMBRAPA. Serviço Nacional de Levantamento e Conservação de Solos. **Levantamento de reconhecimento de média intensidade dos solos e avaliação da aptidão agrícola das terras do triângulo mineiro.** Rio de Janeiro, EMBRAPA-SNLCS/EPAMIG, (Boletim de Pesquisa, 1) 1982, 526p.

EMBRAPA. Serviço Nacional de Levantamento e Conservação de Solos. **Anais da II Reunião de classificação, correlação de solos e interpretação de aptidão agrícola.** Rio de Janeiro. Documentos SNLCS nº 5. 1983, 138p.

EMBRAPA. Serviço Nacional de Levantamento e Conservação de Solos. **Zoneamento edafoclimático do babaçú nos Estados do Maranhão e Piauí.** Rio de Janeiro, EMBRAPA-SNLCS/SUDENE-DRN, 1984. 557p. (EMBRAPA-SNLCS, Boletim de Pesquisa, 26-SUDENE-DRN. Recursos de Solos, 16).

EMBRAPA. Serviço Nacional de Levantamento e Conservação de Solos/IAPAR. Fundação Instituto Agronômico do Paraná. **Levantamento de reconhecimento dos solos do estado do Paraná.** Convênio SUDESUL-EMBRAPA-Governo do Estado do Paraná/IAPAR. Londrina, 1984a; Tomo II: 415-791.

EMBRAPA. Serviço Nacional de Levantamento e Conservação de Solos. **Definição e notação de horizontes e camadas do solo.** 2. ed. rev. atual. Rio de Janeiro, EMBRAPA-SNLCS, 1988a. 54p. (Documento 3).

EMBRAPA. Serviço Nacional de Levantamento e Conservação de Solos. **Critérios para distinção de classes de solos e de fases de unidades de mapeamento; normas em uso pelo SNLCS.** Rio de Janeiro, 1988b. 67p. (Documento 11).

FAO. **Guidelines for Soil Profile Description. 2nd edition.** FAO, Rome, 1977.

FAO-ISRIC. **Guidelines for Soil Description. 3rd edition (revised).** FAO, Rome, 1990.

FAO-Unesco. **Soil Map of the World: 1:5 000 000.** Vol.1, Legend. Unesco, Paris, 1974. vii+59pp.

FAO. **FAO/Unesco Soil Map of the World, Revised Legend** (reprinted with corrections). FAO, Rome, 1990. World Soil Resources Report 60., 119 pp.

Gama, J.R.N.F., T. Kusaba, T. Ota & Y. Amano. **Influência de material vulcânico em alguns solos do Estado do Acre.** R. Bras. Ci. Solo, Campinas, 16: 103-106, 1992.

International Soil Classification Workshop, 1., Rio de Janeiro, 1977. Proceedings. Rio de Janeiro, EMBRAPA-SNLCS, 1978. 376p.

International Soil Classification Workshop, 8., Rio de Janeiro. **Classification, characterization and utilization of oxisols**: proceedings. Rio de Janeiro, EMBRAPA/ SMSS/AID/UPR, 1988. part , 239p.

ISRIC, 1994. Reprint of FAO, 1990.

Ker, J.C. & M. Resende. **Caracterização química e mineralógica de Solos Brunos Subtropicais do Brasil**. R. Bras. Ci. Solo, 14:215-225, 1990.

Kern, D.C. & N. Kämpf. **Antigos assentamentos indígenas na formação de solos com Terra Preta Arqueológica na região de Oriximiná-Pa**. R. Bras. Ci. Solo, 13:219-225, 1989.

MEC/MINTER **Levantamento de Reconhecimento dos Solos de Santa Catarina V.II**. Ministério de Educação e Cultura / Ministério do Interior / Governo do Estado de Santa Catarina. Acordo UFSM-SUDESUL-SA. 1973. 248p.

Oliveira, J.B. & H. do Prado. **Levantamento pedológico semidetalhado do Estado de São Paulo: Quadrícula de São Carlos.II Memorial Descritivo.** Campinas, Instituto Agronômico, 1984. 188p. (Boletim Técnico, 98).

Oliveira, J.B. & H. do Prado. **Levantamento pedológico semidetalhado do Estado de São Paulo:Quadrícula de Ribeirão Preto.II Memorial Descritivo.** Campinas, Instituto Agronômico, 1987. 133p. (Boletim Científico,7).

Oliveira, J.B., J.L. Barbieri, C.L. Rotta & W.A. Tremocoldi. **Levantamento pedológico semidetalhado do Estado de São Paulo: Quadrícula de Araras.** Campinas, Instituto Agronômico, 1982. 180p. (Boletim Técnico, 72).

Oliveira, J.B., P.K.T. Jacomine & M.N. Camargo. **Classes gerais de solos do Brasil. Guia auxiliar para seu reconhecimento.** Jaboticabal, FUNEP, 1992. 201p.

Oliveira, J.B. **Solos da folha e município de Guaíra.** Campinas, Instituto Agronômico, 1995. 126p. (Boletim Científico 33).

Olmos I.L.J. & G. de P. Paolinelli. **Capacidade de troca de cátions, soma de bases e saturação de bases - correlação de resultados do SCS-USDA e do SNLCS-EMBRAPA e implicações conexas.** Rio de Janeiro, EMBRAPA-SNLCS, 1982. 13p (Boletim de Pesquisa 5).

Palmieri, F. **A study of climo-sequence of soils derived from volcanic rock parent material in Santa Catarina and Rio Grande do Sul States, Brazil.** West Lafayette, Purdue University, 1986. 256p (PhD thesis).

Rodrigues, T.E. **Caracterização e gênese de solos brunos do maciço alcalino de Poços de Caldas (MG).** Piracicaba, USP-ESALQ, 1984. 255p. (Doctors Thesis).

Santa Catarina. Secretaria da Agricultura. **Levantamento de reconhecimento de solos do Estado de Santa Catarina: segunda etapa-Campos de Lages e Canoinhas.** "Santa Catarina, UFSM/SUDESUL/Secretaria da Agricultura, 1973. v.2.

Sakai, E. & Lepsch, I.F. **Levantamento pedológico detalhado e distribuição espacial de características de solos do Pôlder Registro I, SP.** Campinas, Instituto Agronômico, 1987. 56p. (Boletim Científico, 10).

Soil Survey Staff. **Soil Taxonomy: a basic system of classification for making and interpreting soil surveys.** United States Department of Agriculture, Soil Conservation Service. Washington D.C., 1975. 754p.

Sombroek, W.G. **Amazon Soils.** Wageningen, Centre of Agricultural Publications and Documentation (PUDOC). 1966. 292p. (Agricultural Research Reports, 672).

Sombroek, W.G. & W. Siderius. **Nitosols, a quest for significant diagnostic criteria.** ISM Annual Report 1981. p11-31.

Thorp, J. & G.D. Smith. **Higher categories of soil classification: Order, Suborder and Great Groups.** Soil Science, Baltimore, 67, 1949: 117-126.

Vettori, L. & H. Pierantoni. **Análise granulométrica. Novo método para determinar a fração granulométrica.** Ministério da Agricultura. Escritório de Pesquisa e Experimentação. Equipe de Pedologia e Fertilidade do Solo. Rio de Janeiro, 1968. Boletim Tecnico no 3. 8pg.

Appendix 1

THE HIGHEST TAXONOMIC LEVELS OF THE SOIL CLASSIFICATION SYSTEM IN USE IN BRAZIL

Grouping	Soil classes at first two hierarchical levels	Diagnostic properties for further subdivision
1.	Mineral soils, not hydromorphic, with latosolic B horizon following any diagnostic A horizon (without turfose). Subdivisions according to type of latosolic B: **LATOSOL**	- Humic A for Humic Latosol; high content of organic carbon and pale soil colour for cryptohumic Latosol. - Base- and Al- saturation (eutrophic, dystrophic, allic) - Presence of lateritic concretions, thin solum, (concretionary, shallow) - Intergradational properties (podzolic, cambic, plinthic), intergrade with Quartzose sands and intergrades with other kinds of Latosols - Type of A horizon (prominent, moderate ...) - Texture class - Phase of vegetation and relief.
1.1	Dusky red to dark reddish brown (redder than 4YR, value ≤ 3; chroma ≤ 6), related to very high content of Fe_2O_3 ($\geq 36\%$)*, very strong magnetic attraction, Ki (silica/alumina molar ratio) 0.1-0.9: **FERRIFEROUS LATOSOL**	
1.2	Dusky red to dark reddish brown, related to high content of Fe_2O_3 (18-40%)*, strong magnetic attraction, Ki 0.2-2.0: **DUSKY RED LATOSOL**	
1.3	Dark red to dark reddish brown, related to medium content of Fe_2O_3 (8-18%)*, weak magnetic attraction, Ki-index 0.2-2.2: **DARK RED LATOSOL**	
1.4	Red, yellowish red to strong brown, related to low content of Fe_2O_3 (7-11%)*, virtually no magnetic attraction, Ki index normally <1.5; $SiO_2/R_2O_3 < 1.4$: **RED-YELLOW LATOSOL**	
1.5	Brown, strong brown, yellowish brown to olive brown colours related to very low content of Fe_2O_3 ($<7\%$)*, virtually no magnetic attraction, Ki index 1.5-2.2; $SiO_2/R_2O_3 > 1.4$: **YELLOW LATOSOL**	
1.6	Yellowish brown, strong brown or yellowish red colour; medium to high content of Fe_2O_3 ($>11\%$)*, virtually no to strong magnetic attraction, Ki index 0.2-2.0: **LATOSOL, UNA VARIANT**	
1.7	Clayey texture, dark brown to dark yellowish brown colours reddening downward related to medium to high content of Fe_2O_3 ($>11\%$)*, virtually no magnetic attraction, Ki index 0.7-2.2: **BROWN LATOSOL**	

* Applied to soils with clay content $\geq 35\%$ (clayey texture). For loamy soils the Al_2O_3/Fe_2O_3 ratio is used as a distinctive criterion; e.g. 3.14 is the upper limit for Dark Red Latosols.

Grouping	Soil classes at first two hierarchical levels	Diagnostic properties for further subdivision
2.	Mineral soils, non hydromorphic, clayey, following any diagnostic A horizon, except turphose. Textural B horizon, having moderate to strong blocky or compound prismatic structure, with associated clay skins that are at least common and moderately developed. Low activity clay; only small clay increase from A to B horizon. Red or brown colours reflecting medium to high content of Fe_2O_3. Subdivisions according to type of B horizon: **STRUCTURED DUSKY RED and BROWN EARTH**	- Base- and Al- saturation - Intergradational properties (latosolic, intergrade with Reddish Brunizem) - Type of A horizon: moderate, prominent or humic - Phase of vegetation and relief.
2.1	Dark reddish brown, dusky red, reddish brown dark red to red colours; $Fe_2O_3 \geq 15\%$; $TiO_2 \geq 1.5\%$; weak to no magnetic attraction; Ki index 0.9-2.3: **STRUCTURED DUSKY RED EARTH**	
2.2	Brown, dark brown, strong brown, reddish brown to yellowish red colours, medium to high content of Fe_2O_3 ($>10\%$), no magnetic attraction; Ki index 1.7-2.1: **STRUCTURED BROWN EARTH**	
3.	Mineral soils, not hydromorphic; any A and/or E horizon, except Turfose; not plinthic; with a textural B horizon that lacks the distinctive features of Planosols: **PODZOLIC**	- Clay activity (high x low) - Base- and Al- saturation - Presence of fragipan, abrupt textural change, thin solum (fragic, abruptic, shallow) - Intergradational properties (latosolic, cambic, plinthic, intergrade with Reddish Brunizem) - Type of A horizon - Texture class of A or E and of Bt horizon - Phase of vegetation and relief
3.1	Red to dark reddish brown; $3.75+(0.0625*clay\%) \leq Fe_2O_3 \leq 15\%$ and $TiO_2 \leq 1.7\%$: **DARK RED PODZOLIC**	
3.2	Red, yellowish red to strong brown; $Fe_2O_3 \leq 3.75+(.0625*clay\%)$: **RED YELLOW PODZOLIC**	
3.3	Upper part of B horizon is dark brown to dark yellowish brown. Lower part of B horizon often presents yellowis brown or reddish brown mottling: **GREY-BROWN PODZOLIC**	
3.4	Brown, strong brown, yellowish brown to olive brown, related to low content of Fe_2O_3; $CEC < 13meq/100g$ clay and $Ki \leq 2.2$); low base saturation: **YELLOW PODZOLIC**	
3.5	Moderate to imperfectly drained, without gley horizon, with greyish textural B horizon: **GREYISH PODZOLIC**	
4.	Mineral soils with a spodic B horizon following any diagnostic E or A horizon	- Base or Al saturation - Presence of fragipan, very thick A + E (albic) horizon, presence of ortstein (fragic, giant, with ortstein) - Intergradational properties (intergrade with Quartzose Marine Sands) - Type of A horizon - Textural class - Phases of vegetation and relief.
4.1	Non hydromorphic: **PODZOL**	
4.2	Hydromorphic: **HYDROMORPHIC PODZOL**	

Grouping	Soil classes at first two hierarchical levels	Diagnostic properties for further subdivision
5.	Mineral soils, non hydromorphic, with incipient or textural B horizon, following a chernozemic A horizon, high activity clay, eutrophic, lacking the diagnostic properties for Planosols	- Presence of calcic or k horizon in Brunizems, calcium carbonate remains in Reddish Brunizems and Brunizems; abrupt textural change, thin solum, (calcic, carbonatic, abruptic, shallow)
5.1	Presence of a clear distinct chernozemic A overlying a dull coloured incipient - or textural - B horizon: **BRUNIZEM**	- Intergradational properties (vertic, planosolic, litholic, intergrade Reddish Brunizem with Dusky Red Earth)
5.2	Moderately developed chernozemic A, overlying a vividly, reddish coloured, textural B horizon: **REDDISH BRUNIZEM**	- Texture class - Phases of vegetation and relief.
6.	Mineral soils, non hydromorphic, clayey, with a textural B horizon below a humic A, high activity clay, mostly reddish colour, moderate to strong prismatic or blocky structure, very high Al saturation (>50%): **RUBROZEM**	- Intergradational properties (cambic, intergrade with Humic Gley) - Texture class - Phase of vegetation and relief.
7.	Mineral soils, non hydromorphic, clayey, with a reddish coloured textural B horizon, strongly contrasting with the A horizon, which is usually weak, massive and hard and seldomly moderate; high base saturation and relatively high activity clay: **NON CALCIC BROWN SOIL**	- Presence of calcium carbonate remains, sodium saturation, abrupt textural change, (carbonatic, solodic, abruptic) - Intergradational properties (litholic, planosolic, vertic), intergrade with Reddish Brunizem, intergrade with Red Yellow Podzolic - Weak or moderate A horizon - Texture class - Phases of vegetation and relief.
8.	Mineral soils with a textural B horizon, underlying an A or E horiozn, abrupt textural change, which presents a fractured boundary when dry; B horizon usually mottled and with dull colours: **PLANOSOL**	- Activity of clay - Base- or Al-saturation - Presence of a fragipan, calcic or k horizon, calcium carbonate remains, sodium saturation (fragic, calcic, carbonatic, solodic) - Intergradational properties (vertic, gleyic, plinthic, intergrade with Brunizem) - Type of A horizon - Texture class - Phases of vegetation and relief.
9.	Mineral soils with a natric B horizon, below any diagnostic E, or moderate or weak A, well contrasting with the natric B usually with faded colours: **SOLODIZED SOLONETZ**	- Activity of clay - Base saturation - Presence of a fragipan, duripan, abrupt textural change, calcium carbonate remains (fragic, duric, abruptic, carbonatic) - Intergradational properties (vertic, plinthic, intergrade with Solonchak) - Weak or moderate A horizon - Texture class - Phases of vegetation and relief.

Grouping	Soil classes at first wo hierarchical levels	Diagnostic properties for further subdivision
10.	Mineral soils, mostly hydromorphic, either with a salic horizon, or saline C horizon (Cgz or Cz) directly underlying the A horizon	- High ESP (sodic, ESP>15%) - Weak or moderate A horizon - Phases of vegetation and relief.
10.1	Developed on terrestrial or semi-terrestrial landscapes: **SOLONCHAK**	
10.2	Developed on semi-aquatic landscapes - usually mangrove land: **UNDIFFERENTIATED COASTAL SALINE SOILS**	
11.	Mineral soils, usually non hydromorphic, with an incipient B horizon, lacking expressive evidences of gleyzation, non plinthic, following any diagnostic A horizon (without turfose): **CAMBISOL**	- Activity of clay - Base- or Al-saturation - Presence of calcium carbonate remains, thin solum, thick A horizon (carbonatic, shallow, humic) - Intergradational properties (latosolic, gleyic, podzolic, litholic, vertic, plinthic) - Type of A horizon and the combination: high base saturation, high activity clay, chernozemic A horizon* - High ESP (sodic: ESP>15%) - Texture class - Phase of vegetation, substratum and relief * Such soils would only be classified as Cambisols if the B horizon has a vivid colour. Similar soils with a dull colour in the B horizon are classified as Brunizems.
12.	Mineral soils with a plinthic horizon, superimposed or not on a textural B, following any E or A diagnostic horizon (without turfose)	- Activity of clay - Base- or Al-saturation - Abrupt textural change, sodium saturation (abruptic, sodic), subdivision according to presence of albic E horizon is not yet established; - Drainage class - Type of A horizon - Texture class - Phase of vegetation and relief.
12.1	Lacking, or with only rare concretions and nodules from hardening of plinthite (petroplinthite): **PLINTHOSOLS**	
12.2	with 15% or more, by volume, of petroplinthite: **PETROPLINTHOSOLS**	
13.	Hydromorphic mineral soils with a gley horizon, superimposed or not on a textural B, in sequence to any diagnostic A horizon, except weak, with or without an intervening E horizon	- Activity of clay - Base- or Al-saturation, - Presence of calcium carbonate remains, fragipan, slight sodium saturation (carbonatic, fragic, solodic. - Intergradational properties (vertic, cambic) - Type of A horizon - Texture class - Phase of vegetation and relief.
13.1	Presence of a gleyic, yet textural B horizon, preceded or not by an E horizon, but anyway lacking an abrupt textural change: **GREY HYDROMORPHIC SOILS**	
13.2	With turfose, humic or prominent A horizon, followed by a non-textural B horizon and lacking sulfidic materials or a sulphuric horizon: **HUMIC GLEY**	
13.3	As 13.2, but with a moderate A horizon: **LOW HUMIC GLEY**	
13.4	With sulfidic material or sulphuric horizon **TIOMORPHIC GLEY**	

Grouping	Soil classes at first two hierarchical levels	Diagnostic properties for further subdivision
14.	Mineral soils with 30% or more clay, weak profile develpment (AC profiles), relatively high activity clay, having marked changes in volume with moisture variation, as shown by cracks at some periods in most years, by intersecting slickensides and eventually wedge-shaped structural aggregates, or gilgai microrelief: **VERTISOL**	- Activity of clay - Base saturation - Presence of calcic or Ck horizon, calcium carbonate remains, Cy horizon, thin soil, slight sodium saturation (calcic, carbonatic, gypsic, solodic). - Intergradational properties (planosolic) - Type of A horizon - Phase of vegetation and relief.
15.	Weakly developed mineral soils, exclusive of Vertisols, without any subsurface diagnostic horizon	
15.1	Non hydromorphic, having AC profile, with chernozemic SA horizon, formed on calcareous material: **RENDZINA**	- Textural class, phases of vegetation and relief
15.2	Non hydromorphic, shallow to hard bedrock (excluding petroplinthite), having AR profile with or without a thin intervening C horizon: **LITHOLIC SOIL**	- Activity of clay, base or Al saturation, type of A horizon, presence of calcic or Ck horizon and calcium carbonate remains (calcic, carbonatic), textural class, phases of vegetation, substratum and relief
15.3	Non hydromorphic, having AC profile, formed on saprolite, pedisediment or other reworked materials, containing weatherable minerals: **REGOSOL**	- Base- or Al-saturation, presence of fragipan (fragic), intergradational properties (cambic) type of A horizon except turfose (histic), textural class, phases of vegetation and relief
15.4	Soils with AC profile, formed on quartzose sands: **QUARTZOSE SAND**	- Base- or Al-saturation, presence of fragipan (fragic), intergradational properties (latosolic, podzolic, intergrade with Podzol), type of A horizon and phases of vegetation and relief
15.5	Soils with AC profile, formed on recent fluvial or lacustrine deposits, showing stratification: **ALLUVIAL SOIL**	- Activity of clay, evidences of hydromorphism (hydromorphic; NOT allowed in upper 50 cm), base or Al saturation, remains of calcium carbonate (carbonatic), slight sodium saturation (solodic), intergradational properties (cambic, vertic, gleyic), type of A horizon except turfose, textural class and phases of vegetation and relief.
16.	Hydromorphic soils consisting of organic materials	
16.1	Lacking sulfidic materials or a sulfuric horizon: **NON-THIOMORPHIC ORGANIC SOIL**	- Base- or Al-saturation - Slight sodium saturation (solodic) - Phase of vegetation and relief.
16.2	With sulfidic materials or sulfuric horizon: **THIOMORPHIC ORGANIC SOIL**	

Source: Camargo et al. (1987), Oliveira et al. (1992).

Appendix 2

ENGLISH X PORTUGUESE X ENGLISH VOCABULARY OF TERMS OF THE BRAZILIAN SYSTEM OF SOIL CLASSIFICATION

English x Portuguese

abrupt - abrupto
abrupt textural change - mudança textural abrupta
abruptic - abrúptico
albic horizon - horizonte álbico
allic - álico
Alluvial Soils - Solos Aluviais
anthropic A horizon - horizonte A antrópico
base saturation - saturação por bases (V)
Brown Latosol - Latossolo Bruno
Brunizem - Brunizém
cambic - câmbico
Cambisol - Cambissolo
carbonatic - carbonático
cation exchange capacity (CEC) - capacidade de troca de cations (CTC)
chernozemic A horizon - horizonte A chernozémico
clayey texture - textura argilosa
coarse texture - textura arenosa
cracks - fendas
cryptohumic - crypto-húmico
Dark Red Podzolic Soil - Podzólico Vermelho Escuro
Dark Red Latosol - Latossolo Vermelho Escuro
diagnostic properties - propriedades diagnósticas
diagnostic horizons - horizontes diagnósticos
durinodes - durinódulos
duripan - duripã
Dusky Red Latosol - Latossolo Roxo
dystrophic - distrófico
easily weatherable minerals - minerais facilmente intemperizáveis
epiallic - epiálico
eutrophic - eutrófico
Ferriferous Latosol - Latossolo Ferrífero
fragic - frágico
fragipan - fragipã
giant Podzol - Podzol gigante
gilgai - gilgai
gley horizon - horizonte glei
gleyic - gleico
Grey Hydromorphic Soil - Solo Hidromórfico Cinzento
Grey-Brown Podzolic Soil - Podzólico Bruno Acinzentado
Greyish Podzolic Soil - Podzólico Acinzentado
high clay activity (Ta) - argila de atividade alta
humic A horizon - horizonte A húmico
humic - húmico
Humic Gley Soil - Solo Glei Húmico
Hydromorphic Podzol - Podzol hidromórfico
incipient B horizon - horizonte B incipiente
intergrade - intergradação
Ki index - índice Ki
Latosol, Una Variant - Latossolo Variação Una
latosolic - latossólico
latosolic B horizon - horizonte B latossólico
Latosols - Latossolos
lithic contact - contato lítico
lithoid contact - contato litóide
litholic - litólico
Litholic soil - Solo Litólico
low clay activity (Tb) - argila de atividade baixa
Low Humic Gley - Solo Glei Pouco Húmico
medium texture - textura média
mineral soil material - material mineral de solo
moderate A horizon - horizonte A moderado
mottling - mosqueamento
natric B horizon - horizonte B nátrico
Non Calcic Brown soil - Solo Bruno Não Cálcico
Non-Thiomorphic Organic Soils - Solos Orgânicos Não Tiomórficos
organic soil material - material orgânico de solo
ortstein - ortstein
(petro)calcic horizon - horizonte (petro)cálcico
(petro)gypsic horizon - horizonte (petro)gípsico
petroplinthic - petroplíntico
petroplinthite - petroplintita
Petroplinthosol - Plintossolo Pétrico
Planosol - Planossolo
planosolic - planossólico
planosolic - planossólico
plinthic - plíntico
plinthic horizon - horizonte plíntico
plinthite - plintita
Plinthosol - Plintossolo
Podzol - Podzol (Não Hidromórfico)
podzolic - podzólico
Podzolic Soil - Podzólico
prominent A horizon - horizonte A proeminente
Quartzose Sands - Areias Quartzosas
Red Yellow Podzolic soil - Podzólico Vermelho Amarelo
Red-Yellow Latosol - Latossolo Vermelho Amarelo
Reddish Brunizem - Brunizém Avermelhado
Regosols - Regossolo
Rendzina - Rendzina
Rubrozem - Rubrozém
salic horizon - horizonte sálico
saline - salino
shallow - raso
shiny ped faces - cerosidade
silty texture - textura siltosa

slickensides - superfícies de fricção[*)]
sodic - sódico
solodic - solódico
Solodized Solonetz - Solonetz-Solodizado
Solonchak - Solonchak
spodic B horizon - horizonte B espódico
Structured Brown Earth - Terra Bruna Estruturada
Structured Dusky Red Earth - Terra Roxa Estruturada
sulfuric horizon - horizonte sulfúrico
sulphidric materials - materiais sulfídricos
textural B horizon - horizonte B textural
Thiomorphic Organic Soils - Solos Orgânicos Tiomórficos
Tiomorphic Gley Soil - Solo Glei Tiomórfico
turphose horizon - horizonte turfoso
Undifferentiated Coastal Saline Soils - Solos Salinos Indiscriminados Costeiros
vertic - vértico
Vertisol - Vertissolo
very fine clayey texture (>60% clay) - textura muito argilosa
weak A horizon - horizonte A fraco
with carbonates - com carbonatos
Yellow Podzolic Soil - Podzólico Amarelo
Yellow Latosol - Latossolo Amarelo

*) Other designations used for slickensides are: "superfícies de deslizamento", "superfícies de escorregamento" e "superfícies de estriamento".

Portuguese x English

abrúptico - abruptic
abrupto - abrupt
álico - allic
Areias Quartzosas - Quartzose Sands
argila de atividade alta - high clay activity (Ta)
argila de atividade baixa - low clay activity (Tb)
Brunizém - Brunizem
Brunizém Avermelhado - Reddish Brunizem
câmbico - cambic
Cambissolo - Cambisol
capacidade de troca de cations (CTC) - cation exchange capacity (CEC)
carbonático - carbonatic
cerosidade - shiny ped faces
com carbonatos - with carbonates
contato lítico - lithic contact
contato litóide - lithoid contact
crypto-húmico - cryptohumic
distrófico - dystrophic
durinódulos - durinodes
duripã - duripan
epiálico - epiallic
eutrófico - eutrophic
fendas - cracks
frágico - fragic
fragipã - fragipan
gilgai - gilgai
gleico - gleyic
horizonte (petro)cálcico - (petro)calcic horizon
horizonte (petro)gípsico - (petro)gypsic horizon
horizonte A chernozémico - chernozemic A horizon
horizonte A fraco - weak A horizon
horizonte A antrópico - anthropic A horizon
horizonte A proeminente - prominent A horizon
horizonte A moderado - moderate A horizon
horizonte A húmico - humic A horizon
horizonte álbico - albic horizon
horizonte B textural - textural B horizon
horizonte B nátrico - natric B horizon
horizonte B incipiente - incipient B horizon
horizonte B latossólico - latosolic B horizon
horizonte B espódico - spodic B horizon
horizonte glei - gley horizon
horizonte plíntico - plinthic horizon
horizonte sálico - salic horizon
horizonte sulfúrico - sulfuric horizon
horizonte turfoso - turphose horizon
horizontes diagnósticos - diagnostic horizons
húmico - humic
índice Ki - Ki index
intergradação - intergrade
latossólico - latosolic
Latossolo Amarelo - Yellow Latosol
Latossolo Bruno - Brown Latosol
Latossolo Ferrífero - Ferriferous Latosol
Latossolo Roxo - Dusky Red Latosol
Latossolo Variação Una - Latosol, Una Variant
Latossolo Vermelho Amarelo - Red-Yellow Latosol
Latossolo Vermelho Escuro - Dark Red Latosol
Latossolos - Latosols
litólico - litholic
materiais sulfídricos - sulphidric materials
material mineral de solo - mineral soil material
material orgânico de solo - organic soil material
minerais facilmente intemperizáveis - easily weatherable minerals
mosqueamento - mottling
mudança textural abrupta - abrupt textural change
ortstein - ortstein
petroplíntico - petroplinthic
petroplintita - petroplinthite
planossólico - planosolic
planossólico - planosolic
Planossolo - Planosol
plíntico - plinthic
plintita - plinthite
Plintossolo - Plinthosol
Plintossolo Pétrico - Petroplinthosol
Podzol gigante - giant Podzol
Podzol hidromórfico - Hydromorphic Podzol
Podzol (não hidromórfico) - (non hydromorphic) Podzol

podzólico - podzolic
Podzólico - Podzolic Soil
Podzólico Acinzentado - Greyish Podzolic Soil
Podzólico Amarelo - Yellow Podzolic Soil
Podzólico Bruno Acinzentado - Grey-Brown Podzolic Soil
Podzólico Vermelho Amarelo - Red Yellow Podzolic soil
Podzólico Vermelho Escuro - Dark Red Podzolic Soil
propriedades diagnósticas - diagnostic properties
raso - shallow
Regossolo - Regosol
Rendzina - Rendzina
Rubrozém - Rubrozem
salino - saline
saturação por bases (V) - base saturation
sódico - sodic
Solo Bruno Não Cálcico - Non Calcic Brown soil
Solo Glei Húmico - Humic Gley Soil
Solo Glei Tiomórfico - Tiomorphic Gley Soil
Solo Glei Pouco Húmico - Low Humic Gley
Solo Hidromórfico Cinzento - Grey Hydromorphic Soil
Solo Litólico - Litholic soil
solódico - solodic
Solonchak - Solonchak
Solonetz-Solodizado - Solodized Solonetz
Solos Aluviais - Alluvial Soils
Solos Orgânicos Tiomórficos - Thiomorphic Organic Soils
Solos Orgânicos Não Tiomórficos - Non-Thiomorphic Organic Soils
Solos Salinos Indiscriminados Costeiros - Undifferentiated Coastal Saline Soils
superfícies de fricção[*)] - slickensides
Terra Bruna Estruturada - Structured Brown Earth
Terra Roxa Estruturada - Structured Dusky Red Earth
textura argilosa - clayey texture
textura arenosa - coarse texture
textura média - medium texture
textura siltosa - silty texture
vértico - vertic
Vertissolo - Vertisol
very fine clayey texture (>60% clay) - textura muito argilosa

*) see slickensides