DRAFTv1.1

WRB Documentation Centre

PROTOTYPE version 1

Example: Ferralsols

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WRB Documentation Centre

Abstract

This text is a contribution to the WRB Documentation Centre that illustrates the Reference Soil Groups (RSG) and all their principal qualifiers in the World Reference Base for Soil Resources (IUSS Working Group WRB, 2022).

This example deals with the RSG of Ferralsols. It provides the soil forming factors and the main characteristics of this RSG and reviews its classification at RSG and qualifier level. Examples of fully documented Ferralsols with their principal qualifiers derived from the soil reference collection of ISRIC World Soil Information are given in an Annex. A second Annex describes the changes in the evolving classification criteria for Ferralsols since the FAO/Unesco Legend of the Soil Map of the World.

The WRB soil classification system will benefit from a core set of documented occurrences of Reference Soil Groups with their principal qualifiers as illustrated here. However, not all qualifiers could be documented and a call for contributions is made to fill the gaps in the present Ferralsol collection.

Call for contributions:

Examples of fully documented (Photograph with tape, soil profile description and associated analytical data; with specification of the description protocol used, the methods for analyses applied and the units of the data) for **Haplic Ferralsols** and **Ferralsols** with **stagnic, gleyic, nitic or skeletic principal qualifiers** will be gratefully acknowledged (Name, title, Institution).

Please contact:

ISRIC, c/o Stephan Mantel: wrbwgsecretariat@gmail.com

and / or

KU Leuven: https://ees.kuleuven.be/en/soil-monoliths/contact

FERRALSOLS

Introduction

Ferralsols are characterized by a ferralic horizon in the subsoil which is the result of long and intense weathering. The clay fraction is dominated by low activity clays (mainly kaolinite) and the the silt and sand fractions by highly resistant minerals such as goethite, hematite and gibbsite. Extreme weathering results in relatively low physical and chemical activity of the soil colloids and a near absence of weatherable minerals. Rock fragments are rare and clay percentage is higher than 8%. Ferralic horizons are associated with old and stable geomorphic surfaces. They typically develop under the high ambient temperatures and rainfall of the humid tropics. The characterization of Ferralsols in this text was based on information from various sources, among others Driessen et al (2001), Klamt and Van Reeuwijck (1993) and Van Wambeke (1974). The classification of Ferralsols is discussed as given in the World Reference Base for Soil Resources (IUSS Working Group WRB, 2022). The findings are illustrated in fully documented monoliths from ISRIC's Soil Museum[1]. Attention is paid to the evolution of classification of Ferralsols in different editions of the World Reference Base for Soil Resources (Deckers et al, 1998; ISSS/ISRIC/FAO 1998; IUSS Working Group WRB 2006, 2007, 2010, 2015) in a separate Annex.

Summary description of Ferralsols

Connotation: red and yellow tropical soils with high content of sesquioxides: from L. *ferrum*, iron and *aluminium*, alum

The Reference Soil Group of the Ferralsols clusters the deeply weathered, red or yellow soils of the humid tropics. These soils have very few weatherable minerals and are dominated by low activity clays (mainly kaolinite) and a high content of sesquioxides.

Names: Local names usually refer to the color of the soil, e.g. in English speaking countries *red earths* or vernacular synonyms are used such as '*ekundu*' in Kiswahili. Internationally Ferralsols correlate to Ferralsols (FAO/Unesco/ISRIC, 1988, 1990), Latosols (Brazil), Oxisols (USA), Sols ferralitiques (France), Ferralitic soils (Russsia), Kandosols, Kurosols, Ferrosols (Australia)

Geographic distribution of Ferralsols

Ferralsols cover extensive areas in the tropical region of South America (Brazil) and Africa (Congo Democratic Republic, Angola, southern Central African Republic, Guinea and eastern Madagascar) and minor ones in Asia, Australia and Central America. The total extent of Ferralsols has been estimated at 750 million hectares. (Map 1).

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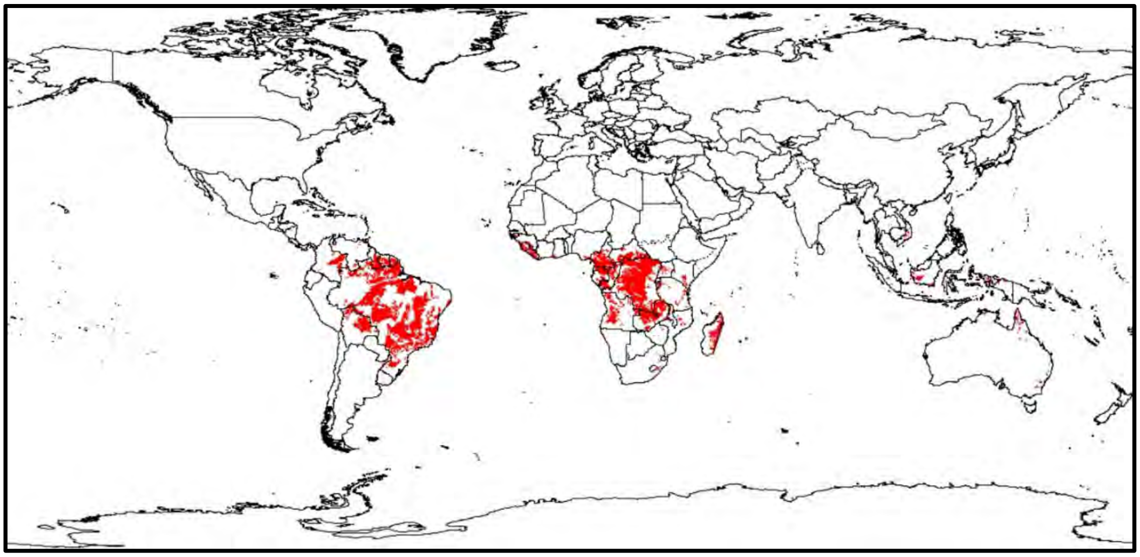
[1] https://isis.isric.org/ and https://wsm.isric.org/gallery.html



Map 1: Distribution of Ferralsols worldwide. (FAO/IIASA, 2022)

Soil Forming factors in Ferralsols

Parent material: strongly weathered material on old, stable geomorphic surfaces. derived from basic rocks rather than from silicious materials.

Climate: Ferralsols have developed in hot tropical humid and sub-humid climates (Af, Am, Aw and Cw Köppen climates; udic and ustic moisture regimes in Soil Taxonomy). Minor occurrences outside these climates are considered to be relics from past eras with a hotter and wetter climate than today.

Age/Time: Ferralsols typically develop on land of Pleistocene age or older; they are less common on younger, easily weathering rocks.

Fauna and Flora: Evergreen to semi-deciduous forests are the most common natural vegetation reflecting the present-day climate.

Topography: Ferralsols occur mainly on stable flat to gently undulating plateaus. Slopes rarely are more than 8%.

Human influence: Although the zones where Ferralsols occur are generally less populated (due to the hot, wet climate and a forest vegetation), a large part of the natural vegetation has been substituted by cultivated crops or grasslands. Many Ferralsols are under shifting cultivation. It is estimated that less than 20% remains under forest.

Soil characteristics of Ferralsols

Morphology

Ferralsols are deep to very deep soils; some are more than 10 meters deep.

The color of Ferralsols is determined by the dominance of iron and aluminium (hydr)oxides present: red when hematite dominates and yellowish when goethite is prevalent.

Ferralsols have a weak macrostructure and a strong microstructure. They have a friable consistence. Even when they contain more than 60% clay, Ferralsols have the pore volume and the mechanical characteristics of lighter textured soils, so-called pseudo sands.

They have excellent internal drainage and mottles characterizing stagnating water are rare in these soils.

Mineralogical characteristics

Easily weathering primary minerals such as glasses and ferro-magnesian minerals and even the more resistant feldspars and micas have disappeared completely from Ferralsols. Quartz is generally the main primary mineral. The clay fraction is dominated by kaolinite, goethite, hematite and gibbsite in varying amounts, depending on the kind of parent rock and the drainage conditions.

Hydrological characteristics

Ferralsols only have a limited capacity to store available water for crops (about 10mm of available water per 10 cm of soil depth). Groundwater tables, when present, are generally very deep. Flooding is rare.

Physical characteristics

Most Ferralsols have good physical properties. The great soil depth, good permeability and stable microstructure make Ferralsols less susceptible to erosion than most other intensely weathered red tropical soils. Moist Ferralsols are friable and easy to work. They are well drained but may in times be drought prone because of their low water storage capacity.

Chemical characteristics

The chemical fertility of Ferralsols is poor: weatherable minerals are absent and cation retention and exchange capacity by the mineral soil fraction is weak, often near zero, and is partly pH dependent. The cation exchange capacity of Ferralsols has a permanent and variable component. Ferralsols are normally low in nitrogen, potassium, secondary nutrients (calcium, magnesium, sulphur) and a score of micro-nutrients. The strong retention of Phosphorus (P - fixation) is another chemical limitation in Ferralsols.

Under natural conditions, due to their occurrence in humid tropical climates, under rain forest the topsoil of Ferralsols may be rich in organic matter that may accumulate to greater depths. However, once cultivated, under low or no input levels, the chemical fertility decreases rapidly.

Biological characteristics

Intense termite activity is at least partly accountable for the typical diffuse boundaries between horizons of Ferralsols. Termites increase the depth of the solum and their nests, tunnels and ventilation shafts increase the permeability of the soil. As termites preferentially move fine and medium sized particles and leave coarse sand, gravel and stones behind, they are thought to contribute to *`stoneline'* formation. The depth of the stoneline would then indicate the depth of termite activity.

Soilscape-relationships of Ferralsols with some other Reference Soil Groups

Ferralsols occupy geomorphologically old land surfaces. They are associated with Cambisols where solid rock comes near to the surface. They occur together with Acrisols, which often seem to be related to the presence of more acidic parent materials (e.g. gneiss). On the more basic rocks (e.g. dolerite) they are associated with Nitisols. Near valleys, Ferralsols merge into Gleysols and Plinthosols.

On continental scale of Africa, a clear zonality has evolved along a climatic gradient. Ferralsols coincide with the humid zone of Central Africa, whereas Acrisols become dominant in a circle in the subhumid zones of West- and East-Africa. In South America a comparable zonality exists with Ferralsols in the oldest more humid parts of the eastern Amazon basin and Acrisols in the western Amazon. Ferralsols commonly occupy the oldest upper positions of the landscape (e.g. upper-plateaus), whereas the rejuvenated lower positions are dominated by Acrisols.

Land use and management of Ferralsols

At present major areas of tropical rainforests are found on Ferralsols. Tropical rainforests are particularly well adapted to this soil because their root systems exploit a large volume of the deep soil to tap nutrients and to protect the trees of occasional drought stress. The land is protected against raindrop impact and direct insolation so that organic matter is built up and preserved. This organic matter-rich surface horizon in Ferralsols contains nearly all fertility and therefore is of vital importance for sustainable land use on these soils.

When taken into cultivation, nutrient supply capacity of these soils decreases very quickly after bush clearing. This means that after two to three years of cultivation a fallow period is required of up to 5-9 years for natural soil fertility to restore in a shifting cultivation system. For permanent agriculture, chemical constraints of these soils may be overcome partly by judicious supply of all plant nutrients, including both phosphate and lime, but attention must be paid to both mode and timing of nutrient application.

In view of the variable charge in Ferralsols, soil fertility needs to be managed carefully. Under prevailing acidic conditions of a rain forest, anion exchange capacity is high (hence P-fixation) and cation exchange/retention capacity is negligible. This awkward plant-nutrient challenge can be remedied by applications of organic manure in combination with lime. Agroforestry systems are particularly suitable as it provides protection of the topsoil and favors nutrient cycling.

Organic matter is mainly concentrated in the topsoil and should be conserved at all cost because it buffers chemical changes, retains cations, is a major source of nitrogen, and plays a key role in plant available phosphate dynamics. Moderate applications of lime are beneficial as long as they do not result in accelerated mineralization of organic matter or create micro-nutrient deficiency (zinc, copper). Usually 0.5 – 2 tons /ha of lime, or preferably dolomite will be sufficient to supply calcium and/or magnesium nutrients and also to buffer the low pH in Ferralsols.

Because of low water holding capacity, annual crops are more exposed to occasional drought periods on Ferralsols than on other soils with comparable clay content. Ferralsols are physically stable soils that resist soil erosion.

The classification of Ferralsols

Ferralsols definition as a Reference Soil Group

Soils having a ferralic horizon starting at ≤ 150 cm from the mineral soil surface that have no argic horizon starting above or at the upper limit of the ferralic horizon, unless the argic horizon has, in its upper 30 cm or throughout, whichever is shallower, one or more of the following: (a). < 10% water-dispersible clay; or (b) b. a ΔpH (pHKCl - pHwater) ≥ 0 (both in 1:1 solution); or (c). ≥ 1.4% soil organic carbon.

Although there are differences, particularly in the consideration of an overlapping argic horizon, the Reference Soil Group of Ferralsols in WRB2022 corresponds to the Oxisols in Soil Taxonomy (Soil Survey Staff, 2022).

In the key of the Reference Soil Groups Ferralsols are placed in 16^{th} position, after Histosols, Anthrosols, Technosols, Cryosols, Leptosols, Solonetz, Vertisols, Solonchaks, Gleysols, Andosols, Podzols, Plinthosols, Planosols, Stagnosols and Nitisols.

Given the characteristics of Ferralsols and the environment in which they develop, most of the other Reference Soil Groups preceding them in the key have characteristics that are incompatible with Ferralsols. This is the case for Histosols (organic not mineral soil material), Leptosols (very shallow or very stony), Cryosols (permafrost), Solonetz and Solonchaks (high salinity or high exchangeable Na content, mainly occurring in dry climates), Vertisols (dominated by 2:1 clay minerals not by 1:1 kaolinite as in Ferralsols), Podzols (developed in cool and cold climates in sandy parent material) and Anthrosols (that require long term intensive cultivation practices seldom observed in tropical climates, with the exception of the Hydragric Anthrosols and the Pretic Ferralsols, discussed later).

Characteristics of the other Reference groups preceding Ferralsols may occur in exceptional circumstances and will be recognized as principal or supplementary qualifiers. This is the case for Planosols (abruptic texture changes are unusual in Ferralsols that have been homogenized over a long time and /or by termite activity), Gleysols (high ground water tables are rare in Ferralsols), Stagnosols (given the high porosity of Ferralsols, stagnic features are unusual, although a very high clay content may trigger them).

Horizons with ferralic characteristics may develop in volcanic parent material but by convention it has been decided to keep these soils in Andosols in view of the relatively young age and the mineralogically rich parent material in which they develop. Characteristics of Nitisols and Ferralsols may be very similar, but by convention it has been decided in WRB to give precedence to the Nitisols. Note this has not always been the case (i.e. since the FAO Legend (1974) and up till WRB1998, Ferralsols preceded Nitisols in the key to the Reference Soil Groups[2]).

A special case are Plinthosols that used to be part of the Ferralsols in the FAO legend (1974, 1988) and still are part of Oxisols in the USDA Soil Taxonomy, but have been considered as a Reference soil Group in its own right by WRB since 1998.

Definition of the Ferralic horizon

There is a broad consensus on a number of characteristics for this horizon in all major classification systems: thickness, textural class, absence of weatherable minerals, the absence of andic (and vitric) properties, the low CEC of the clay and the low sum of exchangeable bases and exchangeable acidity (until WRB 2014). The absence of rock structure is specified in FAO and ST, but not in WRB (See Annex 2)

A minor, but sensible, addition in WRB2022 is to limit the gravel content (<80%) and contain a minimum amount of clay (8% - Sandy Loam in theory can have no clay) that decision also assures a more reliable calculation of the CECclay. FAO74 (FAO-Unesco, 1974) also required a minimum clay content in the ferralic horizon (15%).

A major difficulty since the early days is how to deal with the overlap of an argic horizon in the ferralic horizon. FAO74 gave preference to the argic horizon. FAO88 (FAO/UNESCO/ISRIC 1988, 1990) introduced the silt/clay ratio (of <0.2) as a criterion to decide if a horizon was ferralic or not. WRB2014 allowed the presence an overlapping argic provided one of three conditions were met (water dispersible clay<10% or geric properties or >1.4%OC).

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[2] At the time Wim Sombroek favoring precedence for Nitisols and Hari Eswaran preferring Ferralsols first, had many hot debates over this.

Soil Taxonomy also gave priority to the argillic horizon and created the kandic horizon that catered for argillic horizons with a low CECclay. Most of the Nitisols of WRB fulfill the criteria of the kandic horizon.

WRB2022 goes further in the simplification of the required characteristics by: (a) eliminating the sum of exchangeable bases and exchangeable acidity as a criteria (present in all other taxonomies) and (b) allowing an argic horizon without conditions. The restrictions on the argic horizon are specified in the definition of the Ferralsols and are the same as in WRB2014 (water dispersible clay <10% or geric or >1.4% OC).

Principal Qualifiers of Ferralsols

The principal qualifiers are the main subdivisions of the Ferralsols that are used for mapping and reflect the major occurrences of the Reference Soil Group regionally and globally.

In WRB2022 the following principal qualifiers have been recognized:

Ferritic: indicator for the accumulation of iron sesquioxides. Defined as having >10% pf dithionite extractable iron in a layer more than 30cm thick starting within 100cm from the surface and not being part of a plinthic horizon. Ferritic is also used as a principal qualifier in the Nitisols..

Gibbsic: indicator for the accumulation of aluminium hydroxide (gibbsite). Defined as having a layer >30cm thick containing > 25% gibbsite in the clay fraction. Also used as principal qualifier in the Plinthosols, Acrisols and Lixisols.

Rhodic: dark red colour. Defined as having between 25 and 150 cm of the mineral soil surface a layer, ≥ 30 cm thick, that shows evidence of soil formation a Munsell colour hue redder than 5YR moist, a value of < 4 moist, and a value dry, not more than one unit higher than the moist value.

Xanthic: having a ferralic horizon with yellowish brown colour. Defined as having a ferralic horizon that has in a sub-horizon, ≥ 30 cm thick and starting ≤ 75 cm from the upper limit of the ferralic horizon, in ≥ 90% of its exposed area, a Munsell colour hue of 7.5YR or yellower, a value of ≥ 4 and a chroma of ≥ 5, all moist. Xanthic is also used as principal qualifier in Nitisols Acrisols and Lixisols.

Geric: indicator for extremely poor soils in terms of exchangeable bases with a very low effective CEC. Defined as having within 100 cm of the mineral soil surface a layer that has a sum of exchangeable bases (by 1 M NH4OAc, pH 7) plus exchangeable Al (by 1 M KCl, unbuffered) of < 6 cmolc kg^{-1} clay. Geric is also used as principal qualifier in Nitisols and Plinthosols.

Nitic: indicator for being rich in clay minerals and Fe oxides, having moderate to strong structure and shiny soil aggregate surfaces. Defined by the presence of a nitic horizon starting ≤ 100 cm from the mineral soil surface. Nitic is also used as principal qualifier in the Plinthosols.

Pretic: identifies having a dark horizon with at least moderate content of organic matter and phosphorus with high contents of exchangeable Ca and Mg and with the presence of black carbon (charcoal). It is found in areas that were intensively used in the past by Indian settlers. It is defined by the presence of a pretic horizon. It is also a principal qualifier in Anthrosols, Gleysols, Podzols, Planosols, Stagnosols, Nitisols, Phaeozems, Umbrisols, Retisols, Acrisols, Lixisols, Alisols, Luvisols and Cambisols.

Gleyic: indicative for soils saturated with flowing or upwards moving groundwater permanently or at least long enough that reducing conditions occur. Defined as having a layer, ≥ 25 cm thick and starting ≤ 75 cm from the mineral soil surface, that has gleyic properties throughout and reducing conditions in some parts of every sublayer. Gleyic is used as principal qualifier in many other Reference Soil Groups.

Stagnic: indicative for saturation with surface water, at least temporarily, long enough that reducing conditions occur.. Defined as having a layer, ≥ 25 cm thick and starting ≤ 75 cm from the mineral soil surface, that has stagnic properties and reducing conditions for some time during the year in some parts of the layer that has reductimorphic features. Stagnic occurs as principal qualifier in many other Reference Soil Groups.

Profondihumic: indicates a relatively high organic carbon content throughout the upper meter. Defined as: having to a depth of 100 cm from the mineral soil surface ≥ 1.4% soil organic carbon as a weighted average and ≥ 1% soil organic carbon throughout. Profondihumic is also used as a principal qualifier in Nitisols.

Mollic: identifies a thick, dark-coloured topsoil horizon with high base saturation, moderate to high content of organic matter and at least some soil structure. It is defined by the presence of a mollic horizon. It is used as principal qualifier in many Reference Soil Groups.

Umbric: identifies a thick, dark-coloured topsoil horizon with low base saturation, moderate to high content of organic matter and at least some soil structure. It is defined by the presence of an umbric horizon. It is used as principal qualifier in many Reference Soil Groups.

Acric: having an argic horizon with low effective CEC where exchangeable aluminium is higher than the sum of the exchangeable bases. It is defined as having an argic horizon starting ≤ 100 cm from the mineral soil surface with a CEC (by 1 M NH4OAc, pH 7) of < 24 cmolc kg-1 clay in some subhorizon within 150 cm of the mineral soil surface; and having exchangeable Al > exchangeable (Ca+Mg+K+Na) in half or more of the depth range between 50 and 100 cm. Acric is also used as principal qualifier in Podzols, Planosols, Stagnosols, Nitisols, Umbrisols, and Durisols..

Lixic: having an argic horizon with low effective CEC where exchangeable aluminium is smaller than the sum of the exchangeable bases. It is defined as having an argic horizon starting ≤ 100 cm from the mineral soil surface with a CEC (by 1 M NH4OAc, pH 7) of < 24 cmolc kg-1 clay in some subhorizon within 150 cm of the mineral soil surface; and having exchangeable Al < exchangeable (Ca+Mg+K+Na) in half or more of the depth range between 50 and 100 cm. Lixic is also used as principal qualifier in Planosols, Stagnosols, Nitisols, Phaeozems, Umbrisols and Durisols.

Skeletic: having a high percentage of coarse (> 2mm) fragments**.** It si defined as having ≥ 40% (by volume, related to the whole soil) coarse fragments averaged over a depth of 100 cm from the mineral soil surface or to a limiting layer, whichever is shallower. It is used as principal qualifier in many Reference Soil Groups.

Haplic: means that no other principal qualifier mentioned above applies.

During the preparation of the WRB Documentation Centre a review was done of fully documented soil profiles in monolith collections at ISRIC and KU Leuven (Nachtergaele et al, 2023, 2024). All of the above principal qualifiers could be identified for Ferralsols with the exception of **Nitic, Gleyic, Stagnic, Skeletic and Haplic**.

It is thought that Nitic, Gleyic and Skeletic Ferralsols are probably quite rare, but Stagnic and Haplic Ferralsols should occur more frequently. Assistance is sought from soil experts to provide fully documented sets for these principal qualifiers of Ferralsols.

There has been little change in the naming of the principal qualifiers of Ferralsols, although over the years there have been some changes in their definition, selection and use.

Examples illustrating all Principal qualifiers of Ferralsols present in the reference collection of ISRIC are given in Annex 1, while changes over the years in the classification of these soils are described in Annex 2.

Supplementary Qualifiers of Ferralsol

It is not the intention at this stage to document all supplementary qualifiers in the WRB Documentation Centre, therefore these qualifiers are not discussed in great detail. Examples are given below applicable for Ferralsols. There are 34 different supplementary qualifiers foreseen in Ferralsols in WRB2022.

Supplementary qualifiers allow further characterization of the soil unit at a local level specifically to:

- Specify the granulometry and its distribution with depth (Panto**Clayic**, Kato**Loamic**, **Siltic, Arenic**)

- Indicate the occurrence, the depth of the Soil Reference Group diagnostic (the upper limit of the Ferralic horizon can be specified as **Epic** (< 50cm), **Endi**c (50-100cm) or **Dorsic** (100-150cm);

- Indicate special chemical and physical characteristics of the soil: **Humic** (>1%OC weighted over 50 cm); **Dystric** (low nutrient supply) and **Eutric** (higher nutrient supply); **Posic** (zero or positive charge); **Cohesic** (restricted root penetration rich in kaolinite); **Isopteric** (layers remodelled by termites); **Activic** (having a layer above the Ferralic horizon with CECclay>24cmol(c)/kg; **Ochric** (no mollic or umbric horizon); **Densic** (layer with high bulk density not penetrable by roots); **Litholinic** (having a stone layer); **Oxyaquic** (having a layer saturated with water during a period of ≥ 20 consecutive days without being gleyic); **Saprolithic** (rock structure within 150cm)

- Indicate an intergrade characteristic to another Reference Soil Group that seldom occurs (in the case of Ferralsols this could be **Abruptic** (Planosols), **Folic** (Histosols), **Technic/Kalaic** (Technosols), **Andic** (Andosols), **Fluvic** (Fluvisols))

- Indicate human interventions that have influenced the local characteristics of the Ferralsol (e.g. **Transportic** (an added layer originating from outside the near vicinity), **Aric** (ploughed surface layer); **Pyric** (presence of charcoal), **Toxic** (toxic concentrations)).

- Flag the occurrence of specific horizons or layers not typical for the Reference Soil Group (eg for Ferralsols**: Ferric** (accumulation of Fe and Mn oxides), **Sombric** (organic rich subsurface horizon),

- Indicate local pedogenetic processes such as **Novic** (overlying buried material), **Raptic** (having a lithological discontinuity); **Solimovic** (having transported material)

Conclusions

A summary description of the genesis, characteristics, geographic distribution and land use of Ferralsols has been presented together with a detailed discussion of the classification of the Reference Soil Group with its qualifiers in WRB2022.

A full documentation of the RSG and its principal qualifiers was undertaken that included photographs, soil profile descriptions and associated laboratory analysis and was based on 67 monoliths of Ferralsols present in ISRIC's soil reference collection.

Most principal qualifiers of Ferralsols could be documented, but examples are missing for Gleyic, Nitic, Stagnic, Skeletic and Haplic principal qualifiers. Assistance is sought from soil experts to provide this missing documentation by accessing other source material they have access to.

Examples illustrating all principal qualifiers of Ferralsols present in soil musea are given in Annex 1, while changes over the years in the classification of these soils are described in Annex 2.

It is recommended to establish a WRB Documentation Centre that would collect similar descriptions for all reference soil groups and their principal qualifiers.

Acknowledgment

Mr. Johan Boon (KU Leuven) Jorge Mendes de Jesus and Ingrid Haas (ISRIC) are especially thanked for their advice and assistance in setting up the website.

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ANNEX 1: Fully Documented Ferralsols with Principal Qualifiers

WRB Documentation Centre

Brazil (BR005) **Umbric HyperGeric Rhodic Ferritic** FERRALSOL
Brazil (BR012) **Profundihumic Pretic Xanthic** FERRALSOL
Brazil (BR015) Profundihumic HyperGeric Xanthic **Gibbsic** FERRALSOL
Congo Democratic Republic (CD001) **Geric** Xanthic FERRALSOL
Kenya (KE006) **Mollic** Rhodic FERRALSOL
Mozambique (MZ001) **Lixic** Geric Rhodic FERRALSOL
Zambia (ZM009) **Acric** Geric Xanthic FERRALSOL

Ferralsols and Principal Qualifiers Hyperlinks

Principal Qualifiers	Monolith
Ferritic	BR005
Gibbsic	BR015
Rhodic	BR005;KE006; MZ001
Xanthic	BR012; BR015;CD001;ZM009
HyperGeric	BR005; BR015
Geric	CD001;MZ001;ZM009
Nitic	
(Posic)	BR015
Pretic	BR012
Gleyic	
Stagnic	
Profondihumic	BR012; BR015
Mollic	KE006
Umbric	BR005
Acric	ZM009
Lixic	MZ001
Haplic	

INVITATION: We welcome examples of fully documented **Haplic Ferralsol, Gleyic Stagnosols Stagnic Ferralsols, Nitic Ferralsols and Skeletic Ferralsols.** We shall gratefully acknowledge the provider/authors (Name, title, Institution).

Please submit to: ISRIC, c/o Stephan Mantel: https://www.isric.org/form/contact

and/or

KU Leuven: https://ees.kuleuven.be/en/soil-monoliths/contact

Supplementary Qualifiers

The following Supplementary qualifiers have been documented in Ferralsols

Supplementary Qualifiers
Arenic Loamic Clayic
Hyperdystric Dystric HyperEutric Eutric
Epic Endic Dorsic
Humic Ochric Manganiferric

INVITATION: Examples of fully documented Supplementary Qualifiers for Ferralsols not in the list above are warmly welcome . The providers/authors will be gratefully acknowledged (Name, title, Institution)

Monolith BR005: Brazil Lat/Lon -21.3500, -47.7333

Umbric HyperGeric Rhodic Ferritic FERRALSOL

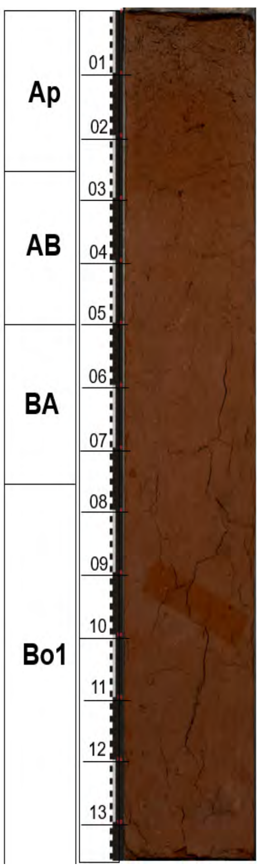
I. Soil Profile Description / Monolith Sampling: ISRIC, Kauffman JH & B Calderano Filho (1984)

I.1. Environmental information

Koppen Climate: Cwa
Parent material: fine-grained basic igneous rock
Physiography: Upper convex slope (2%) of low hill (760m asl)
Hydrology: Well drained soil, never flooded, no groundwater table
Land use: Sugar cane.

I.2 Soil Profile Description

A very deep, dark red, well drained and weakly structured soil derived from basic rock.



Ap 0-26 cm: dark red (2.5YR 3/6, dry) (2.5YR 3/3, moist), clay, moderate fine and medium subangular blocky and crumb, hard, very friable, sticky, slightly plastic, many medium continuous vesicular pores and interstitial pores, few large charcoal inclusions, gradual smooth boundary to,

AB 26-50 cm dark red (2.5YR 3/6, dry) (2.5YR 3/3.5, moist), clay, weak very fine subangular blocky to weak medium subangular blocky, slightly hard, very friable, sticky, slightly plastic, many medium continuous vesicular pores and interstitial pores, few large charcoal inclusions, diffuse smooth boundary to,

BA 50-75 cm dark red (2.5YR 3/6, dry) dark reddish brown (2.5YR 3/4, moist), clay, weak very fine subangular blocky to weak medium subangular blocky, slightly hard, very friable, sticky, slightly plastic, many medium continuous vesicular pores and interstitial pores, few large charcoal inclusions, diffuse smooth boundary to,

Bo1 75-215 cm dark red (2.5YR 3/6, dry) dark reddish brown (2.5YR 3/4, moist), clay, weakly coherent porous, massive, slightly hard, very friable, slightly sticky, slightly plastic, many very fine continuous vesicular pores and interstitial pores, very few medium soft argillaceous nodules and few large charcoal inclusions, few termite channels, diffuse smooth boundary to,

Bo2 215-250 cm dark red (2.5YR 3/6, dry) dark reddish brown (2.5YR 3/4, moist), clay, weakly coherent porous massive, slightly hard very friable, slightly sticky, slightly plastic, many very fine continuous vesicular pores and interstitial pores, few medium cylindrical soft argillaceous nodules and few large charcoal inclusions.

II. Analytical Results (ISRIC)

Horizon	Depth	pH (H2O)	OC	TEB	Exch Al	CECsoil	BS	EBS
	cm		%	cmol(c)/kg	cmol(c)/k	cmol(c)/kg	%	%
Ap	0 - 26	4.7	2.47	0.4	0.7	7.7	5	36
AB	26 - 50	4.9	1.15	0.1	0.0	3.6	3	100
BA	50 - 75	5.4	0.88	0.3	0.0	1.4	21	100
Bo1	75 - 215	5.6	0.80	0.1	0.0	1.6	6	100
Bo2	215 - 250	5.9	0.53	0.1	0.0	0.7	14	100

Horizon	Depth	Clay	Silt	Sand	TXT Class	WDC	CECclay	Fedith
	cm	% w/w	% w/w	% w/w		%	cmol(c)/kg	%
Ap	0 - 26	60.5	27.9	11.6	Ch	27.3	13	9.06
AB	26 - 50	64.4	26.2	9.5	Ch	0.0	6	10.30
BA	50 - 75	62.3	27.9	9.8	Ch	2.4	2	10.70
Bo1	75 - 215	48.5	42.7	8.9	C	24.0	3	9.94
Bo2	215 - 250	56.4	34.1	9.6	C	0.5	1	10..30

Mineralogy:Kaolinite, Hematite and Gibbsite all medium to strong.

III Soil Classification

III.1 Horizons and major soil characteristics.

0 – 26 cm : **Umbric horizon** (>20cm topsoil: OC>0.6%;structured; 2.5YR 3/3 moist, BS<50%)

26 – 250 cm: **Ferralic horizon** (CECclay<16 cmol(c)/kg; TXT class Clay, no plinthite, andic nor vitric properties)

Reference Soil Group: **Ferralsol** (Soils with a Ferraliic horizon within150 cm and no argic horizon present)

HyperGeric (TEB+ Exch Al)/kg clay <2.5 26-250cm); **Rhodic** colors (2.5 YR 3/4 over >30cm)**; Ferritic** (>10% Fedith 26-75 cm). Note **Gibbsitic** not retained (only used when Gibbsic mineralogy is Strong)

PantoClayic (Clay texture from surface to > 100cm); **Eutric** (Major part but not all layers between 20 and 100cm have TEB > Exch Al); **Humic (**weighted average OC over top 50 cm > 1%); **Epic** (Ferralic horizon starts in top 50cm).

III.2 Classification systems:

WRB 2022: Umbric HyperGeric Rhodic Ferritic Ferralsol (PantoClayic, Eutric, Epic, Humic)

Soil Taxonomy (2022): Rhodic Acrustox

FAO 1974: Humic Ferralsol

Brazilian classification: Latossolo Roxo acrico

References

https://rest-wsm.isric.org/monoliths/10per/png/BR-005-def.10per.png

https://isis.isric.org/monoliths/reference-soil-br005#block-system-main

Monolith BR012 Brazil Lat/Lon -2.6000, - 54.5900

Profundihumic Pretic Xanthic FERRALSOL

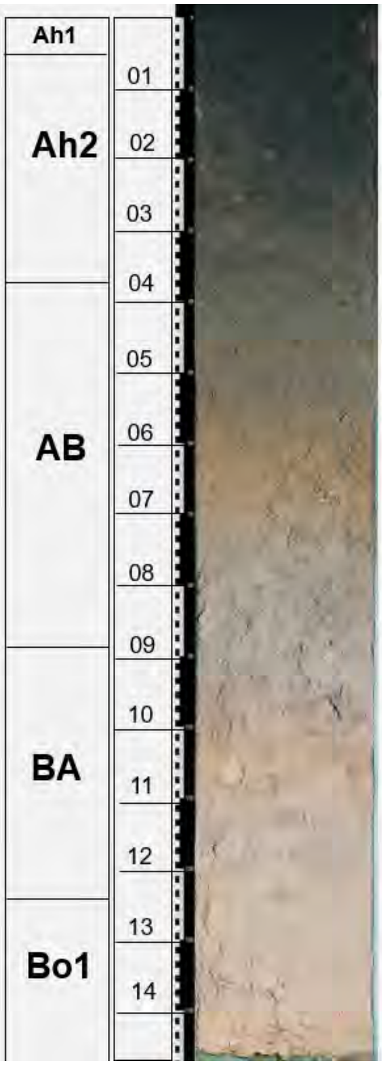
Soil Profile Description / Monolith Sampling: ISRIC, Kauffman JH, WG Sombroek & JS Martins (1984)

I.1. Environmental information

Koppen Climate: Am
Parent material: Clay lacustrine sediment
Physiography: Flat or almost flat (1% slope) lacustrine plain (60 m asl)
Hydrology: Never flooded, no groundwater table
Land use: Extensive rubber estate. Previously managed by Indigenous farmers..

I.2 Soil Profile Description

Black, very deep, well drained clay soil. The soil is strongly determined by past human influences shown by accumulation of organic matter and the many pot sherds in the Ah horizon. The soil has been occupied by Indian settlements during centuries, using household waste for fertilization.



Ah1 0 – 5 cm: black (7.5YR 2/1, moist), clay, moderate very coarse crumb and moderate very coarse subangular blocky structure, slightly hard (dry). friable, slightly sticky slightly plastic, many very fine fine pores, many pottery inclusions, clear smooth boundary to,

Ah2 5 – 38 cm: very dark gray (7.5YR 3/1, moist), clay, moderate very fine and fine crumb and moderate very fine and fine subangular blocky structure, slightly hard (dry), very friable, sticky, plastic, many very fine fine pores, many pottery inclusions, clear wavy boundary to,

AB 38 – 89 cm: dark brown (7.5YR 3/4, moist), clay, weak fine and medium subangular blocky structure, friable, sticky, plastic, many very fine fine pores, gradual smooth boundary to,

BA 89 – 124 cm: strong brown (7.5YR 5/6, moist), clay, weak fine and medium subangular blocky structure, very friable, sticky, plastic, many very fine fine pores, gradual smooth boundary to,

Bo1 124 – 170 cm : strong brown (7.5YR 5/6, moist), clay, weak fine and medium subangular blocky structure, very friable, sticky, plastic, many very fine fine pores, diffuse smooth boundary to,

Bo2 170 – 210 cm: strong brown (7.5YR 5/8, moist), clay, moderately coherent porous massive, diffuse smooth boundary to,

Bo3 210 – 270 cm: strong brown (7.5YR 5/8, moist), clay, moderately coherent porous massive, diffuse smooth boundary to,

Bo4 270 – 360 cm: yellowish red (5YR 5/8, moist), clay, moderately coherent porous massive, diffuse smooth boundary to,

Bo5 360 – 400 cm: yellowish red (5YR 5/8, moist), clay, moderately coherent porous massive,

Analytical Results (ISRIC / EMBRAPA)

Horizon	**Depth**	**pH (H2O)**	**OC**	**TEB**	**Exch Al**	**CECsoil**	**BS**	**EBS**
	cm		%	cmol(c)/kg	cmol(c)/k	cmol(c)/kg	%	%
Ah1	0 - 5	6.2	7.89	33.4	ND	41.5	80	100
Ah2	5 - 38	6.6	6.37	35.0	ND	39.8	88	100
AB	38 - 89	6.5	2.93	16.5	ND	18.6	89	100
BA	89 - 124	6.1	1.74	8.0	ND	10.5	76	100
Bo1	124 - 170	6.2	0.82	3.2	ND	6.3	51	100
Bo2	170 - 210	6.2	0.45	1.5	ND	4.0	38	100
Bo3	210 - 270	6.2	0.3	1.5	ND	2.8	54	100
Bo4	270 - 360	6.4	0.15	1.3	ND	1.9	68	100
Bo5	360 -400	6.3	0.12	1.1	ND	3.0	37	100
Horizon	**Depth**	**Clay**	**Silt**	**Sand**	**TXT Class**	**WDC**	**CECclay**	**Fedith**
	cm	% w/w	% w/w	% w/w		%	cmol(c)/kg	%
Ah1	0 - 5	55.6	27.4	17.0	C	26.7	75	2.10
Ah2	5 - 38	72.5	22.9	4.6	Ch	26.3	55	2.00
AB	38 - 89	72.3	22.9	4.8	Ch	44.2	26	2.10
BA	89 - 124	76.0	20.1	3.9	Ch	47.4	14	2.00
Bo1	124 - 170	76.4	20.5	3.1	Ch	50.8	8	1.90
Bo2	170 - 210	75.8	21.5	2.7	Ch	0.0	5	1.70
Bo3	210 - 270	79.2	20.7	2.1	Ch	0.0	4	1.70
Bo4	270 - 360	69.3	28.6	2.1	Ch	0.0	3	1.80
Bo5	360 -400	68.9	28.8	2.3	Ch	0.0	4	1.70
Mineralogy:Kaolinite strong. Goethite medium to strong								

III. Soil Classification

III.1 Horizons and major soil characteristics

0 – 38 cm **Pretic horizon** (Color value<=4 chroma <=3, OC%>0.6, thickness >20cm, Exch (Ca+Mg)>1cmol(c)/kg note black carbon not described, P not determined). History of the site.

124 – 400 cm **Ferralic horizon** (CECclay<16 cmol(c)/kg; TXT class Clay, no plinthite, andic nor vitric properties)

Reference Soil Group: **Ferralsols** Soils with a Ferralic horizon within 150 cm and having no argic horizon

Qualifiers:

Xanthic (a Munsell colour hue of 7.5YR, a value = 4 and a chroma =5, in a layer >30 cm thick in the upper Ferralic horizon within 100cm); **Profundihumic (**having to a depth of 100 cm from the mineral soil surface ≥ 1.4% soil organic carbon as a weighted average and ≥ 1% soil organic carbon throughout.).

PantoClayic (Clay texture class from surface to >100cm); **HyperEutric** (Exch Al * 4 < TEB) **Dorsic** (Ferralic horizon starts within between 100 and 150 cm).

III.2 Classification systems:

WRB 2022: Profundihumic Pretic Xanthic Ferralsol (PantoClayic, Dorsic, HyperEutric)

Soil Taxonomy (2022): Plaggen with Oxisols not foreseen.

FAO (1974): Xanthic Ferralsol

Local classification : Terra Preta dos Indios.

Brazilian classification: Latossolo Amarelo com A antropico.

References

https://isis.isric.org/monoliths/reference-soil-br015#block-system-main

https://rest-wsm.isric.org/monoliths/10per/png/BR-012-def.10per.png

Monolith BR015: Brazil Lat/Lon -15.6083, -47.7514

Profundihumic HyperGeric Xanthic Gibbsic Ferralsol

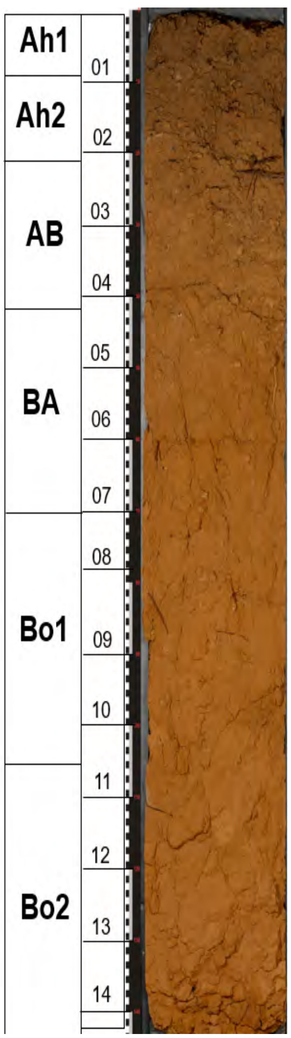
Soil Profile Description / Monolith Sampling: ISRIC, Kauffman JH, JS Madeira & AL Lemos (1986)

I.1. Environmental information

Koppen Climate: Aw
Parent material :highly weathered colluvium
Physiography: Flat or almost flat (1%) plateau (1170m asl)
Hydrology: groundwater table at 320cm .
Land use: nearby Soyabean high level farming.

I.2 Soil Profile Description

A very deep, well drained, yellowish brown clayey soil, derived from extremely weathered parent material.



Ah1 0 – 9 cm: dark brown (10YR 4/3, moist), clay, weak very fine and fine granular and weak very fine and fine crumb structure, soft, friable, slightly sticky, slightly plastic, many very fine pores, clear smooth boundary to,

Ah2 9 – 21 cm: dark yellowish brown (10YR 4/4, moist), clay, weak very fine and fine granular and weak very fine and fine crumb structure, slightly hard, friable, slightly sticky, slightly plastic, many very fine pores, clear smooth boundary to,

AB 21 – 42 cm dark yellowish brown (10YR 4/5, moist), clay, weak very fine and fine subangular blocky structure, slightly hard, friable, slightly sticky, slightly plastic, many very fine tubular random pores, gradual smooth boundary to,

BA 42 – 70 cm: yellowish brown (10YR 5/6.5, moist), clay, weakly coherent, porous massive structure, soft, friable, slightly sticky, slightly plastic, many very fine tubular random pores, gradual smooth boundary to,

Bo1 70-105 cm: strong brown (7.5YR 5/7, moist), clay, weakly coherent porous massive structure, soft, very friable, slightly sticky, slightly plastic, many very fine tubular random pores, diffuse smooth boundary to,

Bo2 105 – 150 cm strong brown (7.5YR 5/8, moist), clay, weakly coherent porous massive structure, soft, very friable, slightly sticky, slightly plastic, many very fine pores, clear smooth boundary to,

Bo3 150 – 160 cm: strong brown (7.5YR 5/6, moist), clay, weakly coherent porous massive structure, soft, very friable, slightly sticky, slightly plastic, many very fine tubular random pores,

Auger 160 – 250 cm: yellowish red (5YR 5/8, moist) clay, diffuse boundary to,

Auger 250 – 350 cm: yellowish red (5YR 5/6, moist), clay, common medium faint mottles (water table at 320 cm)

II. Analytical Results (ISRIC/EMBRAPA)

Horizon	**Depth**	**pH (H2O)**	**pH (KCl)**	**OC**	**TEB**	**Exch Al**	**CECsoil**	**BS**	**EBS**
	cm			%	cmol(c)/kg	cmol(c)/k	cmol(c)/kg	%	%
Ah1	0 - 9	4.5	4.2	3.33	1.4	0.7	6.7	21	66
Ah2	9 - 21	4.7	4.4	2.51	0.3	0.2	3.5	9	60
AB	21 - 42	5.5	4.7	1.87	0.2	0.1	3.4	6	66
BA	42 - 70	5.2	5.0	1.43	0.1	0.1	1.4	7	50
Bo1	70 - 105	5.2	5.6	1.03	0.3	0.1	0.7	43	75
Bo2	105 - 150	5.3	6.0	0.46	0.0	0.0	0.2	0	ND
Bo3	170 - 270	5.8	6.5	0.45	0.0	ND	0.2	0	ND

Horizon	**Depth**	**Clay**	**Silt %**	**Sand %**	**TXT Class**	**WDC**	**CECclay**	**Bulk Dens**	**Fedith**
	cm	% w/w	% w/w	% w/w		%	cmol(c)/kg	kg/dm3	%
Ah1	0 - 9	57.5	26.8	15.7	C	13.8	12.0	ND	2.9
Ah2	9 - 21	57.3	27.5	15.2	C	16.9	6.0	0.87	2.9
AB	21 - 42	65.7	20.6	13.7	Ch	25.9	5.0	1.04	3.2
BA	42 - 70	70.2	17.5	12.3	Ch	20.5	2.0	ND	3.1
Bo1	70 - 105	67.0	21.5	11.5	Ch	5.8	1.0	0.89	3.1
Bo2	105 - 150	59.0	29.0	12.0	C	15.5	0.0	0.83	3.1
Bo3	170 - 270	62.1	27.8	10.1	Ch	33.3	0.0	ND	3.20
Mineralogy:Gibbsite : strong / Kaolinite medium to strong.									

III. Soil Classification

III.1 Horizons and major soil characteristics

0 – 21 cm **Ochric horizon** (too light in color 10YR 4/3 and 4/4 moist)

21 – 270 cm **Ferralic horizon** (CECclay<16 cmol(c)/kg; TXT class Sandy Clay Loam, no plinthite, andic nor vitric properties)

Reference Soil Group: **Ferralsols** Soils with a Ferralic horizon within 150 cm and having no argic horizon (clay increase too small, no cutans in upper part of the ferralic horizon).

Qualifiers:

Gibbsic (having a layer with >25% gibbsite in the clay fraction (strong Gibbsite)); **Xanthic (**a Munsell colour hue of 10YR, a value > 4 and a chroma > 5, in a layer >30 cm thick in the upper Ferralic horizon within 100cm); .**HyperGeric** ((TEB+Exch Al)/Clay%) <1.5 cmol(c)/kg clay within 100cm); **Profundihumic (**having to a depth of 100 cm from the mineral soil surface ≥ 1.4% soil organic carbon as a weighted average and ≥ 1% soil organic carbon throughout.).

PantoClayic (Clayic texture from the surface to a depth of >100cm); **Epic** (Ferralic horizon starts within 50 cm), **Eutric** (dominant EBS between 20 and 100cm >50); **Posic** (having a layer, ≥ 30 cm thick and starting ≤ 100 cm from the mineral soil surface, that has a zero or positive charge (pHKCl - pHwater ≥ 0)).

III.2 Classification systems:

WRB 2022: Profundihumic HyperGeric Xanthic Gibbsic Ferralsol **(**Pantoclayic, Epic, Eutric, Posic)

Soil Taxonomy (2022): Anionic Acrustox

FAO 1974: Humic Ferralsol

Brazilian Classification: Latossolo Vermelho-Amarelo

References

https://rest-wsm.isric.org/monoliths/10per/png/BR-015-def.10per.png

https://isis.isric.org/monoliths/reference-soil-br015#block-system-main

Monolith CD001: Congo Democratic Republic Lat/Lon - 0.8667, 24.4667

Geric Xanthic FERRALSOL

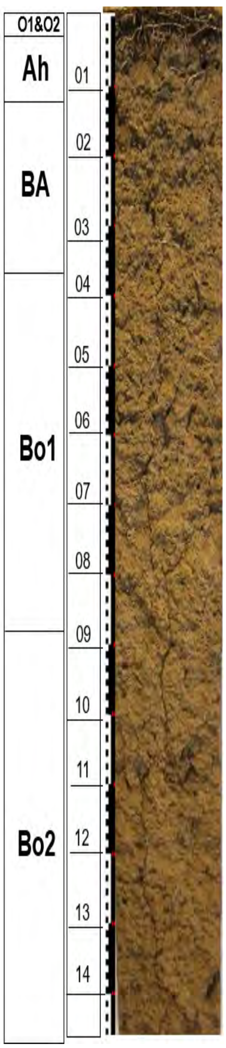
Soil Profile Description / Monolith Sampling: ISRIC, Van Kekum, A.J. (1985)

I.1. Environmental information

Koppen Climate: Af
Parent material :Unconsolidated sediment
Physiography: Upper convex slope (3%) on a plateau (440m asl)
Hydrology: Moderately well drained, no groundwater table
Land use: Evergreen Forest

I.2 Soil Profile Description

A deep, brownish moderately well drained loamy soil derived from unconsolidated sediments.



O1 0 - 1cm: Organic material, no leaves, non-calcareous, abrupt smooth boundary to:

O2 1 – 2 cm: Organic material, moderate amount of leaves, non-calcareous, abrupt smooth boundary to:

Ah 2 – 13 cm: dark brown (7.5YR 3/2, moist), loamy sand, moderate fine crumb and moderate very fine and fine subangular blocky structure, very friable, slightly sticky, slightly plastic, few (2-5%) faint mottles, no cutans, many very fine to coarse tubular pores and common coarse interstitial pores, no inclusions, no fragments, non-calcareous, clear wavy boundary to:

BA 13 – 34 cm: brown (7.5YR 4/4, moist), sandy loam, weak fine crumb and weak to moderate very fine and fine subangular blocky structure, very friable, sticky, plastic, common (5-15%) medium faint dark brown mottles (7.5YR 3/2) and very few (0-2%) medium faint red mottles (2.5YR 5/8), no cutans, many micro to medium tubular and many medium interstitial pores, few medium and coarse roots, charcoal inclusions, charcoal fragments, non-calcareous, gradual smooth boundary to,

Bo1 34 – 82 cm strong brown (7.5YR 4/5, moist)sandy loam, weak coarse subangular blocky parting to weak very fine and fine subangular blocky, very friable sticky plastic, common (5-15%) medium faint mottles (7.5YR 3/2) and few (0-2%) medium faint diffuse mottles (2.5YR 5/8),no cutans, many micro to medium tubular pores and many medium interstitial pores, few medium and coarse roots, charcoal inclusions, charcoal fragments, non-calcareous, diffuse smooth boundary to:

Bo2 82 – 152 cm: strong brown (7.5YR 4.5/6, moist), sandy clay loam, weak to moderate coarse subangular blocky parting to weak to moderate very fine and fine subangular blocky structure, very friable, sticky, plastic, few (2-5%) medium faint diffuse mottles (2.5YR 5/8) mottles, patchy clay cutans between sand grains, many micro medium tubular pores and many medium interstitial pores, no inclusions,no fragments,non-calcareous,

II. Analytical Results (ISRIC)

Horizon	Depth	pH (H2O)	OC	TEB	Exch Al	CECsoil	BS	EBS
	cm		%	cmol(c)/kg	cmol(c)/k	cmol(c)/kg	%	%
Ah	2 - 17	3.9	1.54	0.3	1.5	5.7	5	16
BA	17 -34	4.2	0.40	0.4	1.1	3.5	11	27
Bo1	40 - 70	4.4	0.27	ND	1.0	3.7	ND	ND
Bo21	82 - 110	4.3	0.22	0.2	1.1	3.5	6	15
Bo22	120 - 152	4.3	0.22	ND	1.1	3.3	ND	ND

Horizon	Depth	Clay	Silt	Sand	TXT Class	WDC	CECclay	Fedith
	cm	% w/w	% w/w	% w/w		%	cmol(c)/kg	%
Ah	2 - 17	19.2	2.4	78.4	SL	6.6	30	1.3
BA	17 -34	21.5	2.1	76.5	SCL	12.1	16	1.6
Bo1	40 - 70	25.0	2.1	72.9	SCL	17.3	15	1.7
Bo21	82 - 110	28.1	2.7	69.1	SCL	1.0	12	1.8
Bo22	120 - 152	27.8	2.1	70.2	SCL	0.5	12	1.7

Mineralogy:Kaolinite very strong.

III. Soil Classification

III.1 Horizons and major soil characteristics

0 – 17 cm **Ochric horizon** (<20cm thick not overlying rock)

17 – 152 cm **Ferralic horizon** (CECclay<16 cmol(c)/kg; TXT class Sandy Clay Loam, no plinthite, andic nor vitric properties)

Reference Soil Group: **Ferralsols** Soils with a Ferralic horizon within 150 cm and having no argic horizon (clay increase too small, no cutans in upper part of the ferralic horizon).

Qualifiers:

Xanthic (a Munsell colour hue of 7.5YR, a value = 4 and a chroma =5, in a layer >30 cm thick in the upper Ferralic horizon within 100cm); .**Geric** ((TEB+Exch Al)/Clay%) between 1.5 and 6 cmol(c)/kg clay within 100cm); **Not RelictiStagnic** (reductimorphic features (mottles) with redder hue and higher chroma are less than 10%)**PantoLoamic** (Loamic texture class from surface to >100cm); **Hyperdystric** (Exch Al > 4* TEB and/or very acid pH) Epic (Ferralic horizon starts within 50 cm); **Ochric** (weighted OC% ,1% in upper 50cm).

III.2 Classification systems:

WRB 2022: Geric Xanthic Ferralsol (PantoLoamic, HyperDystric, Epic, Ochric)

Soil Taxonomy (2022): Haplorthox

FAO 1974: Xanthic Ferralsol

Local classification: Sol ferrallitique fortement désaturé jaune

References

https://isis.isric.org/monoliths/reference-soil-cd001#block-system-main

https://rest-wsm.isric.org/monoliths/10per/png/CD-001-def.10per.png

Monolith KE006: Kenya -0.5522, 37.4517

Mollic Rhodic FERRALSOL

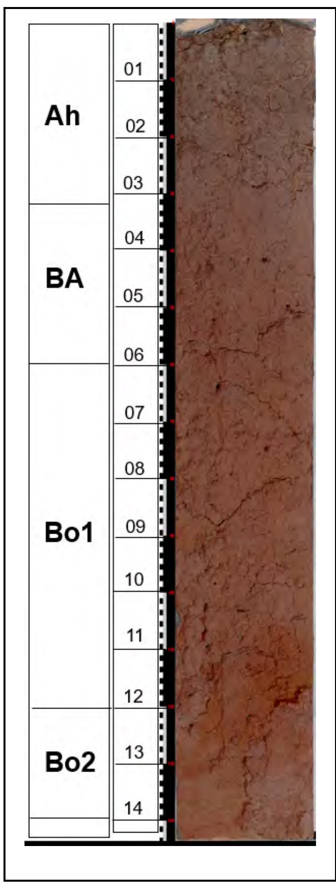
I. Soil Profile Description / Monolith Sampling : ISRIC, Van de Weg RF & JP Mbuvi (1972)

I.1. Environmental information

Koppen Climate: Cw
Parent material: residual gneiss precambian basement complex
Physiography:Pediplain flat (1% slope) 1260 m asl
Hydrology:well-drained soil, never flooded, no groundwater table observed
Land use: Grazed semi-natural grassland

I.2 Soil Profile Description

A very deep, dark red clay soil.



Ah 0 - 32 cm: dusky red (2.5YR 3/2, moist), clay, weak to moderate very fine and fine subangular blocky structure, friable, slightly sticky, slightly plastic, common very fine and fine pores, many fine and common medium roots, non- calcareous, clear smooth boundary to

BA 32 – 60 cm: dark red (2.5YR 3/4, moist), clay, moderate medium subangular blocky structure, very friable, slightly sticky, slightly plastic, many fine and very fine pores, few fine and medium roots, non-calcareous, gradual smooth boundary to,

Bo1 60 - 120 cm: dark red (2.5YR 3/6, moist), clay, moderate medium subangular blocky structure, friable, sticky, plastic, many very fine and medium pores, few fine roots, non-calcareous, gradual smooth boundary to,

Bo2 120 - 140 cm: dark red (2.5YR 3/6, moist), clay, weak fine subangular blocky structure, very friable slightly sticky slightly plastic, common very fine and fine pores, few fine roots, non-calcareous.

II. Analytical Results (ISRIC)

Horizon	Depth	pH (H2O)	OC	TEB	Exch Al	CECsoil	BS	EBS
	cm		%	cmol(c)/kg	cmol(c)/k	cmol(c)/kg	%	%
Ah1	0 - 16	5.6	2.59	9.1	0.1	15.9	57	99
Ah2	16 - 32	5,3	1.67	12.0	0.1	12.8	94	99
BA	32 - 60	5.3	1.04	5.0	0.1	8.5	59	98
Bo1	60 - 122	5.0	0.69	3.8	0.1	7.4	51	97
Bo2	122 - 140	5.1	0.54	3.8	0.0	7.4	51	100

Horizon	Depth	Clay	Silt	Sand	TXT Class	WDC	CECclay	Fedith
	cm	% w/w	% w/w	% w/w		%	cmol(c)/kg	%
Ah1	0 - 16	54.3	11.8	33.9	C	17.1	29	4.60
Ah2	16 - 32	60.6	9.2	30.2	Ch	20.0	21	4.89
BA	32 - 60	62.2	8.5	29.3	Ch	16.3	14	4.90
Bo1	60 - 122	65.5	8.9	25.6	Ch	3.0	12	5.30
Bo2	122 - 140	67.4	10.4	22.2	Ch	4.0	11	5.63

Mineralogy:Kaolinite strong. Gibbsite weak to medium

III Soil Classification

III.1 Horizons and major soil characteristics.

0 – 32 cm : **Mollic horizon** (>20cm topsoil: OC>0.6%;structured; 2.5YR 3/3 moist, BS>50%)

32 – 190 cm: **Ferralic horizon** (CECclay<16 cmol(c)/kg; TXT class Clay, no plinthite, andic nor vitric properties)

Reference Soil Group: **Ferralsol** (soils with a Ferraliic horizon within150 cm and no argic horizon present)

Rhodic colors (2.5 YR 3/4 over >30cm)**;**

PantoClayic (Clay texture from surface to > 100cm); **HyperEutric** (all layers between 20 and 100cm have TEB > 4 * Exch Al); **Humic (**weighted average OC over top 50 cm > 1%); **Epic** (Ferralic horizon starts in top 50cm).

III.2 Classification systems:

WRB 2022: Mollic Rhodic Ferralsol (PantoClayic, Epic, HyperEutric, Humic)

Soil Taxonomy (2022): Rhodic Eutrustox

FAO 1974: Rhodic Ferralsol

References

https://rest-wsm.isric.org/monoliths/10per/png/KE-006-def.10per.png

https://isis.isric.org/monoliths/reference-soil-ke006#block-system-main

Monolith MZ001: Mozambique Lat/Lon -14.5000, 34.3583

Lixic Geric Rhodic FERRALSOL

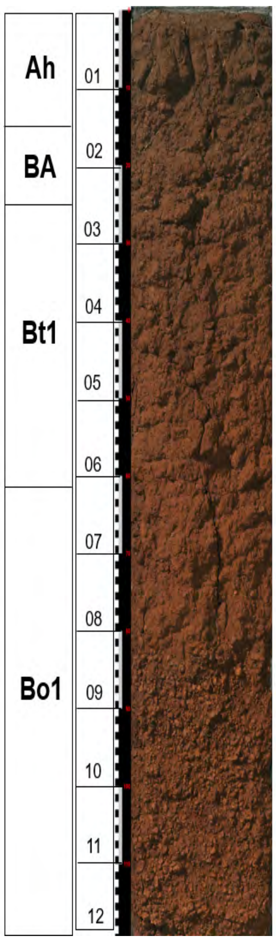
Soil Profile Description / Monolith Sampling: ISRIC, Kauffman, JH. 1982.

I.1. Environmental information

Koppen Climate: Cw
Parent material: Highly weathered gneiss, basement complex.
Physiography: Plateau, convex upper slope (3%) 480 m asl.
Hydrology: No groundwater table observed; never flooded. .
Land use: Low level arable farming (maize)

I.2 Soil Profile Description

A very deep, well drained dark red clay soil; weakly to moderately structured up to 62 cm, then porous massive.



Ah 0 – 15 cm: dark reddish brown (5YR 3/3, moist), sandy clay, moderate very fine and fine subangular blocky and moderate very fine and fine crumb structure, slightly hard (dry), very friable, slightly sticky, slightly plastic (moist), no cutans, many very fine and fine pores, many very fine roots, few termite channels, non-calcareous, gradual smooth boundary to,

BA 15 – 25 cm: dark reddish brown (2.5YR 3/4, moist), clay, moderate fine and very fine subangular blocky structure, hard (dry), friable, slightly sticky, slightly plastic (moist), no cutans, many very fine and fine pores, common fine and very fine roots, few termite channels, non-calcareous, gradual boundary to,

Bt1 25 – 62 cm: dark red (2.5YR 3/6, moist) clay, weak very fine and fine subangular blocky structure, hard (dry), friable, slightly sticky, slightly plastic (moist), broken moderately thick clay cutans, many very fine and fine pores, few very fine and fine roots, few termite channels, non-calcareous, gradual smooth boundary to,

Bo1 62 -170 cm : dark red (2.5YR 3.5/6, moist), clay, porous massive, slightly hard (dry), very friable, slightly sticky, slightly plastic, broken moderately thick clay cutans, many very fine and fine pores, few very fine and fine roots, very few medium spherical hard argilleceous nodules, few termite channels, non-calcareous,

Auger 170 – 400 cm red (2.5YR 4/6, moist), clay, very few medium spherical hard argillaceous nodules, non-calcareous, diffuse boundary to,

Auger 400 – 600 cm red (2.5YR 4/6, moist), clay, few medium spherical hard ferruginous concretions, non-calcareous,

II. Analytical Results (ISRIC)

Horizon	Depth	pH (H2O)	OC	TEB	Exch Al	CECsoil	BS	EBS
	cm		%	cmol(c)/kg	cmol(c)/k	cmol(c)/kg	%	%
Ah1	0 - 4	5.7	1.70	4.6	0.0	11.4	40	100
Ah2	4 - 15	5.5	1.26	3.1	0.0	8.4	37	100
Bt	30 - 45	5.1	0.30	1.5	0.0	8.3	18	100
Bo1	70 - 85	5.6	0.17	1.5	0.0	6.7	22	100
Bo2	130 - 145	5.5	0.16	3.0	0	7.4	41	100

Horizon	Depth	Clay	Silt	Sand	TXT Class	WDC	CECclay	Fedith
	cm	% w/w	% w/w	% w/w		%	cmol(c)/kg	%
Ah1	0 - 4	31.0	18.5	50.5	SCL	8.5	36.7	2.54
Ah2	4 - 15	45.9	9.4	44.7	C	8.9	18.3	2.81
Bt	30 - 45	53.1	12.5	34.4	C	0.5	15.6	3.12
Bo1	70 - 85	41.7	24.9	33.4	C	0.0	16.1	2.81
Bo2	130 - 145	50.8	19.1	30.1	C	0.0	14.6	3.06

Mineralogy:Kaolinite very strong. Gibbsite very weak to weak.

III. Soil Classification

III.1 Horizons and major soil characteristics

0 – 15 cm **Ochric horizon** (too thin for umbric)

15 – 85 cm **Argic horizon** (moderately thick broken cutans and a clay increase marginal for argic), partly coinciding/overlying

85 – 145 cm **Ferralic horizon** (CECclay<16 cmol(c)/kg; TXT class: Clay, no plinthite, andic nor vitric properties).

Reference Soil Group: **Ferralsols** Soils with a ferralic horizon within 150 cm and having an argic horizon that has less than 10% water dispersible clay.

Qualifiers:

Rhodic (showing evidence of soil formation and a color hue redder than 5YR moist, a value of < 4 moist, and a value dry, not more than one unit higher than the moist value).**Geric (**having within 100cm a layer with TEB+Exch Al < 6 cmol(c)/kg clay). **Lixic** (having within 100 cm an argic horizon with CECclay< 24 cmol(c)/kg clay and an EBS>50 % between 50 and 100 cm)

KatoClayic (Clayic texture from a depth between 1 and 50cm to a depth of >100cm); **Epic** (Ferralic horizon starts between 0 and 50 cm from the surface), **HyperEutric** (dominant EBS between 20 and 100cm >75%); **Ochric** (Weighted OC content < 1% in upper 50cm)

III.2 Classification systems:

WRB 2022: Lixic Geric Rhodic Ferralsol (KatoClayic, Epic, HyperEutric, Ochric)

Soil Taxonomy (2022): Rhodic Kandiustalf

FAO 1974: **Ferric Acrisol**

Local Classification: Katonde (Chinhandje/Chichewa)

References

https://isis.isric.org/monoliths/reference-soil-mz001#block-system-main

https://rest-wsm.isric.org/monoliths/10per/png/MZ-001-def.10per.png

Monolith ZM009: Zambia Lat/Lon -10.1667, 31.1667

Acric Geric Xanthic FERRALSOL

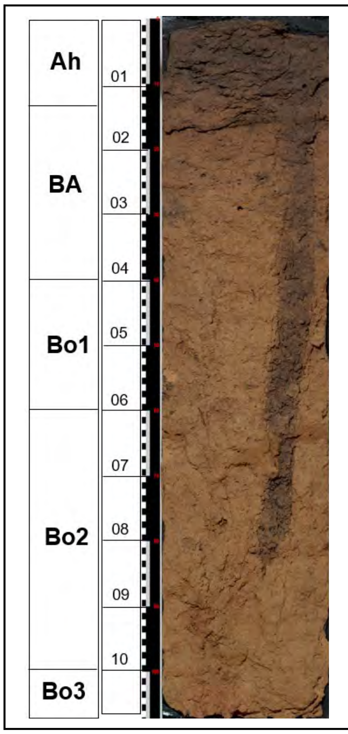
Soil Profile Description / Monolith Sampling: ISRIC, Van Baren JHV & LA van Sleen, 1977.

I.1. Environmental information

Koppen Climate: Aw
Parent material: Residual sandstone/shale. Precambian upper basement complex.
Physiography: Valley, flat to almost flat (2% slope) 1384 m asl.
Hydrology: No groundwater table observed; never flooded. .
Land use: Deciduous secondary forest

I.2 Soil Profile Description

A moderately deep, well drained, yellowish brown sandy clay loam soil, derived from highly weathered sandstone and shale.



Ah 0 – 14 cm: very dark greyish brown (10YR 3/2, moist), sandy loam, weak fine and medium subangular blocky structure, soft, many micro to fine pores, common fine and medium roots, non-calcareous, clear smooth boundary to,

AB 14 – 40 cm: dark yellowish brown (10YR 4/4, moist), sandy clay loam, weak fine subangular blocky structure, soft, many micro to medium pores, common fine roots, non-calcareous, gradual smooth boundary to,

Bo1 40 – 60 cm: yellowish brown (10YR 5/6, moist), sandy clay loam, weak fine subangular blocky, soft, many micro to medium pores, many fine roots, non-calcareous, diffuse smooth boundary to,

Bo2 60 -110 cm: yellowish brown (10YR 5/6, moist), sandy clay loam, porous massive, loose, many micro to medium pores, common fine roots, non-calcareous, diffuse smooth boundary to,

Bo3 110 – 130 cm: strong brown (7.5YR 5/6, moist), sandy clay loam, porous massive, loose, many micro to medium pores, few fine roots, non-calcareous,

II. Analytical Results (ISRIC)

Horizon	Depth	pH (H2O)	OC	TEB	Exch Al	CECsoil	BS	EBS
	cm		%	cmol(c)/kg	cmol(c)/k	cmol(c)/kg	%	%
Ah	0 - 20	5.7	0.71	0.9	0.4	6.8	13	69
Bt1	20 - 40	5.8	0.39	0.7	0.6	6.0	12	54
Bt2	40 - 60	5.9	0.19	0.6	0.2	4.9	12	75
Bo1	60 - 110	5.4	0.16	0.3	0.6	4.8	6	33
Horizon	**Depth**	**Clay**	**Silt**	**Sand**	**TXT Class**	**WDC**	**CECclay**	**Fedith**
	cm	% w/w	% w/w	% w/w		%	cmol(c)/kg	%
Ah	0 - 20	17.1	4.5	78.4	SL	2.0	40	0.30
Bt1	20 - 40	28.0	4.4	67.6	SCL	4.5	21	0.37
Bt2	40 - 60	29.0	7.2	63.8	SCL	0.5	17	0.33
Bo1	60 - 110	33.9	1.4	64.7	SCL	0.5	14	0.38
Mineralogy:Kaolinite very strong.								

III. Soil Classification

III.1 Horizons and major soil characteristics

0 – 14 cm **Ochric horizon** (too thin for umbric)
14 – 60 cm **Argic** horizon (sufficient clay increase)
60 – 110 cm **Ferralic horizon** (CECclay<16 cmol(c)/kg; TXT class: Sandy Clay loam, no plinthite, andic nor vitric properties).

Reference Soil Group: **Ferralsols** Soils with a Ferralic horizon within 150 cm and having an argic horizon that contains less than 10% water dispersible clay.

Qualifiers:

Acric (having an argic horizon within 100 cm with CECclay <24 and Exch Al> TEB in the dominant part between 50 and 100cm); **Geric** (having within 100 cm a layer with (Exch Al+TEB)/kg clay < 6 cmol(c); **Xanthic (**having a horizon, ≥ 30 cm thick with color hue of 7.5YR or yellower, a value of ≥ 4 and a chroma of ≥ 5, all moist within 75 cm of the top of the ferralic horizon)

PantoLoamic (Loamic texture from the surface to a depth of >100cm); **Endic** (Ferralic horizon starts between 50 and 100cm from the surface), **Dystric/Eutric** (Between 20 and 100 cm there is exactly half of the area that has Exch Al>TEB and TEB> Exch Al); **Ochric** (Weighted OC content <1% in upper 50cm)

III.2 Classification systems:

WRB 2022: Acric Geric Xanthic Ferralsol (Pantoloamic, Endic, Dystric/Eutric, Ochric)

Soil Taxonomy (2022): Xanthic Haplustox

FAO 1974: **Xanthic Ferralsol**

References

https://rest-wsm.isric.org/monoliths/10per/png/ZM-009-def.10per.png

https://isis.isric.org/monoliths/reference-soil-zm009#block-system-main

ANNEX II Changing classification criteria for Ferralsols

WRB Documentation Centre

Background

Classification criteria, including definitions of diagnostic horizons, properties and materials have changed over time both in the FAO Legend and WRB. Principal and supplementary qualifiers definitions and rankings also have undergone changes, new ones have been created and some deleted. One of the names of the Reference Group changed, as is the case for Podzoluvisols (FAO74, FAO88) renamed Albeluvisols (WRB1998, WRB2006) to be finally christened Retisols (WRB2014, WRB2022). Last but not least the, ranking of Reference groups in the key may change considerably as was for instance the case for Fluvisols that ranked fourth in the FAO74 key and are now in WRB2022 relegated to rank 28.

This annex has been created to document these changes and, where known, to explain why a certain change was implemented.

Changes that have affected the classification and characterization of Ferralsols

Change in Name and Place of Ferralsols in the key.

Ferralsols were originally known as Oxisols (Soil Survey Staff, 1960; FAO, 1974) as they are still named in Soil Taxonomy and characterized by an Oxic horizon. They were rebaptized Ferralsols in the Revised Legend of the Soil Map of the World (FAO/Unesco/ISRIC, 1988, 1990,1997) because of a change in criteria notably the oxic horizon was not allowed to overlap partly with an argic horizon in FAO74, while this restriction was removed in FAO88.

Ferralsols have not changed much their place in the key and changes resulted from this concerned their place in relation to Nitisols. (Table A1)

FAO74	FAO90	WRB1998	WRB2006	WRB2014	WRB2022
7. Andosols	**8. Andosols**	**9. Andosols**	**10. Andosols**	**10. Andosols**	**10. Andosols**
13. Ferralsols	**13. Ferralsols**	**11. Plinthosls**	**12 Plinthosols**	**12. Plinthisols**	**12. Flinthosols**
23 Nitisols	**23. Nitisols**	**12. Ferralsols**	**13. Nitisols**	**13. Nitisols**	**15. Nititosls**
		23. Nitisols	**14. Ferralsols**	**14. Ferralsols**	**16. Ferralsols**

Table A1. Place in the key of Andosols, Plinthosols, Nitisols and Ferralsols 1974 – 2022

In FAO74 and FAO90 Plinthisols were not recognized as a Reference Group. The drop of Nitisols and Ferralsols between the WRB2014 and WRB2022 version occurred because Planosols and Stagnosols that in previous editions were placed lower in the key did move up and were placed between Plinthosols and Nitisols, thereby grouping Reference Groups strongly affected by hydromorphic features

Changes in the criteria for the Oxic/Ferralic horizon

However, the criteria used to define the Ferralic horizon have changed over time as illustrated in Table A1

Taxonomic system	7th approx. 1960	FAO 1974	FAO 1988	WRB 2014	ST2014	WRB 2022
Characteristic name	Oxic	Oxic	Ferralic	Ferralic	Oxic	Ferralic
Texture Class		SL or finer	SL or finer	SL or finer	SL or finer	SL or finer
Thickness		>30cm	>30cm	>30 cm	>30cm	>30cm
CECclay	(<20)	<16	<16	<16	<16	<16
Weatherable minerals	<1%	Traces	<10%	<10%	<10%	<10%
Andic properties			No	No	No	No
Exch Bases+Exch Acidity		<10	<12	<12	<12	
Rock structure	Little or none	<5%	<5%		<5%	
Clay	>15%	>15%				>8%
Argillic/Natric		Not Allowed	Allowed	Allowed	NO clay increase	Allowed
Horizon Boundaries		Gradual/ Diffuse			Diffuse	
Silt/Clay ratio			<0.2			
Sesquioxides/1:1 Clay	<12					
Soil structure	Blocky or many pores					
Coarse fragments				<80%		<80%
Water dispersible clay	Low			<10% or		
Geric properties				YES or		
Organic carbon				>1.4%		

Table A1: Evolution of criteria and limits for the Ferralic horizon in major soil classification systems 1960 - 2022. (Red: only used in the specific classification system / **Green**: same in all systems / **Orange**: not retained in the specific system / **Yellow**: different rule over time of the characteristic)

Changes in Principal Qualifiers of Ferralsols

The principal qualifiers are the main subdivisions of the Ferralsols that are used for mapping and reflect the major occurrences of the Reference Soil Group regionally and globally.

Over the last 50 years 23 different qualifiers have been proposed for Ferralsols (Table A2). Only two of these have met with consistent approval: **HyperGeric** (named Acric in FAO74 and Soil Taxonomy) and **Haplic** (named Orthic in FAO74). Three others met with general consensus, except in one of the five classification systems: **Plinthic** (not retained in WRB2022 because the definition of the plinthic qualifier was made similar to the requirement of Plinthosols and Plinthosols precede Ferralsols in the key), **Xanthic and Rhodic** (both not retained in WRB2006). Six were only retained in a single version of the classification and clearly got no consensus: **Technic and Andic** (only retained in WRB2006), **Fractic** (only retained in WRB2014) and **Nitic, Stagnic and Gleyic** (only retained in WRB2022). For 12 qualifiers there was clear majority. A 3/2 majority exist for *Humic/Profondihumic, Gibbsic, Posic (Geric), Geric (Vetic), Mollic, Umbric, Acric and Lixic* , while a 3/2 majority exists for not using: *Ferritic, Folic, Pretic and Skeletic* as principal qualifiers.

Soil Unit / Principal Qualifier	FAO74	FAO88	WRB2006	WRB2014	WRB2022	# in Analysis
Plinthic	V	V	V	V	NO	NA
Profundihumic	V (Humic)	V (Humic)	NO	NO	V	3
Hypergeric	V (Acric)	V (Geric)	V (Geric)	V (Geric)	V	15
Rhodic	V	V	NO	V	V	21
Xanthic	V	V	NO	V	V	21
Haplic	V (Orthic)	V	V	V	V	0
Gibbsic	NO	NO	V	V	V	3
Posic	NO	V (Geric)	V (Geric)	V (Geric)	NO	5 (SQ)
Geric	NO	NO	V Vetic)	V (Vetic)	V	35
Mollic	NO	NO	V	V	V	3
Umbric	NO	NO	V	V	V	9
Folic	NO	NO	V	V	NO	NA
Technic	NO	NO	V	NO	NO	NA
Andic	NO	NO	V	NO	NO	NA
Acric	NO	NO	V	V	V	10
Lixic	NO	NO	V	V	V	13
Ferritic	NO	NO	NO	V	V	7
Pretic	NO	NO	NO	V	V	1
Skeletic	NO	NO	NO	V	V	0
Fractic	NO	NO	NO	V	NO	NA
Nitic	NO	NO	NO	NO	V	0
Gleyic	NO	NO	NO	NO	V	0
Stagnic	NO	NO	NO	NO	V	0

Table A2 Soil Units and Principal Qualifiers for Ferralsols in FAO Legends and WRB versions.

(LEGEND: Green: majority consensus to use the qualifier **/ Yellow**: majority consensus not to use the qualifier **/Orange:** unusual absence of the qualifier **/ Red:** unusual presence of the qualifier **/ White:** qualifier open for discussion**)**

However, the analysis shows that the use of qualifiers changes from one classification version to the next and that some were only retained once. Therefore, a call is made to submit examples of those principal qualifiers that are not documented in the ISRIC collection, in particular nitic, gleyic and stagnic that are thought to be very rare. The latter two would correspond with the Aquox of Soil Taxonomy. However, as Gleysols and Stagnosols precede Ferralsols in the key, one would expect that most of the Aquox will be classified as Ferallic Gleysols or Ferralic Stagnosols. It is questionable therefore that Ferralic is only foreseen as a supplementary qualifier in Gleysols and Stagnosols in WRB2022. In WRB2014 Ferralic Gleysols were foreseen. (see next section)

A pretic Ferralsol is illustrated in Annex 1 The presence of a horizon rich in black carbon that has persisted over centuries in a hot tropical climate, although mainly restricted the Amazon basin (Terra Preta de Indio), has pedological and cultural validity.

The Skeletic qualifier may cater for Ferralsols that have thick stone lines (Litholinic), but their extent is likely to be very limited (none were encountered in the Monolith analysis). Examples are sought as none were present in the ISRIC collection.

Note that the naming and the definition of the Geric qualifier have changed in different versions of the classification (changes in bold between 1974 and 2022) illustrated in Box 1. Therefore it would be good to use Hypergeric explicitly as a principal qualifier because the importance of a very low cation retention for the use of Ferralsols in agriculture and also because it corresponds with the original Geric concept used until 2014.

Although not very often, Umbric and with a lesser frequency Mollic topsoil horizons, occur in Ferralsols (Table 1). They can be maintained without difficulty as principal qualifiers.

The same is true for Acric and Lixic that cater for situations where Argic horizons with a low dispersible clay content (or high OC, or geric properties) overlap with the upper part of the ferralic horizon.

Gibbsic and Ferritic may occur in different tropical soils and are not unique for Ferralsols. Nevertheless they are reflecting the Fe- and Al- relative accumulation in these soils and could be maintained as principal qualifiers.

Haplic is the qualifier provided for situations when not a single principal qualifiers applies. However. in Ferralsols this is a rather rare occurrence because nearly 80 % of all soil monoliths are either Geric or Hypergeric and if not, other qualifiers apply (mainly Rhodic and Xanthic). Nevertheless the qualifier should be maintained to assure a comprehensive classification of all variants.

Acric *(FAO74) having a cation exchange capacity (from NH4C1) of 1.5 me or less per 100 g of clay in at least some part of the B horizon within 125 cm of the surface.*

Geric *(FAO90): having a cation exchange capacity (from NH4C1) of 1.5 me or less per 100 g of clay* ***or a delta pH KCl minus pH H2O of +.1 or more.***

Geric (WRB2006;WRB2014) having an ***ECEC*** *(sum of exchangeable bases plus* ***exchangeable acidity*** *in 1 M KCl) of less than 1.5 cmolc kg-1 clay1 ; or a delta pH (pHKCl minus pHwater) of +0.1 or more.*

*Geric (WRB2022) having within 100 cm of the mineral soil surface a layer that has a sum of exchangeable bases (by 1 M NH4OAc, pH 7****) plus exchangeable Al*** *(by 1 M KCl, unbuffered****) of < 6 cmolc kg-1 clay. (delta pH defined separately as posic)***

In WRB2022 the Geric concept of previous WRB versions was split up between Hypergeric and Posic, while the Vetic concept of WRB2006 and WRB2014 was renamed Geric: **Geric (WRB2006;2014) = Hypergeric (WRB2022) + Posic (WRB2022)**

Hypergeric (WRB2022) *: having within 100 cm of the mineral soil surface a layer that has a sum of exchangeable bases (by 1 M NH4OAc, pH 7) plus exchangeable Al (by 1 M KCl, unbuffered) of < 1.5 cmolc kg-1 clay (*

Posic (WRB2022) *a delta pH (pHKCl minus pHwater) of +0.1 or more.*

Vetic *(WRB2006;WRB2014) Having an ECEC (sum of exchangeable bases plus exchangeable acidity in 1 M KCl) of less than 6 cmolc kg-1 clay in some subsurface layer within 100 cm of the soil surface. (no longer used in WRB2022, renamed Geric)*

Box A1 The evolution of the Geric concept in FAO and WRB

Changes in Supplementary Qualifiers of Ferralsols

Supplementary qualifiers allow further characterization of the soil unit at a local level. Although "third level units" were recognized since FAO90, their use was only formalized in WRB2006 (named suffixes at the time, renamed supplementary qualifiers in WRB2014).

The list of supplementary qualifiers has grown in successive editions of WRB: 15 in WRB2006 to 25 in WRB2015 to 34 in WRB2022 (Table A3). Twelve of these remained unchanged between 2006 and 2022. Four were "promoted" to principal qualifiers between editions which was the case for Rhodic and Xanthic in WRB2015 and Gleyic and Stagnic in WRB2022. WRB2022 introduced twelve new supplementary qualifiers, many of which had not been defined before (activic, cohesic, isopteric, kalaic, litholinic, pyric, saprolithic).

One may question why Folic was downgraded to a supplementary qualifier, while Histic was not.

It is thought that stagnic and gleyic Ferralsols are quite rare and examples of their occurrence are sought. In case their extent is found to be quite limited it is suggested to move them back to supplementary qualifiers.

The newly defined supplementary qualifiers in WRB2022 will eventually require documentation, although this is at present beyond the aims of the documentation centre.

WRB2006	WRB2014	WRB2022
Arenic	Arenic	Arenic
Siltic	Siltic	Siltic
Clayic	Clayic	Clayic
	Loamic	Loamic
		Abruptic
		Activic
Alumic		
	Andic	Andic
	Aric	Aric
		Cohesic
Colluvic	Colluvic	Solimovic*
	Densic	Densic
		Dorsic
Dystric	Dystric	Dystric
		Endic
		Epic
Eutric	Eutric	Eutric
(Mangani)Ferric	Ferric	Ferric
	Fluvic	Fluvic
		Folic
	Gleyic	
Humic	Humic	Humic
		Isopteric
		Kalaic
		Litholinic
Novic	Novic	Novic
	Ochric	Ochric
Oxyaquic	Oxyaquic	Oxyaquic
	Posic	Posic
		Pyric
Rhodic		
Ruptic	Raptic	Raptic
		Saprolithic
Sombric	Sombric	Sombric
	Stagnic	
	Technic	Technic
	Toxic	Toxic
	Transportic	Transportic
	Vetic	
Xanthic		
15	25	34

Table A3: Evolution of supplementary qualifiers 2006 - 2022

(Legend Green: retained 2006-2022/Red promoted to Principal Qualifiers/ Blue newly introduced 2022).

Ferralic as a qualifier in other Reference Soil Groups.

Ferralic at soil unit level was originally (FAO74 until WRB1998) used as having ferralic properties, which meant a low CEC of the clay (< 24cmol(C)/kg) or an absolute low CEC of less than 4 cmol (c)/kg) in Arenosols and Cambisols. As this was confusing between horizons and properties, in WRB2014 it was decided to rename the ferralic properties as a sideralic qualifier.

Ferralic as a qualifier has been defined since 2014 as having a ferralic horizon within 150cm. The comparison with WRB2022 is illustrated in Table A4.

WRB 2014		WRB2022	
Principal Qualifier	**Supplementary Qualifier**	**Principal Qualifier**	**Supplementary Qualifier**
Gleysols	**Anthrosols**	**Anthrosols**	**Gleysols**
Nitisols	**Planosols**	**Nitisols**	**Planosols**
Acrisols	**Stagnosols**	**Acrisols**	**Stagnosols**
Lixisols	**Phaeozems**	**Lixisols**	**Phaeozems**
Cambisols	**Umbrisols**		**Umbrisols**

Table A4: The use of the ferralic qualifier in WRB2014 and WRB2022

(Legend: Red: deleted in WRB2022/Green Upgraded to Principal Qualifier and Orange downgraded to Supplementary qualifier in WRB2022).

There have been three changes between 2014 and 2022: one is the fact that ferralic in Gleysols is no longer a principal qualifier, but a supplementary one. The reverse occurred in Anthrosols where in 2022 Ferralic became a principal qualifier. The use of Ferralic in Cambisols in 2014 was probably an error and was corrected in WRB2022.

An elegant alternative might be to consider ferralic a PQ in Stagnosols and Gleysols and stagnic and gleyic as SQ in Ferralsols, but that will require documented examples of hydromorphic soils with a ferralic horizon not present at the moment in the ISRIC collection.