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UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION
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SMR.705 - 2

COLLEGE ON SOIL PHYSICS

(6 - 24 September 1993)

"FAO - UNESCO Soil Map of the World"

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These are preliminary lecture notes, intended only for distribution to participants.

FAO-Unesco Soil Map of the World

Revised Legend - 1989

Text used at ITC, 1991
by Hans van Baren

(first draft)

Some parts have been copied from the Lecture Notes on Soil Taxonomy, by Dik Creutzberg, as used at ITC 1990. It is the intention that both texts be ultimately joined into one publication.

Not for publication, not for reference

1. PRINCIPLES OF CLASSIFICATION

1.1 General concepts

The study of natural objects (e.g. plants, animals, atoms, soils, etc.) begins with observation and **classification** in order to reveal and understand their relationships. As such, classification is an essential part of scientific activity. It involves the ordering and grouping of the observed objects, in the mind, on the basis of one or more properties they have in common. The objects to be classified are called **individuals**.

An individual is "the smallest natural body that can be defined as a thing complete in itself" (Cline, 1949). It is the thing we classify. All the individuals of a natural phenomenon, collectively, are a **population** or a **universe**. Plants, animals, atoms, soils, etc. are populations, each consisting of many individuals which are classified.

A **class**, also called **taxon** (plural: taxa), is a group of individuals, similar in one or more selected properties and distinguished from individuals of all other classes of the population by differences in these properties. These properties, selected in accordance with the purpose of the classification, are termed **differentiating characteristics**, **differentiae** or **diagnostic properties**. They serve to differentiate among classes, i.e. to distinguish one class from all other classes.

When classifying the individuals of a large and widely varying population such as plants or soils, classification is necessary not only of individuals into classes, but also of classes into wider or higher classes, and of those into still higher classes. This is called a **multicategoric** or **hierarchical** system of classification. The individuals are grouped into classes of the lowest **category** at the lowest **level of classification.** These classes are subsequently grouped into classes of higher category, or higher level. The highest categories (at the highest levels of classification) have small numbers of classes, defined in broad general terms by means of a few differentiating characteristics. In the lower categories there are large numbers of classes of narrow range, defined in quite specific terms by a large number of differentiating characteristics.

There are several ways to define a class. One way is that of the class being regarded as a group of individuals in which the central nucleus is used to define the class. This nucleus is called the **central concept** or **modal individual** of the class. It is not a real class member but an idealized individual, which typifies the class. Some individuals of the class are very similar to the central concept so that no doubt can exist about their membership of the class. Other individuals of the class are less strongly resembling the central concept and show similarities with one or more other classes. They may be so much similar to individuals of other classes that doubt may arise whether they should be placed in the one or in the other class. This doubt is avoided if we separate the classes by **class boundaries** for the definition of the classes.

1.2 The purpose of classification

The purposes of classification are manifold. "The purpose of any classification is so to organize our knowledge, that the properties of the objects may be remembered and their relationships may be understood most easily for a specific objective" (Cline, 1949). When we classify the objects of a population, new relationships may become evident and predictions about the behaviour and best use of the objects are possible. Classification helps us to remember the significant properties of the objects and provides us with a "language" by means of which people can exchange knowledge, ideas and information.

1.3 Soil classification

Unlike many other natural phenomena, soils normally do not occur as clearly defined units. For the purpose of soil classification in **Soil Taxonomy** the concept of **pedon** has been introduced (Soil Survey Staff, 1975). The pedon is defined as the smallest volume that can be recognized as a soil individual. It is an artificial individual with artificial boundaries. A pedon has tree dimensions and its lower limit is the vague and somewhat arbitrary limit between soil and "not soil". The lateral dimensions are large enough to permit study of the nature of the horizons. Its area ranges from 1 to 10 square meters, depending on the variability in the horizons.

A soil body consisting of more than one contiguous (i.e. adjoining and being in close contact) pedons is termed a **polypedon**. The polypedon provides the link between the pedons and the soil mapping units.

In the **FAO-Unesco Soil Map of the World Legend** and **Revised Legend** (FAO, 1974 and 1989 respectively) the term pedon is not mentioned, but it is assumed that the name concept applies in both systems.

2. HISTORICAL BACKGROUND

2.1 Soil Taxonomy

Soil Taxonomy is the name of the system of soil classification currently used by the Soil Conservation Service of the United States Department of Agriculture (USDA). It was provisionally introduced in 1960 to replace the "Great Soil Group" system which had been the official classification since 1938. After its first publication, the new system has become widely known outside the U.S.A., very much so because of its novel approach, and also because a number of new concepts were introduced. It is the most detailed attempt so far to accommodate all soils of the world in one comprehensive classification system.

It was foreseen in 1960 that, once the new system was being used and tested in the field, also in countries outside the U.S.A., many shortcomings would become evident. As a consequence, many changes were made to correct inconsistencies and accommodate new findings before the complete system was published in 1975 under the title: "**Soil Taxonomy**".

Even then it was realized that the system represented only the state of knowledge of that time, and since 1975, a number of amendments were circulated, correcting and updating the system in agreement with new findings. An abridged version, presenting the current status of the system was first published in 1983 under the title: "**Keys to Soil Taxonomy**" was published in 1990.

2.2 Soil Map of the World Legend

From 1961 onwards, FAO and Unesco in a joint project with the International Society of Soil Science (ISSS) have developed a system of soil classification, which today is widely used throughout the world (FAO-Unesco, 1974). The original intent was to use this system as a legend for the Soil Map of the World 1 : 5 000 000 which was to serve as an international reference system, but it was successfully adopted by many soil scientists, especially for surveys on a larger scale.[1]

The Legend was recently revised and enlarged, to be used for making national soil maps on a more detailed scale (FAO-Unesco, 1988).

Many of the basic concepts and differentiating criteria of Soil Taxonomy have been adopted by the FAO-Unesco system, some of these in a slightly expanded or simplified form. On the highest level, however, the soils are classed in a more traditional way, using both established and newly devised names.

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[1] Since the classification systems in use show profound divergencies, resulting from differences in approach to classification as such, a common denominator between different soil classification systems was established as far as possible.

3. THE CATEGORIES AND THEIR CLASSES

3.1 The multicategoric system

Soil Taxonomy is a multicategoric system, with one or more diagnostic properties at each categoric level dividing soils into mutually exclusive classes. The system contains six categories. The highest category, **Order**, has eleven classes (orders). At the next lower categoric level, each order has been subdivided into **Suborders**; there are 53 suborders. The lower categories are **Great group**, **Subgroup**, **Family**, and **Series**.

> A multicategoric or multiple category classification system is a hierarchical (i.e. arranged in order of degree of importance) system, designed to classify a large number of individuals, as for instance soils.
> Collectively, the large number of soils occurring in the world is far beyond our powers of comprehension and cannot be remembered. But we can sort the soils, and make classes by grouping together soils which are similar. More precisely: each of the classes contains soils which have one or more important characteristics in common. Such classes (soil series) are more easy to remember because they are characterized by the properties they have in common. They can be used for transfer of knowledge, e.g. by making detailed soil maps.
> But when the individuals are grouped into series only, the number of classes is too large to reveal and understand general relationships among the individuals and classes on regional or world scale. In order to better organize our knowledge of soils, the series are grouped into classes of a higher category (family), and these again in classes of a still higher categories, viz. subgroups, great groups, suborders and orders. A category, as the term is used here, is a set of classes at the same level of classification.

The **FAO-Unesco Soil Map of the World** system is also a multicategoric system, in which only three categories are recognized. The highest two levels have been fully developed and are included in the text (FAO, 1968); the third or lowest categoric level has to be developed further. The highest level, the **Major Soil Grouping**, has 28 classes; they are subdivided at the second level into 153 **Soil Units**. The third or lowest category is formed by the **Soil Subunit.**

The Major Soil Groupings can approximately be compared with (grouped) Suborders of Soil Taxonomy.

4. DIAGNOSTIC HORIZONS AND PROPERTIES

4.1 Selection of differentiating criteria

In both classification systems under discussion, classes at all levels of classification are defined and identified by one or more differentiating criteria. The criteria regarded to be most useful for differentiating classes are those features of soil which are the result of soil forming processes, in the first place considering the pedogenetic horizons. They may also include properties of the soil which affect or control soil processes and soil behaviour, such as soil temperature conditions and the length of the period during which the soil is saturated with water, as applied in Soil Taxonomy.

It must be appreciated, however, that soil scientists have widely differing opinions about the genesis of soil characteristics and their significance. Also, opinions may change as new findings about the pedogenetic origin of such characteristics become available. As a result, misinterpretation of the differentiating criteria may occur if these are merely based on pedogenetic concepts. Consequently, the classification of a particular soil may be influenced by the experience of the individual soil scientist, as well as by new conceptual developments. Yet many persons with diverse background and training are expected to use the classification accurately to transfer experience with the behaviour of soils under a variety of uses.

4.1.1 Morphometric criteria

In order to avoid misinterpretation it is necessary to define the criteria to be used for classification as accurately as possible. Emphasis is placed on those characteristics of the soil **which can be observed and measured,** rather than on the presumed pedogenetic origin of the soil. The classes are defined strictly in terms of **measurable** soil properties. Soil Taxonomy and the FAO-Unesco system are both **morphometric** systems.

Preferably, morphological characteristics which can be observed and measured in the field are used. However, in many cases it appears to be impossible, by field observation only, to separate certain soils even if they have distinctly different properties. In other words, field morphological properties are inadequate for accurate definition of many classes. In such cases, additional chemical or physical properties, determined in the laboratory, are used to define the class.

4.1.2 Operational definitions

In earlier systems of soil classification, definition of classes often was carried out using poorly defined criteria. Some of the criteria were based on unspecified physical and chemical analytical methods. As a result the data were not comparable and could not be used for an exact definition of criteria.

In Soil Taxonomy and in the FAO-Unesco system, the classes are based upon criteria derived from standardized laboratory methods so that the definitions have the most precise meaning possible. The definitions are said to be **operational**, i.e., the operations (= methods) that are used to define the criteria are specified.

> For example: soil colours must be stated in terms of the Munsell Soil Color Chart; organic carbon content, cation exchange capacity, and base saturation must be determined following specified laboratory methods. Take for instance the soils classified as Mollisols/Chernozems. The soils of this order are characterized by having a thick dark-coloured surface horizon with a high base saturation. According to the definition, the thickness of this horizon must be 18 or more (or 10, or 25 cm, under specified conditions); the colours must have Munsell values of 3 or darker when moist and 5 or darker when dry, and a chroma of 3 or less when moist; the organic carbon content must be at least 0.6 percent following the analytical method of Walkley-Black, and the base saturation determined by the NH_4Ac method must be 50 percent or more.

4.1.3 Soil genesis versus soil morphometry

In spite of the strict rule to use only measurable and quantitative properties, the guiding principle to classify soils according to genetic concepts, is retained. Following this principle, soil characteristics were selected for use as differentiating criteria that are thought to have resulted from important pedogenetic processes such as accumulation of organic matter, clay illuviation, or podzolization. For each of these pedogenetic characteristics the normal range of occurrence was established. Now accurately defined and quantified in terms of their range of morphological, physical, and chemical properties, these characteristics are used as differentiating criteria for classes within the classification system.

It should be clear that the underlying concept of the differentiating criteria used is pedogenetic. The definitions of the criteria, however, are given in morphological or other quantitative terms so that they are not affected by changing hypotheses about soil genesis.

As a consequence, soil characteristics which meet the requirements of these morphometric definitions commonly are the result of the presumed genetic process. But this is not always the case because different kinds of processes may produce similar soil characteristics, meeting the same differentiating criterion.

> For example: the dark-coloured, humus and base-rich surface horizon which is characteristic for many soils of the sub-humid grasslands, is defined for use as differentiating characteristic to classify soils occurring in the steppes of the Americas, Europe and Asia. Under special circumstances, however, a similar surface horizon may develop in a wet environment. In spite of its hydromorphic character, this soil, at high categoric level, is placed in the same class as the sub-humid soils.

On the other hand, a soil may show a characteristic which is the result of a genetic process that lies at the base of a differentiating criterion. However, it may happen that this characteristic does not fully meet the definition of the differentiating criterion, e.g. because it is not strongly enough developed.

For example, some soils occurring in the steppe not essentially differing from surrounding soils, may have developed surface horizons with dark colours, which, however, are not dark enough to meet the requirements of the definition of the above mentioned differentiating characteristic. Even though these soils do not differ appreciably from the surrounding soils, they are placed in a different class.

4.2 Diagnostic criteria

The characteristics which have been selected and accurately defined to serve as differentiating criteria are described as **diagnostic**. Some of these are specified soil horizons: these are the **diagnostic horizons** (4.3). Other selected features are called **diagnostic properties** (4.4).

As **phases** are considered features of the land which are not necessarily related to soil formation (4.5).

4.2.1 Diagnostic horizons

A distinction is made between **diagnostic surface horizons**, and **diagnostic subsurface horizons**.

Diagnostic surface horizons, termed epipedons in Soil Taxonomy, are formed at the surface through soil forming processes. Normally, they can be recognized in the field because they are darker in colour than the underlying horizon as a result of the accumulation of organic matter. In this respect they resemble the traditional A horizons (Ah or A1 , Ao or O horizons) but their definition is based on a different concept. If an eluvial horizon, traditionally called a E or A2 horizon, is immediately at the surface, it is also considered to be an epipedon. As a minimum development, an epipedon is recognized if the original parent material at the surface has been destroyed through weathering or soil forming processes.

These horizons may be ploughed. If the original surface horizon, before cultivation, was shallower than the depth of ploughing, the epipedon extends to the ploughing depth. If the original surface horizon is deeper than the depth of ploughing, the lower boundary of the epipedon is placed where the properties of the surface horizon no longer meet the definition of the epipedon.

The properties of a surface horizon may change when the soil is brought under cultivation. To avoid changes in classification of the soil as a result of ploughing, the properties of the epipedon, except for structure, must be determined after the surface soil to a depth of 18 cm has been mixed.

The surface layer of a recent alluvial or eolian deposit, if it is still showing fine stratification, is not considered to be an epipedon. Likewise, an Ap horizon which is directly underlain by stratified material is not regarded as a diagnostic surface horizon.

Diagnostic subsurface horizons normally form at some depth below the surface as a result of soil forming processes. They differ in morphology and in physical and chemical properties from the underlying parent material. The differences may be the result of illuvial accumulation, or loss, of certain constituents. Or they may be evident merely from an alteration of the original material to form silicate clay and sesquioxides, resulting in the formation of soil structure. In this respect the diagnostic subsurface horizons resemble the traditional B horizons, but their definition is based on a different concept. Some diagnostic subsurface horizons may also occur in the lower part of the epipedon or in the C horizon. If the surface horizons are removed, as by erosion, a diagnostic subsurface horizon may be exposed at the surface.

4.2.2 Diagnostic horizons versus A, B, and C horizons

Most diagnostic horizons can be designated as A, or B, or C horizon in the field, but it should be emphasised that these designations are not the same as diagnostic horizons. A diagnostic surface horizon may extend into an underlying diagnostic subsurface horizon which in the field is designated as a B horizon. A diagnostic subsurface horizon may occur in the surface horizon or in another diagnostic subsurface horizon, or in the C horizon. The diagnostic horizons are said to be **not mutually exclusive**.

4.3 The diagnostic horizons in the FAO-Unesco Legend[1]

In all, 15 diagnostic horizons have been recognized, five of them occur at the soil surface. The definitions and nomenclature of these horizons are drawn from those adopted in Soil Taxonomy. The definitions of these horizons have been summarized and sometimes simplified in accordance with the requirements of the FAO-Unesco Legend. The salic, the sombric and the agric horizons of Soil Taxonomy have not been used as diagnostic horizons. The duripan, fragipan and the placic horizon are used as phases. Reference is made to Soil Taxonomy for additional information on the concepts underlying the definitions of the diagnostic horizons and for detailed descriptions of their characteristics. Where there was compatibility between horizon designations and diagnostic horizons, the ABC nomenclature has been combined with the diagnostic qualification.

The cation exchange capacity (CEC), used as a criterion in the definition of diagnostic horizons or properties, is essentially meant to reflect the nature of the mineral component of the exchange complex. However, the CEC determined on the total fine earth fraction, is also influenced by the amount and kind of organic matter present. Where low activity clay is a diagnostic property, it may be desirable to deduct CEC linked to organic matter, preferably by a graphical method for individual profiles. The application of this method requires that

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[1] In Soil Taxonomy, seven epipedons and 18 diagnostic subsurface horizons are recognized. For a full description see Keys to Soil Taxonomy (1990)

the clay mineralogy is homogeneous throughout the soil profile, at least to a depth of 125 cm.

4.3.1 Diagnostic surface horizons

The **histic H-horizon** is an H horizon (horizon with high organic matter content) which is more that 20 cm but less than 40 cm thick. It can be more that 40 cm but less than 60 cm thick if it consists of 75 percent or more, by volume, of sphagnum fibres or has a bulk density when moist of less than 0.1 Mgm^{-3}.

The **mollic A-horizon** is a thick, dark coloured surface horizon which has at least 0.6 percent organic carbon (1 percent organic matter)throughout its thickness, and a base saturation of 50 percent or more. Soil structure normally is well developed.

The **umbric A-horizon** is comparable to the mollic A-horizon in its requirements concerning colour, organic carbon and phosphorus content, consistency, structure and thickness. The umbric A-horizon, however, has a base saturation of less than 50 percent.

The **ochric A-horizon** is an A-horizon that is too light in colour, has too high a chroma, too little organic carbon, or is too thin to be mollic or umbric, or is both hard or very hard and massive when dry. Finely stratified materials, e.g. surface layers of fresh alluvial deposits, do not qualify as an ochric A-horizon and massive when dry.

The **fimic A-horizon** is a man-made surface layer 50 cm or more thick which has been produced by long continued manuring with earthy admixtures. The fimic-A horizon commonly contains artifacts such as bits of brick and pottery throughout its depth. If the fimic A-horizon meets the requirements of the mollic or umbric A-horizon, it is distinguished from it by a P_2O_5 content which is higher than 250 mg/kg soil.

4.3.2 Diagnostic subsurface horizons

The **argic B-horizon** is a subsurface horizon which has a distinctly higher clay content than the overlying horizon. The textural differentiation may be due to an illuvial accumulation of clay or to destruction of clay in the surface horizon, or to selective surface erosion of clay, or to biological activity, or to a combination of two or more of these different processes. Sedimentation of surface materials which are coarser than the subsurface horizon may enhance may enhance a pedogenetic textural differentiation. However, a mere lithological discontinuity, such as may occur in alluvial deposits, does not qualify as an argic B-horizon. If an argic B-horizon is formed by clay illuviation, clay skins may occur on ped surfaces, in fissures, in pores and in channels.

The definition of the argic B-horizon recognizes distinct textural differentiation as a diagnostic feature, even if clay skins cannot be identified. On the other hand, an accumulation layer marked by a low silt-clay ratio, as may occur in Ferralsols, is excluded from the argic B-horizon.

The argillic horizon and kandic horizon, as distinguished in Soil Taxonomy, are collectively called argic B-horizon in the FAO-Unesco Legend.

The **natric B-horizon** has most of the properties of the argic B-horizon. In addition it has a columnar or prismatic structure in some part of the B horizon, or a blocky structure with tongues of an eluvial horizon with uncoated sand or silt grains. Furthermore, it has an exchangeable sodium saturation of more than 15 percent within the upper 40 cm of the horizon.

The **spodic B-horizon** is a subsurface horizon of illuvial accumulation of organic matter and aluminium compounds, with or without iron compounds. The accumulation is the result of the podzolization process. Spodic horizons are often overlain by a bleached (mostly ash-coloured) horizon--the albic E horizon.

The **cambic B-horizon** is an altered horizon lacking the properties that meet the requirements of an argic, natric or spodic B-horizon; lacking the dark colours, organic matter content and structure of the histic H-horizon, or the mollic and umbric A-horizons.

The alteration is moderate, i.e. weathering and pedogenetic processes have transformed the parent material into soil material, but the horizon does neither show extreme weathering appreciable mineral accumulation, nor accumulation of organic matter and sesquioxides.

The **ferralic B-horizon** consists of products of prolonged and intensive weathering, such as kaolinite and various oxides of aluminium and iron. Most, if not all of the original minerals of the parent material are obliterated, except quartz which remains largely unaffected. As a result of the dominance of kaolinitic clays and oxides, the cation exchange change is low and varies with the pH, which affects the behaviour of the soil in various respects, such as phosphate fixation and response to liming.

Like the cambic B-horizon, the ferralic B-horizon consists of altered materials, derived from the parent material without showing any appreciable mineral accumulation such as illuvial clay; but it differs in degree of weathering. The ferralic B-horizon contains only traces of the original parent material, whereas the cambic B-horizon has weatherable minerals.

The **albic E-horizon** is a horizon from which clay and free iron oxides have been removed, or in which the oxides have been segregated to the extent that the colour of the horizon is determined by the colour of the primary sand and silt particles rather than by coatings on these particles.

The **calcic horizon** is a horizon of accumulation of calcium carbonates and/or magnesium carbonate. The carbonate must be of pedogenetic origin. Carbonate accumulation mostly occurs in the B or C horizon, but it may also occur in the A horizon. The calcic horizon may overlap a variety of diagnostic horizons such as the argic B-horizon, the natric B-horizon, the cambic B-horizon, or the mollic A-horizon.

The **petrocalcic horizon** is a continuous cemented or indurated calcic horizon, cemented by calcium carbonate and in places by calcium and some magnesium carbonate. Accessory silica may be present. The petrocalcic horizon is continuously cemented to the extent that dry fragments do not slake in water, and roots cannot enter. It is massive or platy, extremely hard when dry so that it cannot be penetrated by spade or auger, and very firm to extremely firm when moist.

The **gypsic horizon** is a horizon of secondary calcium sulfate enrichment. Gypsum may accumulate uniformly throughout the matrix or as nests of crystals; in gravelly material gypsum may accumulate as pendants below coarse fragments.

The **petrogypsic horizon** is a gypsic horizon that is so cemented with gypsum that dry fragments do not slake in water and roots cannot enter.

A sulfuric horizon is composed of either mineral or organic materials which have both a pH <3.5 (1:1 in water) and jarosite mottles. Jarosite is a potassium iron sulphate [$K_2Fe_6(OH)_{12}(SO_4)_4$] which occurs in the soil as bright yellow mottles. It is formed as a result of drainage and oxidation of sulphide-rich materials ("sulfidic materials").

4.4 Diagnostic properties

'Diagnostic properties' are features of horizons or of soil materials which, when used for soil classification, are quantitatively defined.

The **'abrupt textural change'** refers to a large clay increase between two layers, which takes place over a distance of less than 5 cm.

'Andic properties' refer to soil materials derived from volcanic ash. This material has a high content of extractable Al and Fe, a very low bulk density, and a high phosphate retention.

'Calcareous' applies to soil materials which show strong effervescence with 10 percent HCl in most of the fine earth.

'Continuous hard rock' applies to underlying material which is sufficiently coherent and hard when moist to make hand digging with a spade impracticable. The material is continuous except for a few cracks produced in place. Continuous hard rock does not include subsurface horizons such as a petrocalcic or a petrogypsic horizon, or a duripan or a petroferric layer.

The adjective **'dystric'** refers to a base saturation percentage of less that 50 percent.

The adjective **'eutric'** refers to a base saturation percentage of 50 percent or more.

'Ferralic properties' are used in connection with Cambisols and Arenosols which have a cation exchange capacity of less than 24 cmol(+)/kg clay or less than 4 cmol(+)/kg soil in at least some subhorizon of the cambic B-horizon or the horizon immediately underlying the A-horizon.

'Ferric properties' are used in connection with Luvisols, Alisols, Lixisols and Acrisols showing many coarse reddish mottles or discrete nodules up to 2 cm in diameter, the exteriors of the nodules being enriched and weakly cemented or indurated with iron and having redder hues or stronger chromas that the interiors.

'Fluvic properties' refer to fluviatile, marine and lacustrine sediments which unless empoldered, receive fresh materials at regular intervals. They usually have an organic carbon content that decreases irregularly with depth or that remains high with depth, or that show an appreciable amount of stratification.

'Geric properties' refer to soil materials which are low in extractable bases (Ca^{++}, Mg^{++}, K^{+}, Na^{+}), or have a delta pH (pH KCl minus pH H_2O) of 0.1 or more.

'Gleyic properties' refer to soil materials which are saturated with water at some period of the year or throughout the year in most years, and which show evidence of reduction processes or of reduction and segregation of iron. **Gleyic** properties relate to saturation by ground water; **stagnic** properties relate to saturation by surface water.

Note that in soils in which the content of iron oxides is very low, or in which iron oxides are present in such large quantities or are inert and so well crystallized that they remain brown or red even in reduced conditions, the above colour requirements do not apply.

'Gypsiferous' applies to soil material which contains 5 percent or more gypsum.

'Interfingering' refers to penetrations of an albic E-horizon into an underlying argic or natric B-horizon along ped faces, primarily vertical faces. The penetrations are not wide enough to constitute 'tonguing', but form continuous coatings of clean silt or sand, more than 1 mm thick, on the vertical ped faces ('skeletans').

'Nitic properties' apply to clayey soil material that has a (moderately) strong angular blocky structure which falls easily apart into flat edged ('polyhedric' or 'nutty') elements with shiny ped faces that are either thin clay coatings or pressure faces.

'Organic soil materials' are materials which are saturated with water for long periods, or artificially drained, and, have a high organic carbon content, or are never saturated with water for more than a few days and have a still higher organic carbon content.

'Permafrost' refers to the condition that the temperature of a soil layers is perennially at or below 0°C.

'Plinthite' refers to an iron rich, humus-poor mixture of clay with quartz and other diluents. It commonly occurs as red mottles, usually in platy, polygonal or reticulate patterns, and changes irreversibly to a hardpan or to irregular aggregates on exposure to repeated wetting and drying. In a moist soil, plinthite is usually firm but it can be cut with a spade. When irreversibly hardened, the material is no longer considered plinthite but develops into petroferric or skeletic phase.

'Salic properties' refer to high electrical conductivity of the soil.

'Slickensides' are polished and grooved surfaces that are produced by one soil mass sliding past another. Some of them occur at the base of the slip surface where a mass of soil moves downward on a relatively steep slope. Slickensides are very common in swelling clays in which there are marked seasonal changes in moisture content.

'Smeary consistence' is used in connection with Andosols, and refers to thixotropic soil material,i.e. material that changes under pressure, or by rubbing, from a plastic solid into a liquified stage; the material skids or smears between the fingers.

'Sodic properties' refers to a high saturation of the exchange complex by exchangeable sodium plus magnesium.

'Soft powdery lime' is translocated authigenic lime, soft enough to be cut readily with a finger nail, precipitated in situ from the soil solution, rather than inherited from a soil parent material. It should be present in significant accumulation.

'Strongly humic' is soil material with a high percentage of organic carbon up to great depth.

'Sulfidic materials' refer to waterlogged mineral or organic soil materials containing a high amount of sulfur, mostly in the form of sulfides and having less than three times as much calcium carbonate equivalent as sulfur. Sulfidic materials differ from the sulfuric horizon in their reduced condition, their Ph, and the absence of jarosite mottles.

'Tonguing' is connotative for the penetration of an albic E-horizon into an argic B-horizon along vertical ped surfaces, if peds are present. Tongues must have greater depth than width.

With Chernozems, the term "tonguing' refers to penetrations of the A-horizon into an underlying cambic B-horizon or into a C-horizon.

'Vertic properties' are used in connection with clayey soils which at some period in most years show one or more of the following: cracks, slickensides, wedge-shaped or parallepiped structural aggregates that are not in a combination, or are not sufficiently expressed for the soil to qualify as Vertisol.

'Weatherable minerals' are minerals that are unstable in a humid climate relative to other minerals such as quartz and 1:1 lattice clays, and that, when weathering occurs, liberate plant nutrients and iron and/or aluminium. They include: clay minerals (including all 2:1 lattice clays except aluminium interlayered chlorite), andsand and silt-sized minerals (feldspars, feldspathoids, ferromagnesian minerals, glasses, micas, and zeolites).

4.5 Phases

Phases indicate surface or subsurface features of the land which are not necessarily related to soil formation and (may) cut across the boundaries of soil map units. The features concerned may result from or form a constraint to land use.

An **'anthraquic phase'** marks soils showing stagnic properties at shallow depth due to surface waterlogging associated with long continued irrigation, particularly rice.

A **'duripan phase'** marks soils having a subsurface horizon that is cemented by silica so that dry fragments do not slake during prolonged soaking in water or in hydrochloric acid.

A **'fragipan phase'** marks soils having a loamy subsurface horizon which has a high bulk density relative to the horizons above it, and is hard or very hard and seemingly cemented when dry, and weakly to moderately brittle when moist. When pressure is applied, peds or clods tend to rupture suddenly rather than undergo slow deformation. Dry fragments slake or fracture when placed in water.

The **'gelundic phase'** marks soils showing formation of polygons on their surface due to frost heaving.

The **'gilgai phase'** marks soils showing gilgai, the typical microrelief of clayey soils (mainly Vertisols) that have a high coefficient of expansion with distinct seasonal changes in moisture content. The gilgai microrelief consists of either a succession of enclosed micro-basins and microknolls in nearly level areas, or of microvalleys and microridges that rub up and down the slope.

The **'inundic phase'** marks soils with standing or flowing water present on the soil surface for more than 10 day in the growing period.

The **'lithic phase'** marks soils with continuous hard rock occurring within 50 cm of the surface.

The **'petroferric phase'** refers to the occurrence of a continuous layer of indurated material, in which iron is an important cement and in which organic matter is absent, or present only in traces. The petroferric layer differs from a thin iron pan and from an indurated spodic B-horizon in containing little or no organic matter.

The **'phreatic phase'** refers to the occurrence of a ground water table within 5 m from the surface, the presence of which is not reflected in the morphology of the soil. Its presence is important especially in arid areas where, with irrigation, special attention should be paid to effective water use and drainage in order to avoid salinization as a result of rising ground-water.

The **'placic phase'** refers to the presence of a thin iron pan, a black to dark reddish layer cemented by iron, or by iron and manganese, or by an iron-organic matter complex, the thickness of which ranges generally from 2 mm to 10 mm. It may be associated with stratification in parent materials. It runs roughly parallel to the soil surface and has a pronounced wavy or convolute form. It normally occurs as a single pan, not as multiple sheets underlying one another, but in places it may be bifurcated. It is a barrier to water and roots.

The **'rudic phase'** marks areas where the presence of gravel, stones, boulders or rock outcrops in the surface layers or at the surface makes the use of mechanized agricultural equipment impracticable. Hand tools can normally be used and also simple mechanical equipment if other conditions are particularly favourable.

The **'salic phase'** marks soils which show high electric conductivity. The salic phase is not shown on soil maps for Solonchaks because their definition implies a high salt content. Salinity in a soil may show seasonal variations or may fluctuate as a result of irrigation practices.

The **'skeletic phase'** refers to soil materials which consist for 40 percent or more, by volume, of coarse fragments of oxidic concretions or iron-stone, or other hard materials. The difference from the petroferric phase is that the concretionary layer of the skeletic phase is not continuously cemented.

The **'sodic phase'** marks soils which have a high percentage of exchangeable sodium. The sodic phase is not shown for soils which have a natric B-horizon, or which have sodic properties since a high percentage of sodium saturation is already implied in their definition.

The **'takyric phase'** applies to heavy textured soils which crack into polygonal elements when dry and form a platy or massive surface crust.

The **'yermic phase'** applies to soils which have a low to very low organic carbon content, as these occur in (semi)arid areas. Soils with a yermic phase may have a desert pavement, calcium carbonate and/or gypsum accumulation, blown sand.

5. THE MAJOR SOIL GROUPINGS

A systematic presentation of the complete list of major soil groupings is given below. An endeavour has been made to group them, reflecting a geographical and evolutionary background.

5.1 Arrangements of soils according to geography and soil development stages

Weakly developed soils

Leptosols	Depth <30 cm on continuous hard rock, highly calcareous materials or cemented layers; or <20% fine earth in upper 75 cm (formerly Lithosols, Rankers and Rendzinas)
Regosols	Slight accumulation of organic matter; in unconsolidated deposits other than alluvial; fine or medium textured
Fluvisols	In recent alluvial deposits (river, lake or marine) or colluvia; stratification, sulfuric horizon or sulfidic materials

Soils with strong influence of parent material

Arenosols	In unconsolidated sandy deposits of at least 10 cm thickness, other than alluvial or andic; weakly developed subsurface horizon or albic E horizon
Histosols	Peats; organic layer >40 cm, >60 cm when Sphagnum
Vertisols	Strongly swelling and shrinking clay soils, mostly smectite; deep cracks in dry season, slickensides; with or without gilgai microrelief; 30% or more clay
Andosols	In volcanic material; low bulk density; high percentage or amorphous material-allophane

Slightly developed soils (cambic B)

Cambisols	Alteration of parent material in wet, moist or dry conditions; soil structure; neoformation of clays and iron oxides; lack appreciable illuviation; BSP <50

Soils with marked accumulation of base-saturated organic matter (mollic A)

Kastanozems	Brown-blackish surface horizon; $CaCO_3$ or $CaSO_4$ addition in subsurface horizon
Chernozems	Black surface horizon, $CaCO_3$ addition in subsurface horizon
Phaeozems	Without $CaCO_3$ addition
Greyzems	Bleached coatings on structural aggregates

Soils with marked accumulation of salts

calcic/gypsic soils

Calcisols	Calcic or petrogypsic horizon or concentrations of soft powdery lime within 125 cm
Gypsisols	Gypsic and/or petrogypsic horizon within 125 cm; may also have a (petro) calcic horizon

saline/sodic soils

Solonchaks	Soils, exclusive of those in alluvial deposits, that have a high content of salts
Solonetz	Subsurface horizon with illuvial accumulation of silicate clay; high sodium concentration; columnar/prismatic structure (natric B)

Soils with marked accumulation in subsurface Al and Fe of organic matter (spodic B)

Podzols	Subsurface horizons of illuvial organic matter and aluminium compounds, with or without iron (spodic B)

Soils with marked accumulation of clay (argic B)

Luvisols	BSP 50 or more: CEC 24 me or more per 100 g clay
Lixisols	BSP 50 or more; CEC <24 me/100 g clay (formerly with Luvisols)
Acrisols	BSP <50; CEC <24 me/100 g clay
Alisols	BSP <50; CEC 24 me or more per 100 clay (formerly with Acrisols)

Nitisols	Very thick argic B with nitic properties (shiny ped faces on strong blocky structural peds)
Podzoluvisols	Irregular or broken upper boundary of argic B; vertical tongues of bleached E material into argic B; or discrete nodules with hard iron-enriched exterior

Deep, intensely weathered soils (ferralic B)

Ferralsols	Subsurface horizon consists mainly of kaolinitic clay and residual concentration of quartz and hydrated oxides of iron and aluminium; low capacity to retain cations

Soils with plinthite

Plinthosols	At least 25% plinthite of at least 15 cm thickness

Soils with hydromorphic characteristics

Gleysols	In unconsolidated materials, showing strong influence of groundwater at shallow depth; greyish or bluish colours with or without reddish, brownish or black mottles
Planosols	Strongly leached subsurface horizon (albic E) with mottles, abruptly overlying a slowly permeable horizon

Man-made soils

Anthrosols	Soils with strong human influence, by removal, addition or disturbance of soil material

5.2 Short characteristics of Major Soil Groupings

The definitions of major soil groupings given in this chapter include only a limited number of characteristics, which are necessary and sufficient to separate the different units.

- The units have their upper boundary at the surface, or at less than 50 cm below the surface. When they are covered with a mantle of new material, horizons buried by 50 cm or more of newly deposited surface material are no longer diagnostic for classification purposes.

- Diagnostic horizons and diagnostic properties are assumed to have their upper limit within 125 cm of the surface, unless specified otherwise.

- When two or more B horizons occur within 125 cm of the surface it is the upper B horizon which is determining for the classification, as long as it is sufficiently developed to be diagnostic.

- The expression 'having no diagnostic horizons other than' indicates that one or more of the diagnostic horizons listed may be present.

1a LEPTOSOLS (LP)
Soils which are limited in depth by continuous hard rock or highly calcareous material 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 of the surface; having no diagnostic horizons other than a mollic, umbric, or ochric A horizon, with or without a cambic B horizon.

1b REGOSOLS (RG)
Soils form unconsolidated materials, exclusive of materials that are coarse textured 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 and Andosols; lacking salic properties.

1c FLUVISOLS (FL)
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.

2a HISTOSOLS (HS)
Soils having 40 cm or more of organic soil materials (60 cm or more if the organic material consists mainly of sphagnum or moss or has a bulk density of less than 0.1) either extending down from the surface or taken cumulatively within the upper 80 cm of the soil; the thickness of the H horizon may be less when it rests on rock or on fragmental material in which the interstices are filled with organic matter.

2b ARENOSOLS (AR)
Soils which are coarser than sandy loam to a depth of at least 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.

2c VERTISOLS (VR)

Soils having, after the upper 20 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.

2d ANDOSOLS (AN)

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.

3 CAMBISOLS (CM)

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 of less than 50 percent; lacking salic properties; lacking the characteristics diagnostic for Vertisols or Andosols; lacking gleyic properties within 50 cm of the surface.

4a KASTANOZEMS (KS)

Soils having a mollic A horizon with a moist chroma of more than 2 to a depth of at least 15 cm; having one or more of the following: a calcic or gypsic horizon or concentrations of soft powdery lime 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.

4b CHERNOZEMS (CH)

Soils having a mollic A horizon with a moist chroma of 2 or less to a depth of at least 15 cm; having a calcic horizon or concentrations of soft powdery lime within 125 cm of the surface, or both; 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 quartz grains on structural ped surfaces.

4c PHAEOZEMS (PH)

Soils having a mollic A horizon; lacking a calcic horizon, a gypsic horizon, concentrations of soft powdery lime; having a base saturation which is 50 percent or more throughout within 125 cm of the surface; lacking a ferralic B horizon; lacking a natric B horizon; lacking the characteristics which are diagnostic for Vertisols, Nitisols, 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 quartz 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.

4d GREYZEMS (GR)

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 quartz grains on structural ped surfaces; having an argic B horizon; lacking the characteristics which are diagnostic for Planosols.

5a CALCISOLS (CL)

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 invaded by calcium carbonate; lacking the characteristics which are diagnostic for Vertisols and Planosols; lacking salic properties; lacking gleyic properties within 100 cm of the surface.

5b GYPSISOLS (GY)

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 invaded by gypsum or calcium carbonate, a calcic or a petrocalcic horizon; lacking the characteristics which are diagnostic for Vertisols and Planosols; lacking salic properties; lacking gleyic properties within 100 cm of the surface.

5c SOLONCHAKS (SC)

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 C horizon, a calcic or a gypsic horizon.

5d SOLONETZ (SN)

Soils having a natric B horizon.

6 PODZOLS (PZ)

Soils having a spodic B horizon.

7a LUVISOLS (LV)

Soils having an argic B horizon which has a cation-exchange capacity of 24 me or more per 100 g clay and a base saturation of 50 percent or more throughout the B 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.

7b LIXISOLS (LX)

Soils having an argic B horizon which has a cation exchange capacity of less than 24 me per 100 g clay at least in some part of the B horizon and a base saturation 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, Nitosols and Podzoluvisols respectively.

7c ACRISOLS (AC)

Soils having an argic B horizon which has a cation exchange capacity of less than 24 me per 100 g clay and a base saturation 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.

7d ALISOLS (AL)

Soils having an argic B horizon which has a cation exchange capacity of 24 me or more per 100 g of clay and a base saturation 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.

7e NITISOLS (NT)

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 and vertic properties; lacking plinthite within 125 cm of the surface.

7f PODZOLUVISOLS (PD)

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.

8 FERRALSOLS (FR)

Soils having a ferralic B horizon.

9 PLINTHOSOLS (PT)

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.

10a GLEYSOLS (GL)

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.

10b PLANOSOLS (PL)

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, exclusive of a natric or a spodic B horizon.

11 ANTHROSOLS (AT)

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

6. THE MAJOR SOIL GROUPINGS AND SOIL UNITS

LP LEPTOSOLS
LPe Eutric Leptosols
LPd Dystric Leptosols
LPk Rendzic Leptosols
LPm Mollic Leptosols
LPu Umbric Leptosols
LPq Lithic Leptosols
LPi Gelic Leptosols

RG REGOSOLS
RGe Eutric Regosols
RGc Calcaric Regosols
RGy Gypsic Regosols
RGd Dystric Regosols
RGU Umbric Regosols
RGi Gelic Regosols

FL FLUVISOLS
FLe Eutric Fluvisols
FLc Calcaric Fluvisols
FLd Dystric Fluvisols
FLm Mollic Fluvisols
FLu Umbric Fluvisols
FLt Thionic Fluvisols
FLs Salic Fluvisols

HS HISTOSOLS
HSl Folic Histosols
HSs Terric Histosols
HSf Fibric Histosols
HSt Thionic Histosols
HSi Gelic Histosols

AR ARENOSOLS
ARh Haplic Arenosols
ARb Cambic Arenosols
ARl Luvic Arenosols
ARo Ferralic Arenosols
ARa Albic Arenosols
ARc Calcaric Arenosols
ARg Gleyic Arenosols

VR VERTISOLS
VRe Eutric Vertisols
VRd Dystric Vertisols
VRk Calcic Vertisols
VRy Gypsic Vertisols

AN ANDOSOLS
ANh Haplic Andosols
ANm Mollic Andosols
ANu Umbric Andosols
ANz Vitric Andosols
ANg Gleyic Andosols
ANi Gelic Andosols

CM CAMBISOLS
CMe Eutric Cambisols
CMd Dystric Cambisols
CMu Humic Cambisols
CMc Calcaric Cambisols
CMx Chromic Cambisols
CMv Vertic Cambisols
CMo Ferralic Cambisols
CMg Gleyic Cambisols
CMi Gelic Cambisols

KS KASTANOZEMS
KSh Haplic Kastanozems
KSl Luvic Kastanozems
KSk Calcic Kastanozems
KSy Gypsic Kastanozems

CH CHERNOZEMS
CHh Haplic Chernozems
CHk Calcic Chernozems
CHl Luvic Chernozems
CHw Glossic Chernozems
CHg Gleyic Chernozems

PH PHAEOZEMS
PHh Haplic Phaeozems
PHc Calcaric Phaeozems
PHl Luvic Phaeozems
PHj Stagnic Phaeozems
PHg Gleyic Phaeozems

GR GREYZEMS
GRh Haplic Greyzems
GRg Gleyic Greyzems

CL CALCISOLS
CLh Haplic Calcisols
CLl Luvic Calcisols
CLp Petric Calcisols

GY GYPSISOLS
GYh Haplic Gypsisols
GYk Calcic Gypsisols
GYl Luvic Gypsisols
GYp Petric Gypsisols

SC SOLONCHAKS
SCh Haplic Solonchaks
SCm Mollic Solonchaks
SCk Calcic Solonchaks
SCy Gypsic Solonchaks
SCn Sodic Solonchaks
SCg Gleyic Solonchaks
SCi Gelic Solonchaks

SN SOLONETZ
SNh Haplic Solonetz
SNm Mollic Solonetz
SNk Calcic Solonetz
SNy Gypsic Solonetz
SNj Stagnic Solonetz
SNg Gleyic Solonetz

PZ PODZOLS
PZh Haplic Podzols
PZb Cambic Podzols
PZf Ferric Podzols
PZc Carbic Podzols
PZg Gleyic Podzols
PZi Gelic Podzols

LV LUVISOLS
LVh Haplic Luvisols
LVf Ferric Luvisols
LVx Chromic Luvisols
LVk Calcic Luvisols
LVv Vertic Luvisols
LVa Albic Luvisols
LVj Stagnic Luvisols
LVg Gleyic Luvisols

LX LIXISOLS
LXh Haplic Lixisols
LXf Ferric Lixisols
LXp Plinthic Lixisols
LXa Albic Lixisols
LXj Stagnic Lixisols
LXg Gleyic Lixisols

AC ACRISOLS
ACh Haplic Acrisols
ACf Ferric Acrisols
ACu Humic Acrisols
ACp Plinthic Acrisols
ACg Gleyic Acrisols

AL ALISOLS
ALh Haplic Alisols
ALf Ferric Alisols
ALu Humic Alisols
ALp Plinthic Alisols
ALj Stagnic Alisols
ALg Gleyic Alisols

NT NITISOLS
NTh Haplic Nitisols
NTr Rhodic Nitisols
NTu Humic Nitisols

PD PODZOLUVISOLS
PDe Eutric Podzoluvisols
PDd Dystric Podzoluvisols
PDj Stagnic Podzoluvisols
PDg Gleyic Podzoluvisols
PDi Gelic Podzoluvisols

FR FERRALSOLS
FRh Haplic Ferralsols
FRx Xanthic Ferralsols
FRr Rhodic Ferralsols
FRu Humic Ferralsols
FRg Geric Ferralsols
FRp Plinthic Ferralsols

PT PLINTHOSOLS
PTe Eutric Plinthosols
PTd Dystric Plinthosols
PTu Humic Plinthosols
PTa Albic Plinthosols

GL GLEYSOLS
GLe Eutric Gleysols
GLk Calcic Gleysols
GLd Dystric Gleysols
GLa Andic Gleysols
GLm Mollic Gleysols
GLu Umbric Gleysols
GLt Thionic Gleysols
GLi Gelic Gleysols

PL PLANOSOLS
PLe Eutric Planosols
PLd Dystric Planosols
PLm Mollic Planosols
PLu Umbric Planosols
PLi Gelic Planosols

AT ANTHROSOLS
ATa Aric Anthrosols
ATc Cumulic Anthrosols
ATf Fimic Anthrosols
ATu Urbic Anthrosols

7. KEY TO MAJOR SOIL GROUPINGS

Soils having an 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 fragmented material of which the interstices are filled with organic matter:

HISTOSOLS (HS)
(page 19)[1]

Other soils in which human activities resulted in profound modification of the original soil characteristics:

ANTHROSOLS (AT)
(page 35)

Other soils which are limited in depth by continuous hard rock or highly calcareous materials or a continuous cemented layer within 30 cm of the surface, or having less than 20 percent fine earth over a depth of 75 cm from the surface; having no diagnostic horizons other than a mollic, umbric, or ochric A-horizon with or without a cambic B-horizon:

LEPTOSOLS (LP)
(page 115)

Other soils having, after the upper 20 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 one or more of the following: intersecting slickensides or wedge-shaped or parallelepiped structural aggregates at some depth between 25 and 100 cm from the surface:

VERTISOLS (VR)
(page 67)

Other 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:

FLUVISOLS (FL)
(page 93)

Other soils showing 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:

SOLONCHAKS (SC)
(page 181)

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[1]page numbers refer to Driessen & Dudal, 1989. Lecture Notes on the Major Soils of the World.

Other 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 if underlying an albic E-horizon or a horizon which shows stagnic properties within 50 cm of the surface or gleyic properties within 100 cm of the surface:

PLINTHOSOLS (PT)
(page 139)

Other soils having a ferralic B-horizon:

FERRALSOLS (FR)
(page 147)

Other 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, exclusive of a natric or a spodic B-horizon:

PLANOSOLS (PL)
(page 253)

Other soils having a natric B-horizon:

SOLONETZ (SN)
(page 191)

Other soils 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 plinthite within 125 cm of the surface:

GLEYSOLS (GL)
(page 105)

Other 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:

ANDOSOLS (AN)
(page 47)

Other soils which are coarser than sandy loam to a depth of at least 100 cm from the surface, having no diagnostic horizons other than an ochric A-horizon or an albic E-horizon:

ARENOSOLS (AR)
(page 59)

Other soils having no diagnostic horizons other than an ochric or umbric A-horizon:

REGOSOLS (RG)
(page 119)

Other soils having a spodic B-horizon:

PODZOLS (PZ)
(page 254)

Other soils having a mollic A-horizon with a moist chroma of 2 or less to a depth of at least 15 cm, showing uncoated silt and quartz grains on structural ped surfaces; having an argic B-horizon:

GREYZEMS (GR)
(page 231)

Other soils having a mollic A-horizon with a moist chroma of 2 or less to a depth of at least 15 cm; having a calcic horizon, or concentrations of soft powdery lime within 125 cm of the surface, or both:

CHERNOZEMS (CH)
(page 219)

Other soils having a mollic A-horizon with a moist chroma of more than 2 to a depth of at least 15 cm; having one or more of the following: a calcic or gypsic horizon, or concentrations of soft powdery lime within 125 cm of the surface:

KASTANOZEMS (KS)
(page 215)

Other soils having a mollic A-horizon; having a base saturation (by 1M NH_4OAc at pH 7.0) of 50 percent or more throughout the upper 125 cm of the soil:

PHAEOZEMS (PH)
(page 227)

Other soils having an argic B-horizon showing an irregular or broken upper boundary resulting from deep tonguing of the E-horizon 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:

PODZOLUVISOLS (PD)
(page 247)

Other soils having a gypsic or a petrogypsic horizon 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 invaded by gypsum or calcium carbonate, a calcic or a petrocalcic horizon:

GYPSISOLS (GY)
(page 197)

Other soils having a calcic or a petrocalcic horizon, or a concentration 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 invaded by calcium carbonate:

CALCISOLS (CL)
(page 203)

Other soils having an argic B-horizon with 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:

NITISOLS (NT)
(page 157)

Other soils having an argic B-horizon which has a cation exchange capacity equal to or more than 24 cmol(+)/kg clay and a base saturation (by 1M NH_4OAc at pH 7.0) of less than 50 percent at least in some part of the B-horizon within 125 cm of the surface:

ALISOLS (AL)
(page 167)

Other soils having an argic B-horizon which has a cation exchange capacity of less than 24 cmol(+)/kg clay and a base saturation (by 1M NH_4OAc at pH 7.0) of less than 50 percent in at least some part of the B-horizon within 125 cm of the surface:

ACRISOLS (AC)
(page 161)

Other soils having an argic B-horizon which has a cation exchange capacity equal to or more than 24 cmol(+)/kg clay and a base saturation (by 1M NH_4OAc at pH 7.0) of 50 percent or more throughout the B-horizon to a depth of 125 cm:

LUVISOLS (LV)
(page 241)

Other soils having an argic B-horizon which has a cation exchange capacity of less than 24 cmol(+)/kg clay and a base saturation (by 1M NH_4OAc at pH 7.0) of 50 percent or more throughout the B-horizon to a depth of 125 cm:

LIXISOLS (LX)
(page 171)

Other soils having a cambic B-horizon:

CAMBISOLS (CM)
(page 125)

SOIL HORIZON DESIGNATIONS

A soil horizon may be defined as a layer of soil, approximately parallel to the soil surface, with characteristics produced by soil-forming processes. A soil horizon is commonly differentiated from the one adjacent by characteristics that can be seen or measured in the field – such as colour, texture, structure, consistence – and many times also in laboratory tests.

A soil is usually characterised by describing and defining the properties of its horizons. Abbreviated horizon designations, which have a genetic connotation, are used for showing the relationships among horizons within a profile and for comparing horizons among different soils.

Horizon designations are therefore an element in the definition of soil units and in the description of representative profiles. Horizon designations are defined in broad qualitative terms, and of course do not substitute for clear and complete descriptions of the morphological characteristics of each horizon.

Though the ABC horizon nomenclature is used by the great majority of soil scientists, the definition of these designations and their qualification with suffixes or figures vary widely. Within the framework of the Soil Map of the World project, the International Society of Soil Science (ISSS) convened a panel of experts to work out a system of soil horizon designations which could be recommended for international use.

The symbols used to designate soil horizon are as follows:

Capital letters H, O. A, E, B, C and R indicate master horizons, or dominant kinds of departure from the assumed parent material.

Strictly, C and R should not be labelled as 'soil horizons' but as 'layers', since their characteristics are not produced by soil-forming factors. They are listed here with the master horizons as important elements of a soil profile. A combination of capital letters is used for transitional horizons.

Lower case letters are used as suffixes to qualify the master horizons in terms of the kind of departure from the assumed parent material. The lower case letters immediately follow the capital letter. Two lower case letters may be used to indicate two features which occur concurrently.

Arabic figures are used as suffixes to indicate vertical subdivision of a soil horizon. For A and B horizons the suffix figure is always preceded by a lower case letter suffix.

Arabic figures are used as prefixes to mark lithological discontinuities.

Master horizons

Under master horizons are listed the principal soil horizons and layers in soil profiles: H, O, A, E and B and the underlying C and R.

Organic horizons

H: organic horizon, saturated with water for prolonged periods. 18% or more organic carbon if over 60% clay; 12% or more organic carbon if no clay in the mineral fraction, or intermediate proportions.

O: organic horizon, not saturated with water for more than a few days a year. 20% or more organic carbon.

Mineral horizons

A: mineral horizon that either: shows an accumulation of OM intimately associated with the mineral fraction, or: has a morphology acquired by soil formation but lacks the properties of E and B horizons.

E: mineral horizon showing a concentration of sand and silt fractions high in resistant minerals, resulting from a loss of silicate clay, iron or aluminium or some combination of them.

B: mineral horizon with one or more of: an illuvial concentration of silicate clay, iron, aluminium, or OM, alone or in combinations; a residual concentration of sesquioxides relative to source materials; a layer in which silicate clays are formed, oxides are liberated, or both, or granular, blocky or prismatic structure is formed.

C: mineral horizon/layer of unconsolidated material from which the solum is presumed to have formed.

R: layer of continuous indurated rock.

Transitional horizons

Soil horizons in which the properties of two master horizons merge are indicated by the combination of two capital letters (for instance AE, EB, BE, BC, CB, AB, BA, AC, and CA). The first letter marks the master horizon to which the transitional horizon is most similar.

Mixed horizons that consist of intermingled parts, each of which are identifiable with different master horizons, are designated by two capital letters separated by a diagonal stroke (for instance E/B, B/C). The first letter marks the master horizon that dominates.

Letter suffixes

A small letter may be added to the capital letter to qualify the master horizon designation. Suffix letters can be combined to indicate properties which occur concurrently in the same master horizon (for example, Ahz, Btg, Cck). Normally no more than two suffixes should be used in combination. In transitional horizons no use is made of suffixes which qualify only one of the capital letters. A suffix may be used, however, when it applies to the transitional horizon as a whole (for example, BCk, ABg).

The suffix letter used to qualify the master horizons are as follows:

b. buried or bisequal soil horizon (for example, Btb).

c. accumulation in concretionary form; this suffix is commonly used in combination with another which indicates the nature of the concretionary material (for example, Bck, Ccs).

g. mottling reflecting variations in oxidation and reduction (for example, Bg, Btg, Cg).

h. accumulation of organic matter in mineral horizons (for example, Ah, Bh); for the A horizon, the h suffix is applied only where there has been no disturbance or mixing from ploughing, pasturing or other activities of man (h and p suffixes are thus mutually exclusive).

i. occurrence of permafrost.

j. occurrence of jarosite.

k. accumulation of calcium carbonate.

m. strongly cemented, consolidated, indurated; this suffix is commonly used in combination with another indicating the cementing material (for example, Cmk marking a petrocalcic horizon with a C horizon, Bms marking an iron pan within a B horizon).

n. accumulation of sodium (for example, Btn).

p. disturbed by ploughing or other tillage practices (for example, Ap).

q. accumulation of silica (Cmq, marking a silcrete layer in a C horizon).

r. strong reduction as a result of groundwater influence (for example, Cr).

s. accumulation of sesquioxides (for example, Bs).

t. accumulation of clay (for example, Bt).

u. unspecified; this suffix is used in connection with A and B horizons which are not qualified by another suffix but have to be subdivided vertically by figure suffixes (for example, Au1, Au2, Bu1, Bu2). The addition of u to the capital letter is provided to avoid confusion with the former notations A1, A2, A3, B1, B2, B3 in which the figures has a genetic connotation. If no subdivision using figure suffixes is needed, the symbols A and B can be used without u.

w. alteration in situ as reflected by clay content, colour, structure (for example, Bw).

x. occurrence of a fragipan (for example, Btx).

y. accumulation of gypsum (for example, Cy).

z. accumulation of salts more soluble than gypsum (for example, Az or Ahz).

Figure suffixes

Horizon designated by a single combination of letter symbols can be vertically subdivided by numbering each subdivision consecutively, starting at the top of the horizon (for example, Bt1 - Bt2 - Bt3 - Bt4). The suffix number always follows all of the letter symbols. The number sequence applies to one symbol only so that the sequence is resumed in case of change of the symbol (for example, Bt1 - Bt2 - Btx1 - Btx2). A sequence is not interrupted, however, by a lithological discontinuity (for example, Bt1 - Bt2 - 2Bt3).

Numbered subdivisions can also be applied to transitional horizons (for example, Ab1 - AB2), in which case it is understood that the suffix applies to the entire horizon and not only to the last capital letter.

Numbers are not used as suffixes of undifferentiated A or B symbols, to avoid conflict with the old notation system. If an otherwise unspecified A or B horizon should be subdivided, a suffix u is added.

Figure prefixes

When it is necessary to distinguish lithological discontinuities, Arabic (replacing former Roman) numerals are prefixed to the horizon designations concerned (for instance, when the C horizon is different from the material in which the soil is presumed to have formed the following soil sequence could be given: A, B, 2C. Strongly contrasting layers within the C material could be shown as an A, B, C, 2C, 3C ... sequence).

APPENDIX 2 THE FAO-UNESCO SOIL MAP OF THE WORLD

The Soil Map of the World is based on factual information, derived from actual surveys available in the 1960's and 1970's. It has about 5000 **mapping units**, which consist of (associations of) **soil units**.

All mapping units present the included **soil unit**(s), the **textural class** of the dominant soil and the **slope class** of the mapping unit.

Textural classes

Textural classes reflect the relative proportions of clay (fraction less than 2 μm), silt (2-50 μm) and sand (50-2000 μm) in the soil.

The texture of soil horizon is one of its most permanent characteristics. It is also a very important one since, in combination with other properties, it is directly related to soil structure, consistence, porosity and cation exchange capacity.

Three textural classes are recognized (marked by the figures 1, 2 and 3 on the map).

1. Coarse textured: sands, loamy sands and sandy loams with less than 15 percent clay, and more than 70 percent sand.
2. Medium textured: sandy loams, loams, sandy clay loams, silt loams, silt, silty clay loams and clay loams with less than 35 percent clay and less than 70 percent sand; the sand fraction may be as high as 85 percent if a minimum of 15 percent clay is present.
3. Fine textured: clays, silty clays, sandy clays, clay loams and silty clay loams with more than 35 percent clay.

Slope classes

Slope is an integral part of the land surface. It influences drainage, run-off, erosion, exposure, accessibility. The slope classes refereed to here indicate the slope which dominates the area of a soil association.

Three slope classes are distinguished (marked by the symbols, a, b and c on the map):

a. level to gently undulating: dominant slopes ranging between 0 and 8 percent.
b. rolling to hilly: dominant slopes ranging between 8 and 30 percent.
c. steeply dissected to mountainous: dominant slopes are over 30 percent.

Cartographic representation

The printed soil maps made use of symbols, colours and overprints to represent the mapped units.

Symbols

The soil associations can be shown on maps by the symbol of the dominant soil unit, followed by a figure which refers to the descriptive legend in which the full composition of the association is given.

Example:

LVx5	Chromic Luvisols with associated Calcic Vertisols
FRh2	Haplic Ferralsols with associated Ferralic Arenosols

Associations in which Leptosols are dominant are marked by the Leptosols symbol LP combined with one or two associated soil units.

Example:

LPd-CMd	Dystric Leptosols and Dystric Cambisols
LPe-LVx-ANh	Eutric Leptosols, Chromic Luvisols and Haplic Andosols

Where there are no associated soils or where the associated soils are not known, the symbol LP alone is used.

If information on the texture of the surface layers (upper 30 cm) of the dominant soil is available, the textural class figure follows the association symbol, separated from it by a dash.

Example:

LVx5-3	Chromic Luvisols, fine textured, and Calcic Vertisols
FRh2-2	Haplic Ferralsols, medium textured, and Ferralic Arenosols

Where two groups of textured occur that cannot be delimited on the map, two figures may be used.

Example:

PLm2-2/3	Mollic Planosols, medium and fine textured, and Eutric Vertisols.

Where information on relief is available, the slope classes are indicated by a small letter a, b or c, immediately following the textural notation.

Example:

LVx5-3a	Chromic Luvisols, fine textured, and Calcic Vertisols, level to gently undulating.

In complex areas where two types of topography occur that cannot be delimited on the map two letters may be used.

Example:

FRx1-2ab   Xanthic Ferralsols, medium textured, level to rolling.

If information on texture is not available, then the small letter indicating the slope class will immediately follow the association symbol.

Example:

LPe-CMe-c   Eutric Leptosols and Eutric Cambisols, steeply dissected.

Colours

Each of the soil units used for the Soil Map of the World has been assigned a specific colour. The map units are coloured according to the dominant soil unit. Map units having the same dominant soil unit but which differ in their associated soils are separated on the map by different symbols.

Colour selection has been made by clusters so that soil regions of genetically related soils will show up clearly.

Overprints

Phases which indicate land characteristic not reflected by the soil units or by the composition of the soil associations are to be shown on the map by overprints. The phases used are: anthraquic, duripan, fragipan, gelundic, gilgai, inundic, lithic, petroferric, phreatic, placic, rudic, salic, skeletic, sodic, takyric and yermic. Phases are normally shown only when they apply to the whole area covered by a map unit.

Areas of dunes or shifting sands, glaciers and snow caps, salt flats, rock debris or desert detritus are also shown by overprints as miscellaneous land units.

Explanatory Texts

The map sheets of each of the major regions of the world are accompanied by an explanatory text. Each volume describes the specific development of the Soil Map of the World project for this region, and indicates sources of information and the correlation work carried out.

Environmental conditions, climate, vegetation, physiography and lithology are dealt with in relation to soil distribution.

Each volume lists the soil associations which have been separated on the map with indication of associated soil, inclusions, phases, areas of units in 1000 ha, climate, countries of occurrence, vegetation and lithology of parent materials.

The distribution of the major soils is discussed in terms of broad soil regions. Special attention is given in each volume to the present land use and the suitability of the land for both traditional and improved farming methods.

For each region a number of site and profile descriptions, with analyses, are given in an appendix.