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SOIL MAP OF THE WORLD

REVISED LEGEND with corrections
and updates

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I. INTRODUCTION

The background

The preparation of the FAO/Unesco Soil Map of the World, at scale 1:5 000 000, was undertaken in response to a recommendation of the International Society of Soil Science (ISSS) at its seventh Congress held at Madison, Wisconsin (USA) in 1960. The project started in 1961.

Successive drafts of the soil map and of the legend were prepared from a compilation of existing material combined with systematic field identification and correlation. The first draft of the Soil Map of the World was presented to the ninth Congress of the ISSS held at Adelaide (Australia) in 1968. The Congress approved the outline of the legend, the definitions of soil units and the proposed nomenclature. In accordance with the recommendation of the Congress that the Soil Map of the World be published at the earliest possible date, the first sheets, those covering South America, were issued in 1971. The last two of the total of nineteen sheets were published in 1981. The Soil Map of the World was completed over a span of twenty years, involving over three hundred soil scientists from all over the world (FAO, 1971-1981).

The deliberations of the Advisory Panel, the results of field correlation in different parts of the world and the various drafts of the legend were published as issues of FAO's World Soil Resources Reports (FAO, 1961-1988).

Looking back on the completion of the project it may be worthwhile to assess how far the objectives set for the Soil Map of the World were met. These objectives were :

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

A global inventory of the world's soil resources proved to be most valuable at a time when countries became increasingly interdependent for their supplies of food and other agricultural products. Problems of land degradation, disparity of production potentials and of population carrying capacities arose as

international concerns. The Soil Map of the World was a basis for establishing policies of development and optimization of land use at a global level through the preparation of a World Map of Desertification

(FAO/Unesco/WMO, 1977), a methodology for soil degradation assessment (FAO/UNEP/Unesco, 1979) and a study of the potential population supporting capacity of lands in the developing world (Higgins et al., 1982). The Soil Map of the World made it possible to delineate equivalent agro-ecological zones throughout the world marking the suitability for the production of major agricultural commodities in different regions (FAO, 1978-1981). This study laid a scientific basis for the transfer of experience between areas with similar environments and for establishing the complementarity of areas with different production potential.

Over the years, the Legend of the Soil Map of the World came to be used as a common denominator for correlating different soil classification systems. In a number of publications and soil maps the legend of the Soil Map of the World is listed jointly with the national soil classification. It has been used at international congresses and meetings to characterize and name soils to be studied in the field. It has been adopted by a number of libraries and data processing facilities as a key to stratify the soils universe.

The preparation of the Soil Map of the World has stimulated the initiation or intensification of soil surveys in a number of developing countries. Though the legend was originally designed for a soil inventory at scale 1:5 000 000, it also proved useful for reconnaissance surveys at larger scales. In a number of countries national soil maps were prepared using the Soil Map of the World legend, eventually introducing third level soil subunits (e.g. in Botswana, Egypt, Indonesia, Japan, Kenya, Mexico, Poland, Sierra Leone, Uruguay, Zambia). Recently the European Economic Community published a Soil Map of its member countries at scale 1:1 000 000 on the basis of the Soil Map of the World legend. Statistical information derived from the Soil Map of the World has been widely referred to for example, as giving the best possible estimates of saline land, dark cracking clays, acid tropical soils, volcanic ash soils and soil variations by country.

For educational, research and development activities the Soil Map of the World has proved to be a valuable tool. Among the natural resources (geology, vegetation, climate, soils, water) the Soil Map is the most detailed inventory completed at a global level. It is being used for teaching, the study of soil geography, the preparation of development projects, the selection of representative sites for research, the stratification of experimental data and the ecological characterization at a regional level.

The Soil Map of the World project has, over the last twenty-five years, considerably strengthened the international contacts in the field of soil science. The different schools of thought regarding soil classification have grown closer together. For the major soils a consensus is emerging as to the place which they should occupy in a taxonomic system, the criteria according to which they should be separated and the way in which they should be subdivided. The need for a generally accepted reference base for soil classification is felt by the international soils community more strongly now than ever before. It is hoped that the present revision and elaboration of the FAO/Unesco Soil Map of the World legend will contribute to the establishment, by the ISSS, of an International Reference Base for soil classification. This effort is of necessity of a long term nature for which the ISSS should offer the framework and continuity.

It can be said that the stated objectives of the Soil Map of the World have largely been met. However, in order to retain its value, it is imperative that the maps and the definition of the soil units be updated as new knowledge develops and new surveys throw more light on the world's soil cover.

A need for revision

Publication of the first maps of the Soil Map of the World started in 1969. Hence the data shown on some of these maps have now aged. The development of the legend was frozen at the time that the first map sheets went to print. In the years that followed soil survey in developing countries was considerably expanded. The Soil Map of the World project and the publication of Soil Taxonomy, in 1975, were stimuli toward the preparation of more accurate soil inventories at the country level. For a large number of countries systematic surveys were initiated or improved maps were drawn.

Numerous surveys were carried out for development and investment purposes with the support of UN Agencies or bilateral assistance programmes. If the Soil Map of the World is to retain its value as a compendium of information on the distribution of soils in the world, it is necessary to incorporate new information. However, before the soil boundaries can be revised it is essential to bring the legend up to date to take account of new classification concepts and better understanding of soil conditions. An intensive international exchange of ideas took place and new experience was gained through the Congresses of the ISSS and meetings of its working groups, the international soil correlation meetings held by FAO, the international soil correlation workshops organized by the USDA Soil Management Support Services, now Natural Resources Conservation Service, the activities of the International Soil Reference and Information Centre (ISRIC), the characterization of Man and the Biosphere (MAB) reserves by Unesco, the work of the Tropical Soils Consortium of USA Universities and the workshops on tropical soils sponsored by the International Board for Soil Research and Management (IBSRAM).

Considering the shortage of financial resources it is unlikely that a new edition of the Soil Map of the World could be envisaged. It is the intention, however, to continuously to update the maps through digitized storage of new material in a geographic information system from which up-to-date printouts or statistical data could be obtained upon request. The legend will likewise be made available in a computerized form. The procedures for incorporating new map material are described in Appendix 3.

The present publication is essentially devoted to modifications proposed in the legend. It will be noted that these modifications are relatively few and that the general structure and rationale on which the original legend was constructed are maintained. The original legend (FAO, 1974) remains the one to be used for the reading and interpretation of the published maps. The revised legend will be used, however, for updating the maps and for the preparation of new maps at scale 1:5 000 000 or larger.

The amendments outlined below are related to the diagnostic horizons and diagnostic properties, the definitions of major soil groupings and of soil units, the introduction of third level soil subunits, and the phases. In order to make this publication self-contained the various elements of the legend are defined in full following this introductory chapter. It will be useful to refer to Volume I, Legend of the Soil Map of the World (FAO, 1974) in order to comprehend fully the amendments proposed.

Diagnostic horizons

The use of diagnostic horizons for identifying soil units has proved to be most appropriate. These sets of quantitatively defined properties, produced by soil forming processes, have made it possible to base the classification on general principles of soil genesis. Objectivity was secured in that the processes themselves are not used as criteria but only their effects expressed in terms of morphological properties that have identification value.

Two major diagnostic horizons, however, appeared to be difficult to apply in the field, namely the argillic and oxic B horizons. Separating these two horizons has been a problem especially in tropical regions where low activity clays prevail. The main difficulty arises with pedons, the subsurface of which fulfils the textural requirements for an argillic B horizon but where the accessory property, the presence of clay skins, is so weakly expressed that consistent quantification is doubtful, either by field observation or laboratory analyses. In order to meet these difficulties, in the present legend the argillic and oxic B horizons have been redefined respectively under the names of argic and ferralic B horizons.

The duripan, fragipan, and the placic horizon are not used as diagnostic horizons. On small-scale maps these features are shown as phases where they can be observed and delineated.

A fimic A horizon (from L. *finus*, manure, mud, slurry) has been introduced which groups the anthropic and plaggen epipedons of the USDA Soil Taxonomy (U.S. Soil Conservation Service, 1975).

The definitions of the diagnostic horizons used in the present revision of the legend are given in Chapter IV.

Diagnostic properties

Diagnostic properties are soil characteristics which do not constitute distinct horizons but which are of importance for classification purposes.

The definitions of 'albic material', 'thin iron pan', 'aridic moisture regime' and 'high organic matter content in the B horizon' have been deleted since these properties are no longer used in the definitions of the present major soil groupings and soil units.

The 'exchange complex dominated by amorphous material' used in the definition of Andosols has been replaced by 'andic properties' in accordance with the findings of the International Committee on Andisols (ICOMAND, 1987).

The requirement of a cation exchange capacity of less than 24 cmol(+) kg⁻¹ clay has been deleted from the definition of 'ferric properties'. The qualification of the clay activity is now incorporated in the definition of the soil units concerned.

Hydromorphic properties have been replaced by gleyic and stagnic properties to distinguish water saturation due to a groundwater table from water saturation resulting from surface waterlogging. Concurrently, the definitions have been refined, taking into account earlier work by Schlichting and Blume (1966).

New diagnostic properties including 'fluvic properties', 'continuous hard rock', 'nitic properties', 'sodic properties' and 'geric properties' have been introduced in order to improve the definition of the Fluvisols, Leptosols, Nitisols, Solonchaks and Ferralsols respectively. The term 'highly saline' has been replaced by 'salic properties'.

The terms 'calcareous' and 'gypsiferous' have been defined and are used in the definitions of the relevant calcaric and gypsic units.

The definitions of all diagnostic properties used in the present revision are given in Chapter V.

Soil units

The original legend of the Soil Map of the World was composed of 26 major soil groupings at a first level of generalization, subdivided at a second level into 106 soil units. This structure has proved to be effective for giving a comprehensive picture of the world's soil cover. The greater number of first level units in the Soil Map of the World legend, when compared to existing classification systems, provides a greater flexibility for delineating major soil areas and for separating, even at a small scale, soil regions which are strikingly different with regard to management and production potential. The separation as major soil groupings of, for instance, Andosols, Nitisols, Planosols and Arenosols has been most appropriate. The need to lift these soils to higher categorical levels has in the meantime also been recognized in other classification schemes.

With the present revision some major soil groupings and soil units were deleted whereas others were added in accordance with additional experience gained. There are now 28 major soil groupings, subdivided at the second level into 153 soil units.

Lithosols, Rendzinas and Rankers have been difficult to show separately. Furthermore, the limited distribution of Rendzinas and Rankers no longer justifies their distinction at the first level. These units are now grouped, together with the Lithosols, under a major grouping of Leptosols (from Gr. leptos, thin; connotative of shallow soils) and are further separated at the second level.

The coarse textured Regosols have been incorporated into the Arenosols, since the grouping of sandy soils proved to be important.

An important addition at the first level is the introduction of the Lixisols (from L. lixivium, washing, connotative of strong weathering), which are soils with an argic B horizon, high base saturation but low clay activity. This latter characteristic separates them from the Luvisols which by definition are now soils with high clay activity. Over the last ten years the importance of this separation has been highlighted (Moormann, 1985; Uehara and Gillman, 1980) in terms of management and soil formation. This distinction allows for a delineation of two major soil regions, those with Luvisols in cool or warm temperate areas and those with Lixisols in subtropical and tropical environments.

A similar separation has been made by splitting the Acrisols, soils with an argic B horizon and low base saturation, into Acrisols now defined as soils with low clay activity, and Alisols (from L. alumen; connotative of high exchangeable alumen content) with high activity clays.

With the subdivision of poorly drained soils into those with a groundwater table and those with surface waterlogging caused by an impermeable layer, stagnic units have been introduced and gleyic units redefined.

A major change is the deletion of the Yermosols and Xerosols, the definition of which was based on the occurrence of an aridic moisture regime. One of the general principles adopted for the construction of the Soil Map of World legend was that no climatic criteria would be used to define the soil units. An exception was made for Yermosols and Xerosols since no other characteristics than moisture regime could be found to separate them. The aridic moisture regime was however not taken into account when Vertisols, Ferralsols, Regosols, Arenosols, Solonchaks, Solonetz or Fluvisols were concerned. This arrangement was therefore unsatisfactory. Furthermore the separation between Yermosols and Xerosols on the basis of the contents of organic matter in the ochric A horizon was not applicable in practice. Henceforth all soils occurring in arid areas will be classified according to their morphology. A 'yermic phase' has been introduced denoting particular features of the land surface due to sand blowing, lack of leaching and prolonged drought in arid environments.

New major groupings of Calcisols and Gypsisols have been introduced to distinguish soils in which the accumulation of calcium carbonate or gypsum, or both, is the dominant soil forming process. Though such soils are not limited to arid regions they occur dominantly under arid and semi-arid conditions.

Recent surveys in South America, especially in Brazil have revealed the occurrence of large areas of soils with plinthite causing surface waterlogging and flooding in flat or gently undulating relief. A distinction at the first level of classification is now made under the name of Plinthosols (from Gr. plinthos, brick; connotative of mottled clayey material which hardens upon exposure). These soils are markedly different from Ferralsols with which they were previously grouped.

Humic units have been introduced for soils which may have either mollic or umbric A horizons. The Humic Podzols have been changed to Carbic Podzols to distinguish the high organic carbon in the spodic B horizon of some Podzols from organic matter accumulated in the topsoil.

A major grouping of Anthrosols (from Gr. anthropos, man) has been added to accommodate soils which have been strongly influenced by human interference. It is anticipated that soils with a fimic A horizon, landfillings, mine tailings, waste disposals, accretion of sediments by long-lasting irrigation or horizon obliteration by deep cultivation, will find a place here.

Some of the major soil groupings have been further subdivided or some of their subdivisions have been modified. These modifications are shown in the list of soil units which follows and will appear clearly from the newly proposed definitions. They are given in full in Chapter VI.

Since the Soil Map of the World legend has been and is being used for mapping at scales larger than 1:5 000 000 the need for third level soil subunits has been felt. These subunits are either intergrades between first or second level units or mark characteristics in addition to those used in the definitions at soil unit level. It is not possible at present to draw up a comprehensive list of third level subunits at a global scale. They need to be defined in accordance with specific needs. Chapter VII is devoted to general guidelines for distinguishing soil subunits. It is essential to keep local applications of the legend from drifting apart and thus vitiating a main objective of the World Soil Map, which is to provide a universally understood nomenclature.

Phases

Phases are features of the land which are significant to its use and management. Phases usually cut across soil boundaries and hence have not been used to define individual soil units. It should be noted that some phases are not necessarily related to present soil formation (e.g. petroferic horizons may be fossil).

The phases recognized in the original legend are being retained except for the 'cerrado phase'. This phase referred to a type of vegetation occurring in Brazil which is closely related to strongly depleted soils on old land surfaces. With the progress of soil survey in Brazil the delineation of these soils has now been made on the basis of their own characteristics so that the vegetative indicator is no longer required.

Phases to mark gilgai, flood hazards, modification by long lasting paddy cultivation, frost heaving and the occurrence of a thin iron pan or takyric features have been added under the terms gilgai, inundic, anthraquic, gelundic, placic and takyric respectively. As indicated above a yermic phase has been introduced to mark particular land features which are the result of aridity.

The term 'rudic' (from L. rudus, broken stone) has been introduced to rename the 'stony phase'.

The definitions of the phases used in the present revision are given in Chapter VIII.

Nomenclature

For the development of the legend it was a policy to make use, as much as possible, of existing soil names which had acquired international status, such as Chernozems, Kastanozems, Podzols, Planosols, Solonetz, Solonchaks and Regosols.

Names which in recent years had acquired a more general acceptance like Vertisols, Andosols, Gleysols, Histosols and Ferralsols had also been adopted. For a number of soil units it was necessary to coin new names. They were mostly derived from Latin and Greek roots with a view to facilitate their use at international level and ensure easy translation in different languages. New names introduced for major soil groupings and presently retained, are Fluvisols, Arenosols, Phaeozems, Greyzems, Cambisols, Luvisols, Podzoluvisols, Acrisols and Nitisols. With the present revision of the legend additional major groupings added are the Anthrosols, Alisols, Calcisols, Gypsisols, Leptosols, Lixisols and Plinthosols. The formative elements of the names of major soil groupings and soil units are given in Chapter III.

Climatic zones

With the preparation of the Soil Map of the World it was recognized that a separation should be made between soils which were morphologically similar but occurred in different climatic environments. It was decided, however, not to incorporate climatic characteristics into the definition of the soil units. In order to keep the number of soil units within manageable limits, climatic data used in a soil classification have necessarily to be of a general nature and therefore they are not sufficient to carry a significant interpretation value. Furthermore it was felt that the classification of soils should not be subordinated to the availability of climatic data which are scarce in many developing countries.

FAO's Agro-ecological zones study (FAO, 1978-1981) provides the means to make climatic separations through an overlay on the soil map of major climates and of lengths of growing period. The data available so far apply mainly to developing countries. Additional information is being compiled for developed countries so that climatic zones could be applied uniformly at a global level.

Major climates and lengths of growing period are commented upon in Chapter IX.

A tool for development

Over the years the use of the Soil Map of the World legend for surveys at scales larger than 1:5 000 000 has proved to be adequate for actual soil surveys. The incorporation in the mapping units of textural and slope classes has appeared to be most useful for interpretation purposes. Though the textural and slope classes are presently limited to three each, they could be further subdivided so as to further

qualify these two characteristics which are of paramount importance for management. The overlay on the soil map of climatic zones fulfils the need for data required for land evaluation and suitability ratings for specific types of land use.

It should be stressed that the Soil Map of the World legend is not meant to replace national soil classification systems. The legend, even though now expanded, is still not meant to be a taxonomic classification. It groups soils which are known to be mappable, are known to exist and are representative of the soil cover in major regions of the world. The legend aims at being a common denominator between various systems so that comparisons can be made. In other instances it may also become a tool for soil survey and land evaluation in countries which have not adopted a specific system of classification and wish to conduct soil inventories within the overall framework of the Soil Map of the World.

Because of its universality and simplicity, many people other than soil scientists, are familiar with and use the legend, so bringing the results of soil studies into wider and easier use. Contractors have applied it in feasibility studies. The legend is effective as a tool for development and for the transfer of experience.

Acknowledgements

The original legend of the Soil Map of the World was developed under the scientific authority of an international Advisory panel (FAO, 1974). Many scientists and national institutions contributed to the preparation of the regional map sheets and hence also to the elaboration of the legend. Their cooperation is herewith acknowledged and is individually mentioned in the relevant volumes of the Soil Map of the World.

The Unesco secretariat was represented by V.A. Kovda, M. Batisse and S.V. Evteev. The responsibility for the coordination of the project rested with FAO. It was successively assumed by D.L. Bramão, L.D. Swindale and R. Dudal. Soil correlation and the preparation of the legend were entrusted to R. Dudal.

This 1988 revision of the legend was carried out by a joint FAO/Unesco/ISRIC Working Group composed of G.M. Higgins, R. Brinkman and M.F. Purnell (FAO), F. Fournier (Unesco) and W.G. Sombroek (ISRIC). R. Dudal, J. Lozet and A. Pérot served with the Working Group as FAO consultants.

The amendments of the legend are based on discussions held at various international fora on soil classification, suggestions made by a great number of colleagues, FAO staff and contributors to the project from many different countries, findings of recent soil surveys and additional insight gained in the areal distribution of major soils in the world. The Working

Group expresses its great appreciation for all the inputs which it has received.

On behalf of the three participating organizations this Revised Legend is published in FAO's World Soil Resources Reports series¹

Suggestions and comments are invited. They should be sent to the

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NOTE:

Appendix 1,
Soil Horizon Designations
is taken from:
Guidelines for Soil Description
3rd edition (Revised)
FAO, Rome, 1990
p. 27-38

and

Directives pour la Description des Sols
3^e édition (révisée)
FAO, Rome, 1994

¹ The bibliographic reference to this report is :
Food and Agriculture Organization of the United Nations,
1988. FAO/Unesco Soil Map of the World, Revised Legend.
World Soil Resources Report 60, FAO. Rome.

II. GENERAL PRINCIPLES

Lack of a generally accepted system of soil classification was a major obstacle to the preparation of the Soil Map of the World. The systems in use show profound divergencies resulting from differences in approach to classification as such, varying concepts of soil formation, and dissimilarities in the environments to which the systems were to be applied. It was therefore necessary to establish a common denominator between different soil classification systems, and to combine into one outline the major soil units which have been recognized in all parts of the world, both in virgin conditions and under cultivation.

The soil units adopted were selected to the extent possible on the basis of present knowledge of the formation, characteristics and distribution of the soils covering the earth's surface, their importance as resources for production and their significance as factors of the environment. These units do not correspond to equivalent categories in different classification systems, but they are generally comparable to the 'great group' level.

To secure reliable identification and correlation in areas far apart, the soil units have been defined in terms of measurable and observable properties. To keep the system 'natural', the differentiating criteria are essential properties of the soil itself. Key properties have been selected on the basis of generally accepted principles of soil formation so as to correlate with as many other characteristics as possible. Such clusters of properties are combined into so-called 'diagnostic horizons' which have been adopted for formulating the definitions. Many key properties are relevant to soil use and have a practical value for application. As a result, the units which have been distinguished have prediction value for the use of the soil.

The construction of the legend was based on an international agreement regarding the major soils to be represented on the Soil Map of the World. No consensus could be obtained, however, on the 'weight' which each of these units should have within a classification 'system'. It is precisely in the concepts on which the subdivisions in categories are based - zonality, evolution, morphology, ecology or geography - that existing soil classification systems differ most. It appeared that, apart from differences in approach, available knowledge of the world's soils makes it difficult to apply any of these concepts on a global basis.

A systematic presentation of the complete list of soil units and major soil groupings is shown in Chapter III on pages 14 and 15. An endeavour has been made to group them in columns reflecting a geographical and evolutionary background.

The first column includes the soils which are not bound to specific, zonal climatic conditions: the Fluvisols, Gleysols, Regosols and Leptosols.

The second column comprises soils in which soil formation is conditioned by the parent material: Arenosols, Andosols and Vertisols.

The Cambisols stand alone as soils of initial soil formation of various kinds more strongly expressed in other soils.

The soils in the next column show accumulations of salts, they generally occur in aridic conditions or are physiologically droughty: Calcisols, Gypsisols, Solonchaks and Solonetz.

The fifth column groups soils characterized by a marked surface accumulation of base-saturated organic matter. They normally occur in steppe, or forest-steppe environments: Kastanozems, Chernozems, Phaeozems and Greyzems.

The soils in the sixth column show an accumulation of clay, or of sesquioxides and organic matter, in the subsurface horizons: Luvisols, Planosols, Podzoluvisols and Podzols.

The seventh column comprises the large group of soils which are dominant in tropical and sub-tropical regions where weathering is intense: Lixisols, Acrisols, Alisols, Nitisols, Ferralsols and Plinthosols.

In the last column the Histosols are organic soils in contrast to all the mineral soils listed previously. The Anthrosols are distinctive in having characteristics and processes profoundly modified by human influences.

The degree of soil profile development cannot be used consistently for classification purposes, since soils in different parts of the world are not members of a continuous sequence of soil formation. For example, one can hardly compare the degree of development of Podzols and Ferralsols, or of Luvisols and Kastanozems, since these soils are products of different environments and of different combinations of soil-forming processes. The same applies to the concept of zonality, since the influence of climatic factors is often secondary to the effect of parent material or age: for instance, Podzols may occur both under boreal and tropical climates; Planosols are formed under conditions of alternating wetness and dryness which are often bound to specific physiographic conditions rather than to overall climate.

The soil classification used for the Soil Map of the World is not a mere summation of elements but is meant to allow for a creative synthesis and factual inventory for the distribution and characteristics of the world's soils which can be used for both practical and scientific purposes. Although the present attempt has shortcomings, some of which result from the necessity of reaching an international consensus, it is hoped that it will be an important aid in the adoption of a generally accepted international reference base (IRB) for soil classification which is being developed by the ISSS.

III. NOMENCLATURE

For easy reference and communication, the use of soil names is a necessity. Names are meant to sum up, in an easily remembered term, a set of characteristics which have been found to be representative of a particular soil in different parts of the world.

An attempt has been made to use as many 'traditional' names as possible, such as Chernozems, Kastanozems, Podzols, Planosols, Solonetz, Solonchaks and Regosols. Names which in recent years have acquired a more general acceptance, like Vertisols, Andosols, Gleysols and Ferralsols, have also been adopted. Sharpening the definitions of these units by the use of precisely defined terms may have created a narrower concept than that found in the literature for units bearing the same names. It should therefore be stressed that the uniformity aimed at in the preparation of the Soil Map of the World will be reached only if the names are used in accordance with the definitions which have been agreed upon, possibly at the cost of restricting the meaning which they have acquired locally.

A number of terms, such as Podzolized, Podzolic, Brown Forest, Prairie, Mediterranean, Desert, Semi-arid Brown, Lateritic and Alluvial soils, though firmly established in current soils literature, could not be retained without perpetuating the confusion created by the dissimilar use of these terms in different countries. For a limited number of soils it was imperative to coin new names. Their selection was influenced by the requirement for international work that the names would not change markedly with translation nor have different meanings in different countries.

Throughout the years the terms 'podzolized' and 'podzolic' have come to be used to indicate illuvial clay accumulation, the formation of a bleached horizon, the penetration of bleached tongues of eluvial material in a B horizon, an abrupt textural change between an eluvial horizon and a B horizon, and illuviation of acid organic matter or sesquioxides. In order to avoid the confusion which has arisen from the different uses of these terms, the names Luvisols (from L. *luere*, to wash, 'lessiver'), and Acrisols (from L. *acer*, acetum, strong acid) have been introduced for soils in which the essential characteristic is the accumulation of clay under conditions of, respectively, high or low base saturation.

In this revised edition a distinction is made between Luvisols, having high activity clays, and other soils showing clay accumulation and high base saturation but having low activity clays. The latter being located mainly in tropical areas were called Lixisols (from L. *lixivia*, washing). Similarly, the Acrisols were subdivided on the basis of their clay activity into Acrisols proper, having low cation exchange capacity, and Alisols (from L. *alumen*) having a higher cation exchange capacity and generally having a high total exchangeable aluminium content.

Soils in which an abrupt textural change is due not only to clay accumulation but possibly to a destruction of clay in the surface horizon, are distinguished as Planosols (from L. planus, level, flat; connotative of the level or depressed relief in which these soils generally develop).

The term Podzols is reserved here for soils which have a B horizon showing an illuvial accumulation of iron or organic matter, or both, but lacking clayskins on ped faces or in pores. Soils characterized by an illuvial accumulation of clay, tonguing of the E horizon into the B horizon, and an accumulation of iron and organic matter in addition to the accumulation of clay, have been called Podzolusols. The name Glossisols (from Gr. glossa, tongue) was also proposed because of the tonguing which is characteristic of these soils. However, as they are called podzolic in large areas of Europe, it was decided that this precedence should be taken into account in coining the new name.

In literature the name 'Brown Forest soils' has been used to describe a wide variety of different soils. In its original concept it was a soil developing in sub-humid temperate climates, having a 'mull' humus, a B horizon with a stronger coloration and a slightly higher clay content than the C horizon, but showing no signs of clay illuviation, and having calcium carbonate in the lower part of the solum. Subsequently this term was used also for acid soils (Acid Brown Forest soils), tropical soils (Sols bruns tropicaux eutrophes) and for soils with clay illuviation (Podzolized Brown Forest soils). Further difficulties arise in separating Brown Forest soils from Brown Wooded soils, Burozems, Brunosols or Brown soils, and in justifying how certain Brown Forest soils may be red or yellow or may never have borne any type of forest. For these reasons the name Cambisols was coined as a common denominator (from late L. cambiare, to change; connotative of changes in colour, consistence and structure which result from weathering in situ).

The term Phaeozems (from Gr. phaios, dusky; connotative of the dark colour of the A horizon) has been coined for soils which occur in a transitional belt between Chernozems or Kastanozems and Luvisols. In the literature these soils have been known as Prairie soils, Brunizems, Chernozems or degraded Chernozems. These terms were not suitable for international use because of the restricted meaning resulting from the reference either to vegetative cover or to colour.

List of soil units

FL FLUVISOLS

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

AR ARENOSOLS

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

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

AN ANDOSOLS

ANh Haplic Andosols
ANm Mollic Andosols
ANu Umbric Andosols
ANz Vitric Andosols
ANG Gleyic Andosols
ANi Gelic Andosols

VR VERTISOLS

RG REGOSOLS

RGe Eutric Regosols
RGc Calcaric Regosols
RGy Gypsic Regosols
RGd Dystric Regosols
RGu Umbric Regosols
RGi Gelic Regosols

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

LP LEPTOSOLS

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

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

CL CALCISOLS

CLh Haplic Calcisols
CLl Luvic Calcisols
CLp Petric Calcisols

GY GYPISISOLS

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

SN SOLONETZ

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

SC SOLONCHAKS

SCh Haplic Solonchaks
SCm Mollic Solonchaks
SCh Calcic Solonchaks
SCy Gypsic Solonchaks
SCn Sodid Solonchaks
SCg Gleyic Solonchaks
SCi Gelic Solonchaks

KS	KASTANOZEMS	LV	LUVISOLS
KSh	Haplic Kastanozems	LVh	Haplic Luvisols
KSI	Luvic Kastanozems	LVf	Ferric Luvisols
KSk	Calcic Kastanozems	LVx	Chromic Luvisols
KSy	Gypsic Kastanozems	LVk	Calcic Luvisols
		LVv	Vertic Luvisols
CH	CHERNOZEMS	LVa	Albic Luvisols
		LVj	Stagnic Luvisols
CHh	Haplic Chernozems	LVg	Gleyic Luvisols
CHk	Calcic Chernozems		
CHI	Luvic Chernozems		
CHw	Glossic Chernozems	PL	PLANOSOLS
CHg	Gleyic Chernozems		
		PLe	Eutric Planosols
		PLd	Dystric Planosols
PH	PHAEZEMS	PLm	Mollic Planosols
		PLu	Umbric Planosols
PHh	Haplic Phaeozems	PLi	Gelic Planosols
PHc	Calcaric Phaeozems		
PHl	Luvic Phaeozems		
PHj	Stagnic Phaeozems	PD	PODZOLUVISOLS
PHg	Gleyic Phaeozems		
		PDe	Eutric Podzoluvisols
		PDd	Dystric Podzoluvisols
GR	GREYZEMS	PDj	Stagnic Podzoluvisols
		PDg	Gleyic Podzoluvisols
GRh	Haplic Greyzems	PDi	Gelic Podzoluvisols
GRg	Gleyic Greyzems		
		PZ	PODZOLS
		PZh	Haplic Podzols
		PZb	Cambic Podzols
		PZf	Ferric Podzols
		PZc	Carbic Podzols
		PZg	Gleyic Podzols
		PZi	Gelic Podzols

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

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

HS HISTOSOLS

HSI Follic Histosols
HSs Terric Histosols
HSf Fibric Histosols
HSst Thionic Histosols
HSi Gelic Histosols

AT ANTHROSOLS

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

The terms 'laterite' and 'lateritic soils' are not used here. They were originally restricted to soils, or to weathered material, rich in iron which hardens upon exposure. The term was progressively extended to soils with mottled clay, soils with layers of loose concretions, soils with thick iron pans and, even more broadly, to red or yellow soils of tropical regions. For the non-hydromorphic soils having a low silica-sesquioxide ratio and absence of an argic B horizon, the name Ferralsols, which combines brevity, connotation and a fairly wide acceptance, has been retained. The hydromorphic soils containing a bleached horizon above plinthite ('mottled clay') are separated as Plinthosols. Irreversibly hardened sesquioxide materials are separated as skeletal or petroferic phases of Ferralsols or other major soil groupings such as Acrisols and Lixisols. Plinthite layers which are not associated with waterlogging are accommodated as plinthic units of Ferralsols, Acrisols or Lixisols.

The term 'lateritic' is particularly inappropriate for the so-called Reddish-Brown Lateritic soils which show a movement of clay within the profile but have diffuse horizon boundaries and a deeply stretched clay bulge. These soils generally have a low clay activity but because of their favourable physical properties and their often higher fertility, especially when derived from basic rock, they are separated from the Ferralsols. They have been called Nitisols (from L. nitidus, shiny, bright, lustrous, connotative of shiny ped faces).

Widely divergent use has also been made of the term 'Alluvial soils'. In its most restricted sense this name has been applied to soils on recent alluvial deposits, enriched at regular intervals by fresh sediments and showing no profile development. In contrast, the broadest connotation of the term includes soils developed from alluvial deposits, regardless of age, in which some profile development may have taken place. In order to avoid differences of interpretation the name Fluvisols has been introduced and newly defined.

Newly introduced names such as Histosols (from Gr. histos, tissue) for organic soils, Anthrosols (from Gr. anthropos, man) for soils resulting from human activities, Arenosols (from L. arena, sand) for weakly developed coarse textured soils, Calcisols (from L. calx, lime) for soils with a marked accumulation of calcium carbonate, Gypsisols (from L. gypsum) for soils with a marked accumulation of gypsum, Leptosols (from Gr. leptos, thin) connotative of shallow soils, Plinthosols (from Gr. plinthos, brick) for soils with mottled clays which harden on exposure, are self-explanatory.

The formative elements of the names of the major soil groupings and soil units are given below, explaining the etymology of the name:

Formative elements used for naming Major Soil Groupings (level 1)

ACRISOLS : from L. *acer*, acetum, strong acid; connotative of low base saturation.

ALISOLS : from L. *alumen*; connotative of high aluminium content.

ANDOSOLS : from Japanese *an*, dark and *do*, soil; connotative of soils formed from materials rich in volcanic glass and commonly having a dark surface horizon.

ANTHROSOLS : from Gr. *anthropos*, man; connotative of human activities.

ARENOSOLS : from L. *arena*, sand; connotative of weakly developed coarse textured soils.

CALCISOLS : from L. *calx*, lime; connotative of accumulation of calcium carbonate.

CAMBISOLS : from late L. *cambiare*, to change; connotative of changes in colour, structure and consistence.

CHERNOZEMS : from Russian *chern*, black and *zemlja*, earth, land; connotative of soils rich in organic matter having a black colour.

FERRALSOLS : from L. *ferrum* and *alumen*; connotative of a high content of sesquioxides.

FLUVISOLS : from L. *fluvius*, river; connotative of alluvial deposits.

GLEYSOLS : from Russian local name *gley*, mucky soil mass; connotative of an excess of water.

GREYZEMS : from Anglo-Saxon *grey*, and Russian *zemlja*, earth, land; connotative of uncoated silt and quartz grains which are present in layers rich in organic matter.

GYPSISOLS : from L. *gypsum*; connotative of accumulation of calcium sulphate.

HISTOSOLS : from Gr. *histos*, tissue; connotative of fresh or partly decomposed organic material.

KASTANOZEMS : from L. *castanea*, chestnut, and from Russian *zemlja*, earth, land; connotative of soils rich in organic matter having a brown or chestnut colour.

LEPTOSOLS : from Gr. *leptos*, thin; connotative of weakly developed shallow soils.

LIXISOLS : from L. *lixivia*, washing; connotative of accumulation of clay and strong weathering.

LUVISOLS : from L. *luere*, to wash, 'lessiver'; connotative of accumulation of clay.

NITISOLS : from L. *nitidus*, shiny; connotative of shiny ped faces.

PHAEZEMS : from Gr. *phaios*, dusky and Russian *zemlja*, earth, land; connotative of soils rich in organic matter having a dark colour.

PLANOSOLS : from L. *planus*, flat, level; connotative of soils generally developed in level or depressed relief with seasonal surface waterlogging.

PLINTHOSOLS : from Gr. *plinthos*, brick; connotative of mottled clayey materials which harden upon exposure.

PODZOLS : from Russian *pod*, under and *zola*, ash; connotative of soils with a strongly bleached horizon.

PODZOLUVISOLS : from *Podzols* and *Luvissols*.

REGOSOLS : from Gr. *rhegos*, blanket; connotative of a mantle of loose material overlying the hard core of the earth.

SOLONCHAKS : from Russian *sol*, salt, and *chak*; connotative of salty area.

SOLONETZ : from Russian *sol*, salt, and *etz*, strongly expressed.

VERTISOLS : from L. *vertere*, to turn; connotative of turnover of surface soil.

Formative elements used for naming Soil Units (level 2)

ALBIC : from L. *albus*, white; connotative of strong bleaching.

ANDIC: from Japanese *an*, dark and *do*, soil; connotative of Andosols.

ARIC : from L. *arare*, to plough; connotative of plough layer.

- CALCARIC : from L. *calcarius*, calcareous; connotative of the presence of calcareous material.
- CALCIC : from L. *calx*, lime; connotative of accumulation of calcium carbonate.
- CAMBIC : from late L. *cambiare*, change; connotative of change in colour, structure or consistence.
- CARBIC : from L. *carbo*, charcoal; connotative of high organic carbon content in spodic B horizons.
- CHROMIC : from Gr. *chromos*, colour; connotative of soils with bright colours.
- CUMULIC : from L. *cumulare*, to accumulate; connotative of accumulation of sediments.
- DYSTRIC : from Gr. *dys*, ill, dystrophic, infertile; connotative of low base saturation.
- EUTRIC : from Gr. *eu*, good, eutrophic, fertile; connotative of high base saturation.
- FERRALIC : from L. *ferrum* and *alumen*; connotative of a high content of sesquioxides.
- FERRIC : from L. *ferrum*, iron; connotative of ferruginous mottling or an accumulation of iron.
- FIBRIC : from L. *fibra*, fibre; connotative of weakly decomposed organic material.
- FIMIC : from L. *finum*, manure, slurry, mud; connotative of a horizon formed by long continued manuring.
- FOLIC : from L. *folium*, leaf; connotative of undecomposed organic material.
- GELIC : from L. *gelu*, frost; connotative of permafrost.
- GERIC : from Gr. *geraios*, old; connotative of strong weathering.
- GLEYPIC : from Russian local name *gley*, mucky soil mass.
- GLOSSIC : from Gr. *glossa*, tongue; connotative of tonguing of a horizon into the underlying layers.
- GYPSIC : from L. *gypsum*; connotative of an accumulation of gypsum.
- HAPLIC : from Gr. *haplous*, simple; connotative of soils with a simple, normal horizon sequence.

- HUMIC : from L. *humus*, earth; rich in organic matter.
- LITHIC: from Gr. *lithos*, rock; connotative of very thin soils.
- LUVIC : from L. *luere*, to wash, 'lessiver'; connotative of accumulation of clay.
- MOLLIC : from L. *mollis*, soft; connotative of good surface structure.
- PETRIC: from L. *petra*, stone; connotative of the presence of an indurated layer at shallow depth.
- PLINTHIC : from Gr. *plinthos*, brick; connotative of mottled clay materials which harden irreversibly upon exposure.
- RENDZIC : from Polish colloquial *rzedzic*, connotative of noise made by plough over shallow stony soil.
- RHODIC : from Gr. *rhodon*, rose; connotative of red coloured soils.
- SALIC : from L. *sal*, salt; connotative of high salinity.
- SODIC: from L. *sodium*; connotative of high content of exchangeable sodium.
- STAGNIC: from L. *stagnare*, to flood; connotative of surface water-logging.
- TERRIC : from L. *terra*, earth; connotative of well decomposed and humified organic materials.
- THIONIC : from Gr. *theion*, sulfur; denoting the presence of sulfidic materials.
- UMBRIC : from L. *umbra*, shade; denoting the presence of an umbric A horizon.
- URBIC : from L. *urbs*, town; connotative of disposal of wastes.
- VERTIC : from L. *vertere*, to turn; connotative of a turnover of surface soil.
- VITRIC : from L. *vitrum*, glass; connotative of soils rich in vitric material.
- XANTHIC : from Gr. *xanthos*, yellow; connotative of yellow coloured soils.

IV. DIAGNOSTIC HORIZONS

Soil horizons that combine a set of properties which are used for identifying soil units are called 'diagnostic horizons'. Since the characteristics of soil horizons are produced by soil-forming processes, the use of diagnostic horizons for separating soil units relates the classification to general principles of soil genesis. Objectivity is secured, however, in that the processes themselves are not used as criteria but only their effects, expressed in terms of quantitatively defined morphological properties that have identification value.

The definitions and nomenclature of the diagnostic horizons used here are drawn from those adopted in Soil Taxonomy (U.S. Soil Conservation Service, 1975). 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 horizon terminology 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 clay activity is a diagnostic property, it may be desirable to deduct CEC linked to organic matter preferably by a graphical method for individual profiles (Bennema and Camargo, 1979; Brinkman, 1979; Klamt and Sombroek, 1987). The application of this method requires that the clay mineralogy is homogeneous throughout the soil profiles, at least to a depth of 125 cm.

The terminology used to describe soil morphology is the one adopted in Guidelines for Soil Description 3rd Edition (revised), FAO, Rome, 1990, and Directives pour la Description des Sols 3^e édition (révisée) FAO, Rome, 1994. Colour notations are according to the Munsell Soil Color Charts. Chemical and physical characteristics are expressed on the basis of Soil Survey Laboratory Methods and Procedures for Collecting Soil Samples (U.S. Department of Agriculture, 1984). A further elaboration of these methods is given in the ISRIC Procedures for Soil Analyses (ISRIC, 1995).

HISTIC H HORIZON

The histic H horizon is an H horizon which has its upper boundary within 40 cm of the surface and is more than 20 cm but less than 40 cm thick. It can be more than 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 Mg m^{-3} .

A surface layer of organic material less than 25 cm thick also qualifies as a histic H horizon if, after having been mixed to a depth of 25 cm, it has 16 percent or more organic carbon and the mineral fraction contains more than 60 percent clay, or 8 percent or more organic carbon and the mineral fraction contains no clay, or intermediate proportions of organic carbon for intermediate contents of clay. The same criteria apply to a plough layer which is 25 cm or more thick.

MOLLIC A HORIZON

The mollic A horizon is an A horizon which, after the surface 18 cm are mixed, as in ploughing, has the following properties:

1. the soil structure is sufficiently strong that the horizon is not both massive and hard or very hard when dry. Very coarse prisms larger than 30 cm in diameter are included in the meaning of massive if there is no secondary structure within the prisms.
2. both broken and crushed samples have colours with a chroma of less than 3.5 when moist, a value darker than 3.5 when moist and 5.5 when dry; the colour value is at least one unit darker than that of the C (both moist and dry) unless the soil is strongly humic or is derived from dark coloured parent material, in which cases the colour contrast criterion is waived. If a C horizon is not present, comparison should be made with the horizon immediately underlying the A horizon. If there is more than 40 percent finely divided lime, the limits of colour value dry are waived; the colour value, moist, should then be 5 or less.
3. the base saturation (by NH_4OAc) is 50 percent or more.
4. the organic carbon content is at least 0.6 percent throughout the thickness of mixed soil, as specified below. The organic carbon content is at least 2.5 percent if the colour requirements are waived because of finely divided lime. The upper limit of organic carbon content of the mollic A horizon is the lower limit of the histic H horizon.
5. the thickness is 10 cm or more if resting directly on hard rock, a petrocalcic horizon, a petrogypsic horizon or a duripan; the thickness of the A must be at least 18 cm and more than one third of the thickness of the solum where the solum is less than 75 cm thick, and must be more than 25 cm where the solum is more than 75 cm thick. The measurement of the thickness of a mollic A horizon includes transitional horizons in which the characteristics of the A horizon are dominant - for example, AB, AE or AC.

6. the content of P_2O_5 soluble in 1 percent citric acid is less than 250 mg kg^{-1} soil. This restriction is made to eliminate plough layers of very old arable soils or kitchen middens. The restriction does not apply, however, if the amount of P_2O_5 soluble in citric acid increases below the A horizon or when it contains phosphate nodules, as may be the case in highly phosphatic parent materials.

FIMIC A HORIZON

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. The fimic horizon as defined here includes the plaggen epipedon and the anthropic epipedon of Soil Taxonomy (U.S. Soil Conservation Service, 1975). If the fimic A horizon meets the requirements of the mollic or umbric A horizon it is distinguished from it by an acid-extractable P_2O_5 content which is higher than 250 mg kg^{-1} soil by 1 percent citric acid. This figure is retained as a limit of most natural soils. Many such man-made layers have a P_2O_5 content, soluble in citric acid, which is higher than $1\,000 \text{ mg kg}^{-1}$ soil. Both the analytical method and the limiting value are likely to be changed in future.

UMBRIC A HORIZON

The requirements of the umbric A horizon are comparable to those of the mollic A in colour, organic carbon and phosphorus content, consistency, structure and thickness. The umbric A horizon, however, has a base saturation (by NH_4OAc) of less than 50 percent.

OCHRIC A HORIZON

An ochric A horizon is one 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 and massive when dry. Finely stratified materials do not qualify as an ochric A horizon, e.g. surface layers of fresh alluvial deposits.

ARGIC B HORIZON

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 a destruction of clay in the surface horizon, or to a 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 a pedogenic textural differentiation. However, a mere lithological discontinuity, such as may occur in alluvial deposits, does not qualify as an argic B horizon. When an argic B horizon is formed by clay illuviation, clay skins (argillans, clay cutans, clay coatings)

may occur on ped surfaces, in fissures, in pores and in channels.

In order to be diagnostic an argic B horizon has to meet the following requirements:

1. have a texture that is sandy loam or finer in the fine earth fraction, and have at least 8% clay.
2. lack the set of properties which characterize the ferralic B horizon.
3. contain more total clay than an overlying coarser textured horizon (exclusive of differences which result from a lithological discontinuity only):
 - a. if the overlying horizon has less than 15 percent total clay in the fine earth fraction, the argic B horizon must contain at least 3 percent more clay (for instance, 17 percent versus 14 percent);
 - b. if the overlying horizon has 15 percent or more and less than 40 percent total clay in the fine earth fraction, the ratio of clay in the argic B horizon to that in the overlying horizon must be 1.2 or more (for instance, 36 percent versus 30 percent);
 - c. if the overlying horizon has 40 percent or more total clay in the fine earth fraction, the argic B horizon must contain at least 8 percent more clay (for instance, 50 percent versus 42 percent).
4. if at least some part of the argic B horizon shows clay skins on at least 1 percent of ped surfaces or in the pores, or shows oriented clay in at least 1 percent of the cross section, the increase in clay content must be reached within a vertical distance of 30 cm. If less than 1 percent or no clay skins or oriented clay are observed, the increase in clay content must be reached within a vertical distance of 15 cm.
5. the argic B horizon should be at least one tenth the thickness of the sum of all overlying horizons and should be at least 7.5 cm thick. If the argic B horizon is entirely composed of lamellae, the lamellae should have a combined thickness of at least 15 cm.
6. if there is no evidence of clay skins or oriented clay, the coarser textured horizon overlying the argic B horizon must be at least 18 cm thick after mixing, or 5 cm if the textural transition to the argic B horizon is abrupt. If the coarser textured overlying horizon has been eroded or if there is a lithological discontinuity above or within the argic B horizon, or if only a plough layer overlies the argic B horizon, there is evidence of clay skins or oriented clay in at least some subhorizon of the argic B horizon.

7. lack the structural and sodium saturation characteristics of the natric B horizon.

The above definition of the argic B horizon is an attempt to overcome the difficulties experienced with the field application of the former argillic B horizon and to allow for the recognition, as a diagnostic feature, of a distinct textural differentiation even when clay skins cannot be identified. On the other hand clay accumulation, which may occur in Ferralsols, is excluded from the argic B horizon on account of the low CEC, the low content of water-dispersible clay and the low silt-clay ratio.

It is realized that the implications of this definition will need to be tested in the field and that further adjustments may be needed. New elements in this definition are the textural limit of sandy loam or finer and the lower limit for clay content (also adopted for the cambic and ferralic B horizons). Thus most coarse textured soils are grouped as Arenosols (with a differentiation between luvisc, cambic and ferralic units) and other soils with very low clay content as Regosols, which are logical separation geographically and for management.

NATRIC B HORIZON

The natric B horizon has the properties 1 to 6 of the argic B horizon as described above. In addition, it has :

1. a columnar or prismatic structure in some part of the B horizon, or a blocky structure with tongues of an eluvial horizon in which there are uncoated silt or sand grains extending more than 2.5 cm into the horizon.
2. a saturation with exchangeable sodium of more than 15 percent within the upper 40 cm of the horizon; or more exchangeable magnesium plus sodium than calcium plus exchange acidity (at pH 8.2) within the upper 40 cm of the horizon if the saturation with exchangeable sodium is more than 15 percent in some subhorizon within 200 cm of the surface.

CAMBIC B HORIZON

The cambic B horizon is an altered horizon lacking 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, or the mollic and umbric A horizons; having the following properties:

1. has a texture that is sandy loam or finer in the fine earth fraction, and has at least 8% clay.
2. is at least 15 cm thick with its base at least 25 cm below the soil surface.

3. soil structure is at least moderately developed or rock structure is absent in at least half the volume of the horizon.
4. has a cation exchange capacity of more than $16 \text{ cmol}(+) \text{ kg}^{-1}$ clay, or has a content of 10 percent or more weatherable minerals in the 50-200 μm fraction, or has more than 10 percent water dispersible clay, or has a silt-clay ratio which is more than 0.2.
5. shows evidence of alteration in one of the following forms:
 - a. stronger chroma, redder hue, or higher clay content than the underlying horizon;
 - b. evidence of removal of carbonates. Particularly, the cambic B horizon has less carbonate than an underlying horizon of calcium carbonate accumulation. If all coarse fragments in the underlying horizon are completely coated with lime, some in the cambic B horizon are partly free of coatings. If coarse fragments in the horizon showing calcium carbonate accumulation are coated only on the underside, those in the cambic B horizon should be free of coatings;
 - c. if carbonates are absent in the parent material and in the dust that falls on the soil, the required evidence of alteration is satisfied by the presence of soil structure and the absence of rock structure in more than 50 percent of the horizon.
6. shows no cementation, induration or brittle consistence when moist.

SPODIC B HORIZON

A spodic B horizon meets one or more of the following requirements below a depth of 12.5 cm, or, when present, below an A horizon or an E horizon:

1. a subhorizon more than 2.5 cm thick that is continuously cemented by a combination of organic matter with iron or aluminium or with both.
2. a sandy or coarse-loamy texture with distinct dark pellets of coarse silt size or larger or with sand grains covered with cracked coatings which consist of organic matter and aluminium with or without iron.
3. one or more subhorizons in which:
 - a. if there is 0.1 percent or more extractable iron, the ratio of iron plus aluminium extractable by pyrophosphate at pH 10 to percentage of clay is 0.2 or more, or if there is less than 0.1 percent extractable iron, the ratio of aluminium plus organic carbon to clay is 0.2 or more; and

b. the sum of pyrophosphate-extractable iron plus aluminium is half or more of the sum of dithionite-citrate extractable iron plus aluminium; and

c. the thickness is such that the index of accumulation of amorphous material in the subhorizons that meet the preceding requirements is 65 or more. This index is calculated by subtracting half of the clay percentage from CEC at pH 8.2 expressed in $\text{cmol}(+)\text{kg}^{-1}$ clay and multiplying the remainder by the thickness of the subhorizon in centimetres. The results of all subhorizons are then added.

FERRALIC B HORIZON

The ferralic B horizon is a horizon that:

1. has a texture that is sandy loam or finer in the fine earth fraction.
2. is at least 30 cm thick.
3. has a cation-exchange capacity equal to or less than $16 \text{ cmol}(+) \text{ kg}^{-1}$ clay or has an effective cation-exchange capacity equal to or less than $12 \text{ cmol}(+) \text{ kg}^{-1}$ clay (sum of NH_4OAc exchangeable bases plus 1 M KCl-exchangeable acidity).
4. has less than 10 percent weatherable minerals in the 50 - 200 μm fraction.
5. has less than 10 percent water-dispersible clay.
6. has a silt-clay ratio which is 0.2 or less.
7. does not have andic properties.
8. has less than 5 percent by volume showing rock structure.

CALCIC HORIZON

The calcic horizon is a horizon of accumulation of calcium carbonate. The accumulation may be in the C horizon, but it may also occur in a B or in an A horizon.

The calcic horizon is enriched with secondary carbonate over a thickness of 15 cm or more, has a calcium carbonate equivalent content of 15 percent or more and at least 5 percent greater than that of a deeper horizon. The latter requirement is expressed by volume if the secondary carbonates in the calcic horizon occur as pendants on pebbles, or as concretions or soft powdery forms. If such a calcic horizon rests on very calcareous materials (40 percent or more calcium carbonate equivalent), the percentage of carbonates need not decrease with depth.

PETROCALCIC HORIZON

A 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. Non-capillary pores are filled; hydraulic conductivity is moderately slow to very slow. It is usually thicker than 10 cm. A laminar capping is commonly present but is not required. Carbonates constitute half or more of the weight of the laminar horizon if this is present.

GYPSIC HORIZON

The gypsic horizon is enriched with secondary calcium sulphate, is 15 cm or more thick, has at least 5 percent more gypsum than the underlying C horizon, and the product of the thickness in centimetres and the percent of gypsum is 150 or more. The percentage of gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) is calculated as the product of gypsum content, expressed as $\text{cmol}(+) \text{ kg}^{-1}$ soil and the equivalent weight of gypsum, 86, divided by 10^3 . Gypsum may accumulate uniformly throughout the matrix or as nests of crystals; in gravelly material gypsum may accumulate as pendants below the coarse fragments.

PETROGYPSIC HORIZON

A petrogypsic horizon is a gypsic horizon that is so cemented with gypsum that dry fragments do not slake in water and roots cannot enter. The gypsum content in the petrogypsic horizon is commonly far greater than the minimum requirements for the gypsic horizon and usually exceeds 60 percent.

SULFURIC HORIZON

The sulfuric horizon forms as a result of artificial drainage and oxidation of mineral or organic materials which are rich in sulphides. It is at least 15 cm thick and characterized by a pH less than 3.5 (H_2O , 1:1) and generally has jarosite mottles with a hue of 2.5Y or more and a chroma of 6 or more.

ALBIC E HORIZON

The albic E horizon is one 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.

An albic E horizon has a colour value moist of 4 or more, or a value dry of 5 or more, or both. If the value dry is 7 or more, or the value moist is 6 or more, the chroma is 3 or less either dry or moist. If the value dry is 5 or 6, or if the value moist is 4 or 5, the chroma is closer to 2 than to 3 either dry or moist. If the parent materials have a hue of 5YR or redder, a chroma moist of 3 is permitted in the albic E horizon where the chroma is due to the colour of uncoated silt or sand grains.

V. DIAGNOSTIC PROPERTIES

Some of the characteristics which are used to separate soil units cannot be considered as horizons. They are diagnostic features of horizons or of soil materials which, when used for classification purposes, need to be quantitatively defined.

ABRUPT TEXTURAL CHANGE

An abrupt textural change is a clay increase between two layers, which takes place over a distance of less than 5 cm, where the lower layer shows the following:

1. a clay content which is at least twice the amount of clay in the overlying layer, if the latter has less than 20 percent clay (for instance 34 percent versus 17 percent); and
2. an absolute clay increase of 20 percent or more over the amount of clay in the overlying layer, if the latter has 20 percent clay or more (for instance 50 percent versus 30 percent).

ANDIC PROPERTIES

The term 'andic properties' applies to soil materials which meet one or more of the following three requirements:

1. a. acid oxalate extractable aluminium plus $\frac{1}{2}$ acid oxalate extractable iron is 2.0 percent or more in the fine earth fraction; and
b. bulk density of the fine earth fraction, measured in the field moist state, is 0.9 Mg m^{-3} or less; and
c. phosphate retention is more than 85 percent.
2. a. more than 60 percent by volume of the whole soil is volcanoclastic material coarser than 2 mm; and
b. acid oxalate extractable aluminium plus $\frac{1}{2}$ acid oxalate extractable iron is 0.40 percent or more in the fine earth fraction.
3. the 0.02 to 2.0 mm fraction is at least 30 percent of the fine earth fraction and meets one of the following:
 - a. if the fine earth fraction has acid oxalate extractable aluminium plus $\frac{1}{2}$ acid oxalate extractable iron of 0.40 percent or less, there is at least 30 percent volcanic glass in the 0.02 to 2.0 mm fraction; or
 - b. if the fine earth fraction has acid oxalate extractable aluminium plus $\frac{1}{2}$ acid oxalate extractable iron of 2.0 percent or more, there is at least 5 percent volcanic glass in the 0.02 to 2.0 mm fraction; or
 - c. if the fine earth fraction has acid oxalate extractable aluminium plus $\frac{1}{2}$ acid oxalate extractable iron of between 0.40 percent and 2.0 percent, there is a proportional content of volcanic glass in the 0.02 to 2.0 mm fraction between 30 and 5 percent.

CALCAREOUS

The term 'calcareous' applies to soil material which shows strong effervescence with 10 percent HCl in most of the fine earth or which contains more than 2 percent calcium carbonate equivalent.

CALCARIC

The term 'calcaric' refers to soils which are calcareous throughout the depth between 20 and 50 cm.

CONTINUOUS HARD ROCK

The term '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 few cracks produced in place without significant displacement of the pieces and horizontally distant an average of 10 cm or more. The material considered here does not include subsurface horizons such as a duripan, a petrocalcic or a petrogypsic horizon or a petroferric phase.

FERRALIC PROPERTIES

The term 'ferralic properties' is used in connection with Cambisols and Arenosols which have a cation exchange capacity (by NH_4OAc) of less than $24 \text{ cmol}(+) \text{ kg}^{-1}$ clay or less than $4 \text{ cmol}(+) \text{ kg}^{-1}$ soil in at least some subhorizon of the cambic B horizon or the horizon immediately underlying the A horizon.

FERRIC PROPERTIES

The term 'ferric properties' is used in connexion with Luvisols, Alisols, Lixisols and Acrisols showing one or more of the following: many coarse mottles with hues redder than 7.5YR or chromas more than 5, or both; 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 than the interiors.

FLUVIC PROPERTIES

The term 'fluvic properties' refers to fluvatile, marine and lacustrine sediments, which receive fresh materials at regular intervals, or have received them in the recent past, and which have one or both of the following properties:

1. an organic carbon content that decreases irregularly with depth or that remains above 0.20 percent to a depth of 125 cm. Thin strata of sand may have less organic carbon if the finer sediments below, exclusive of buried A horizons, meet the requirement.
2. stratification in at least 25 percent of the soil volume within 125 cm of the surface.

GERIC PROPERTIES

The term 'geric properties' refers to soil materials which have either:

1. 1.5 cmol(+) kg⁻¹ clay or less of exchangeable bases (Ca, Mg, K, Na) exchangeable acidity plus unbuffered 1M KCl extractable acidity; or
2. a delta pH (pH KCl minus pH H₂O) of +0.1 or more.

GLEYIC AND STAGNIC PROPERTIES

The terms 'gleyic and stagnic 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.

1. Reduction is evidenced by one or more of the following:

a. a value of $rH = \frac{Eh(mV)}{29} + 2 \text{ pH} \leq 19$

b. the appearance of a solid dark blue colour on a freshly broken surface of a field-wet soil sample, after spraying it with a solution in water of 1 percent potassium ferric cyanide, $K_3Fe(III)(CN)_6$;

c. the appearance of a strong red colour on a freshly broken surface of a field-wet soil sample, after spraying it with a 0.2 percent α, α dipyridyl solution in 10 percent acetic acid.

2. Gleyic properties related to saturation by groundwater are reflected by at least two of the following:

a. reduction conditions as defined under 1 for a part of the year or throughout the year;

b. groundwater standing in a deep unlined borehole at such a depth that the capillary fringe reaches the soil surface; the water in the borehole is stagnant and remains coloured when dye is added to it;

c. white to black (N), or blue to green (GY, BG, G or B) colours in more than 95 percent of the soil matrix; high chroma oxidized mottles, when present, occur on ped faces or in root or animal channels.

3. Stagnic properties, related to saturation by surface water, are reflected by the following, within 50 cm of the surface:

- a. reduction as defined under 1 for a part of the year;
- b. if mottling is present, a dominant moist chroma of 2 or less on the surface of peds and mottles of higher chroma occurring within the peds, or a dominant moist chroma of 2 or less in the soil matrix and mottles of higher chroma or iron-manganese concretions or both occurring within the soil material;
- c. if no mottling is present, a dominant moist chroma of 1 or less on the surfaces of peds or in the soil matrix;
- d. the dominant moist chroma on the surfaces of peds and of the soil matrix increasing with depth.

4. For soils in which the content of iron oxides is very low, or in which iron oxides are present in such large amounts or are inert and so well crystallized that they remain brown or red even in reduced conditions, the above colour requirements do not apply. For Podzols the absence of iron oxides on the sand and silt grains in the material in or immediately below the spodic B horizon reflects gleyic or stagnic properties. This can be checked by igniting a sample. When it becomes greyish it points to the absence of iron oxide coatings. In other instances, especially for soils with a high content of iron oxides, the colour of which does not change markedly in reducing conditions, repeated determination of Eh and pH may be required. The limits indicating reduction are given above. This procedure may also need to be applied to Vertisols for which a relationship between reduced conditions which may occur in these soils and colour patterns, has not yet been established.

In the present legend, soils which are influenced by groundwater at shallow depth key out at the first level as Gleysols or Fluvisols. The influence of groundwater in the Gleysols is dominant, and they have no diagnostic horizons other than an A or H horizon, or a calcic, sulfidic, cambic, or gypsic horizon. Soils which show groundwater influence at greater depth constitute the 'gleyic' units at the second level.

Soils which are influenced by the stagnation of surface water, key out either at the first level, as Planosols or Plinthosols, or at the second level as 'stagnic' units. Most Vertisols are subjected to surface water stagnation at some period of the year. However, no Stagnic Vertisol has been distinguished because of the lack of precise information as to the occurrence, duration and location of reduction in these soils. Furthermore, a relationship between reduction and visual criteria has not been established.

Soils which are subject to flooding or show reduction as a result of irrigation are marked by the 'inundic' and 'anthraquic' phases respectively.

At the second level the gleyic properties key out before the stagnic properties. If necessary, soils which show stagnic in addition to gleyic properties can be distinguished at the third level.

GYPSIFEROUS

The term 'gypsiferous' applies to soil material which contains 5 percent or more gypsum.

INTERFINGERING

Interfingering consists of 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 skeletans (ped coatings of clean silt or sand, more than 1 mm thick on the vertical ped faces). A total thickness of more than 2 mm is required if each ped has a coating of more than 1 mm. Because quartz is such a common constituent of soils, the skeletans are usually white when dry, and light grey when moist, but their colour is determined by the colour of the sand or silt fraction. The skeletans constitute more than 15 percent of the volume of any subhorizon in which interfingering is recognized. They are also thick enough to be obvious, by their colour, even when moist. Thinner skeletans that must be dry to be seen as a whitish powdering on a ped are not included in the meaning of interfingering.

NITIC PROPERTIES

The term 'nitic properties' applies to soil material that has 30 percent or more clay, has a moderately strong or strong angular blocky structure which falls easily apart into flat edged ('polyhedral' or 'nutty') elements which show shiny ped faces that are either thin clay coatings or pressure faces. This soil structure is apparently associated with the presence of significant amounts of active iron oxides and is indicative of a high effective moisture storage and favourable phosphate sorption - desorption properties.

Laboratory facilities permitting, the characterization of 'nitic properties' can be enhanced by the determination of Fe_2O_3 extractable from the fine earth by acid oxalate (AO iron) and the Fe_2O_3 extractable from the fine earth by dithionate-citrate-bicarbonate (DCB iron). Soil materials with nitic properties have more than 0.2 percent AO iron which moreover is at least 5 percent of the DCB iron.

ORGANIC SOIL MATERIALS

Organic soil materials are:

1. saturated with water for long periods or are artificially drained and, excluding live roots, (a) have 18 percent or more organic carbon if the mineral fraction is 60 percent or more clay, (b) have 12 percent or more organic carbon if the mineral fraction has no clay, or (c) have a proportional content of organic carbon between 12 and 18 percent if the clay content of the mineral fraction is between zero and 60 percent; or
2. never saturated with water for more than a few days and have 20 percent or more organic carbon.

PERMAFROST

Permafrost is a layer in which the temperature is perennially at or below 0°C.

PLINTHITE

Plinthite is 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. Such hardened material is shown as a petroferic or a skeletal phase.

SALIC PROPERTIES

The term 'salic properties' refers to an electric conductivity of the saturation extract of more than 15 dS m⁻¹ at 25°C at some time of the year, within 30 cm of the surface or of more than 4 dS m⁻¹ within 30 cm of the surface if the pH (H₂O, 1:1) exceeds 8.5.

SLICKENSIDES

Slickensides are polished and grooved surfaces that are produced by one mass sliding past another. Some of them occur at the base of a 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

The term 'smeary consistence', as used in connection with Andosols, refers to thixotropic soil material, that is material that changes under pressure or by rubbing from a plastic solid into a liquefied stage and back to the solid condition. In the liquefied stage the material skids or smears between the fingers.

SODIC PROPERTIES

The term 'sodic properties' refers to a saturation in the exchange complex of 15 percent or more of exchangeable sodium or of 50 percent or more exchangeable sodium plus magnesium.

SOFT POWDERY LIME

Soft powdery lime refers to translocated authigenic lime, soft enough to be cut readily with a finger nail, precipitated in place from the soil solution rather than inherited from a soil parent material. As a diagnostic property it should be present in a significant accumulation.

To be identifiable, soft powdery lime must have some relation to the soil structure or fabric. It may disrupt the fabric to form spheroidal aggregates, or white eyes, that are soft and powdery when dry, or the lime may be present as soft coatings in pores or on structural faces. Concentrations of soft powdery lime, if present as coatings, cover 50 per cent or more of the structural faces and are thick enough to be visible when moist. If present as soft nodules, the volume is 5 per cent or more. Filaments (pseudomycelia), which come and go with changing moisture conditions, are not included in the definition of soft powdery lime.

STRONGLY HUMIC

Soil material with more than 1.4 g organic carbon per 100 g fine earth as a weighted average over a depth of 100 cm from the surface. The same weighted average over 100 cm applies if the soil is 50-100 cm deep. This calculation assumes a bulk density of 1.5 Mg m⁻³.

SULFIDIC MATERIALS

Sulfidic materials are waterlogged mineral or organic soil materials containing 0.75 percent or more sulfur (dry weight), mostly in the form of sulfides, having less than three times as much calcium carbonate equivalent as sulfur, and having a pH above 3.5. Sulfidic materials accumulate in a soil that is permanently saturated and having a pH above 3.5, generally with brackish water. If the soil is drained the sulfides oxidize to form sulfuric acid. The pH, which is normally near neutrality before drainage, drops below 3.5. At this point these materials become a sulfuric horizon. Sulfidic material differs from the sulfuric horizon in its reduced condition, its pH and the absence of jarosite mottles with a hue of 2.5Y or more or a chroma of 6 or more.

TONGUING

The term 'tonguing' is connotative of the penetration of an albic E horizon into an argic B horizon along ped surfaces, if peds are present. Penetrations to be considered tongues must have greater depth than width, have horizontal dimensions of 5 mm or more in fine textured argic B horizons (clay, silty clay and sandy clay), 10 mm or more in moderately fine textured argic B horizons, and 15 mm or more in medium or coarser textured argic B horizons (silt loams, loams and sandy loams), and must occupy more than 15 percent of the mass of the upper part of the argic B horizon.

With Chernozems, the term tonguing refers to penetrations of the A horizon into an underlying cambic B horizon or into a C horizon. The penetrations must have greater depth than width, and must occupy more than 15 percent of the mass of the upper part of the horizon in which they occur.

VERTIC PROPERTIES

The term 'vertic properties' is used in connexion with clayey soils which at some period in most years show one or more of the following: cracks, slickensides, wedge-shaped or parallelepiped structural aggregates, that are not in a combination, or are not sufficiently expressed, for the soils to qualify as Vertisols.

WEATHERABLE MINERALS

Minerals included in the meaning of 'weatherable minerals' are those 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 or aluminium. They include:

1. clay minerals : all 2:1 lattice clays except aluminium - interlayered chlorite. Sepiolite, talc and glauconite are also included in the meaning of this group of weatherable clay minerals, although they are not always of clay size.
2. silt- and sand-size minerals (0.02 to 0.2 mm in diameter): feldspars, feldspathoids, ferromagnesian minerals, glasses, micas, and zeolites.

VI. MAJOR SOIL GROUPINGS AND SOIL UNITS

The descriptions of major soil groupings and soil units in this chapter should not be taken as definitions. They include only a limited number of necessary characteristics which are indicative of the nature of the soil units and are sufficient to separate the units; to reduce repetition they do not relate all the features which are excluded. They must therefore be interpreted in conjunction with the key in Chapter X. The order followed is the same as in the complete list on pages 16 to 11.

The diagnostic horizons and diagnostic properties used in this section have been described and defined in Chapters IV and V. The soil horizon designations are defined in Appendix 1.

The following principles have also been applied.

- The soil 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. When the mantle of new material has andic properties, horizons buried by 35 cm or more surface material are no longer diagnostic.
- Diagnostic horizons and diagnostic properties are assumed to have their upper limit within 125 cm of the surface, unless specified otherwise.
- When a choice exists between two or more diagnostic B horizons occurring within 125 cm of the surface it is the upper B horizon which is determining for the classification.
- The expression 'having no diagnostic horizons other than' indicates that one or more of the diagnostic horizons listed may be present.
- All the soil units listed below, with the exception of Histosols, refer to mineral soils; that is, soils that are lacking an H horizon of 40 cm or more (60 cm or more if the organic material consists mainly of sphagnum 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, or lacking an H horizon of a thickness even less than 40 cm when it rests on rocks or on fragmental material of which the interstices are filled with organic material.
- Climatic data are not used as such to separate soil units.
- The analytical data which are used in the definitions are based on laboratory procedures described in soil survey laboratory methods and procedures for collecting soil samples (U.S. Department of Agriculture, 1984; ISRIC, 1995).

FLUVISOLS (FL)¹

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.

Eutric Fluvisols (FLe) Fluvisols having a base saturation (by NH_4OAc) of 50 percent or more at least between 20 and 50 cm from the surface but which are not calcareous at the same depth; lacking a sulfuric horizon and sulfidic material within 125 cm of the surface; lacking salic properties.

Calcaric Fluvisols (FLc) Fluvisols which are calcareous at least between 20 and 50 cm from the surface; lacking a sulfuric horizon and sulfidic material within 125 cm of the surface; lacking salic properties.

Dystric Fluvisols (FLd) Fluvisols having a base saturation (by NH_4OAc) of less than 50 percent at least between 20 and 50 cm from the surface; lacking a sulfuric horizon and sulfidic material within 125 cm of the surface.

Mollic Fluvisols (FLm) Fluvisols having a mollic A horizon or a eutric histic H horizon; lacking a sulfuric horizon or sulfidic material within 125 cm of the surface; lacking salic properties.

Umbric Fluvisols (FLu) Fluvisols having a umbric A horizon or a dystric histic H horizon; lacking a sulfuric horizon or sulfidic material within 125 cm of the surface; lacking salic properties.

Thionic Fluvisols (FLt) Fluvisols having a sulfuric horizon or sulfidic material, or both, at less than 125 cm from the surface.

Salic Fluvisols (FLs) Fluvisols having salic properties; lacking a sulfuric horizon or sulfidic material within 125 cm of the surface.

¹Most but not all Fluvisols show gleyic properties. However, on small scale maps it is hardly possible to make a separation between different drainage classes; such a separation may be feasible between different soil subunits at the third level.

GLEYSOLS (GL)

Soils formed from unconsolidated materials, exclusive of coarse textured materials (except when a Histic H horizon is present) 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 sulfuric, 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.

Eutric Gleysols (GLE) Gleysols having a base saturation (by NH_4OAc) of 50 percent or more at least between 20 and 50 cm from the surface; having no diagnostic horizons other than an ochric A horizon and a cambic B horizon; lacking andic properties; lacking permafrost within 200 cm of the surface.

Calcic Gleysols (GLk) Gleysols which have a calcic or a gypsic horizon, or both, within 125 cm of the surface; having no diagnostic horizons other than an ochric A horizon and a cambic B horizon; lacking andic properties; lacking permafrost within 200 cm of the surface.

Dystric Gleysols (GLd) Gleysols having a base saturation (by NH_4OAc) of less than 50 percent at least between 20 and 50 cm from the surface; having no diagnostic horizons other than an ochric A horizon and a cambic B horizon; lacking andic properties; lacking permafrost within 200 cm of the surface.

Andic Gleysols (GLa) Gleysols having andic properties; lacking permafrost within 200 cm of the surface.

Mollic Gleysols (GLm) Gleysols having a mollic A horizon or a eutric histic H horizon; lacking andic properties; lacking permafrost within 200 cm of the surface.

Umbric Gleysols (GLu) Gleysols having an umbric A horizon or a dystric histic H horizon; lacking andic properties; lacking permafrost within 200 cm of the surface.

Thionic Gleysols (GLt) Gleysols having a sulfuric horizon or sulfidic material at less than 125 cm from the surface; lacking permafrost within 200 cm of the surface.

Gelic Gleysols (GLi) Gleysols having permafrost within 200 cm of the surface.

REGOSOLS (RG)

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

Eutric Regosols (RGe) Regosols having a base saturation (by NH_4OAc) of 50 percent or more at least between 20 and 50 cm from the surface but which are not calcareous within this depth; lacking permafrost within 200 cm of the surface.

Calcaric Regosols (RGc) Regosols which are calcareous at least between 20 and 50 cm from the surface; lacking permafrost within 200 cm of the surface.

Gypsic Regosols (RGy) Regosols which are gypsiferous at least between 20 and 50 cm from the surface; lacking permafrost within 200 cm of the surface.

Dystric Regosols (RGd) Regosols having a base saturation (by NH_4OAc) of less than 50 percent at least between 20 and 50 cm from the surface; lacking permafrost within 200 cm of the surface.

Umbric Regosols (RGu) Regosols having an umbric A horizon; lacking permafrost within 200 cm of the surface.

Gelic Regosols (RGi) Regosols having permafrost within 200 cm of the surface.

LEPTOSOLS (LP)

Soils which are limited in depth by continuous hard rock or highly calcareous material (calcium carbonate equivalent of more than 40 percent) *or a continuous cemented layer within 30 cm of the surface, or having less than 20 percent of fine earth over a depth of 75 cm of the surface;*

Eutric Leptosols (LPe) Leptosols having an ochric A horizon and a base saturation (by NH_4OAc) of 50 percent or more throughout; lacking hard rock and a continuous cemented layer within 10 cm and permafrost within 200 cm of the surface.

Dystric Leptosols (LPd) Leptosols having an ochric A horizon and a base saturation (by NH_4OAc) of less than 50 percent in at least some part of the soil; lacking hard rock and a continuous cemented layer within 10 cm and permafrost within 200 cm of the surface.

Rendzic Leptosols (LPk) Leptosols having a mollic A horizon¹ which contains or immediately overlies calcareous material with a calcium carbonate equivalent of more than 40 percent; lacking hard rock and a continuous cemented layer within 10 cm and permafrost within 200 cm of the surface.

Mollic Leptosols (LPm) Leptosols having a mollic A horizon which does not contain or immediately overlie calcareous material with a calcium carbonate equivalent of more than 40 percent; lacking hard rock and a continuous cemented layer within 10 cm and permafrost within 200 cm of the surface.

Umbric Leptosols (LPu) Leptosols having an umbric A horizon; lacking hard rock and a continuous cemented layer within 10 cm and permafrost within 200 cm of the surface.

Lithic Leptosols (LPq) Leptosols which are limited in depth by continuous hard rock or a continuously cemented layer within 10 cm of the surface.

Gelic Leptosols (LPi) Leptosols having permafrost within 200 cm of the surface.

ARENOSOLS (AR)

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

Haplic Arenosols (ARh) Arenosols having no diagnostic horizon other than an ochric A horizon; lacking ferralic properties; lacking gleyic properties within 100 cm of the surface; non-calcaric.

Cambic Arenosols (ARb) Arenosols showing colouring or alteration characteristic of a cambic B horizon immediately below the A horizon; lacking lamellae of clay accumulation; lacking ferralic properties; lacking an albic E horizon with a minimum thickness of 50 cm; lacking gleyic properties within 100 cm of the surface; non-calcaric.

¹When the A horizon contains more than 40 per cent of finely divided calcium carbonate the colour requirements of the mollic A horizon may be waived.

Luvic Arenosols (ARI) Arenosols showing an increase of 3 percent clay or more or lamellae of clay accumulation within 125 cm of the surface; lacking an albic E horizon with a minimum thickness of 50 cm; lacking gleyic properties within 100 cm of the surface; non-calcaric.

Ferralic Arenosols (ARo) Arenosols showing ferralic properties, and colouring of the horizon immediately underlying the A horizon expressed by chromas of 5 or more or hues redder than 10YR; lacking a clay increase or lamellae of clay accumulation within 125 cm of the surface; lacking an albic E horizon with a minimum thickness of 50 cm; lacking gleyic properties within 100 cm of the surface; non-calcaric.

Albic Arenosols (ARa) Arenosols having an albic E horizon with a minimum thickness of 50 cm within 125 cm from the surface; lacking gleyic properties within 100 cm of the surface; non-calcaric.

Calcaric Arenosols (ARc) Arenosols which are calcaric; lacking gleyic properties within 100 cm of the surface.

Gleyic Arenosols (ARg) Arenosols showing gleyic properties within 100 cm of the surface.

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.

Haplic Andosols (ANh) Andosols having an ochric A horizon and a cambic B horizon; having a smeary consistence and having a texture which is silt loam or finer on the weighted average for all horizons within 100 cm of the surface; lacking gleyic properties within 100 cm of the surface; lacking permafrost within 200 cm of the surface.

Mollic Andosols (ANm) Andosols having a mollic A horizon; having a smeary consistence, and having a texture which is silt loam or finer on the weighted average for all horizons within 100 cm of the surface; lacking gleyic properties within 100 cm of the surface; lacking permafrost within 200 cm of the surface.

Umbric Andosols (ANu) Andosols having an umbric A horizon; having a smeary consistence and having a texture which is silt loam or finer on the weighted average for all horizons within 100 cm of the surface; lacking gleyic properties within 100 cm of the surface; lacking permafrost within 200 cm of the surface.

Vitric Andosols (ANz) Andosols lacking a smeary consistence or having a texture which is coarser than silt loam on the weighted average for all horizons within 100 cm of the surface, or both; lacking gleyic properties within 100 cm of the surface; lacking permafrost within 200 cm of the surface.

Gleyic Andosols (ANg) Andosols showing gleyic properties within 100 cm of the surface; lacking permafrost within 200 cm of the surface.

Gelic Andosols (ANi) Andosols having permafrost within 200 cm of the surface.

VERTISOLS (VR)

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

Eutric Vertisols (VRe) Vertisols having a base saturation (by NH_4OAc) of 50 percent or more at least between 20 and 50 cm from the surface; lacking a calcic or a gypsic horizon.

Dystric Vertisols (VRd) Vertisols having a base saturation (by NH_4OAc) of less than 50 percent at least between 20 and 50 cm from the surface, lacking a calcic or a gypsic horizon.

Calcic Vertisols (VRk) Vertisols having a calcic horizon or concentrations of soft powdery lime within 125 cm of the surface; lacking a gypsic horizon.

Gypsic Vertisols (VRy) Vertisols having a gypsic horizon within 125 cm of the surface.

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 (by NH_4OAc) 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.

Eutric Cambisols (CMe) Cambisols having an ochric A horizon and a base saturation (by NH_4OAc) of 50 percent or more at least between 20 and 50 cm from the surface but which are not calcareous within this depth; lacking vertic properties; having a cambic B horizon which is not strong brown to red¹; lacking ferralic properties in the cambic B horizon; lacking gleyic properties within 100 cm of the surface; lacking permafrost within 200 cm of the surface.

Dystric Cambisols (CMd) Cambisols having an ochric A horizon and a base saturation (by NH_4OAc) of less than 50 percent at least between 20 and 50 cm from the surface; lacking vertic properties; lacking ferralic properties in the cambic B horizon; lacking gleyic properties within 100 cm of the surface; lacking permafrost within 200 cm of the surface.

Humic Cambisols (CMu) Cambisols having an umbric A horizon or a mollic A horizon overlying a cambic B horizon with a base saturation (by NH_4OAc) of less than 50 percent; lacking vertic properties; lacking ferralic properties in the cambic B horizon; lacking gleyic properties within 100 cm of the surface; lacking permafrost within 200 cm of the surface.

Calcaric Cambisols (CMc) Cambisols having an ochric A horizon and are calcareous at least between 20 and 50 cm from the surface; lacking vertic properties; lacking gleyic properties within 100 cm of the surface; lacking permafrost within 200 cm of the surface.

Chromic Cambisols (CMx) Cambisols having an ochric A horizon and a base saturation (by NH_4OAc) of 50 percent or more at least between 20 and 50 cm from the surface but which are not calcareous within this same depth; having a strong brown to red cambic B horizon; lacking ferralic properties in the cambic B horizon; lacking vertic properties; lacking gleyic properties within 100 cm of the surface; lacking permafrost within 200 cm of the surface.

Vertic Cambisols (CMv) Cambisols having an ochric A horizon; showing vertic properties; lacking gleyic properties within 100 cm of the surface; lacking permafrost within 200 cm of the surface.

Ferralic Cambisols (CMo) Cambisols having an ochric A horizon and a cambic B horizon with ferralic properties; lacking vertic properties; lacking gleyic properties within 100 cm of the surface; lacking permafrost within 200 cm of the surface.

¹Rubbed soil having a hue of 7.5YR and a chroma of more than 4, or a hue redder than 7.5YR.

Gleyic Cambisols (CMg) Cambisols showing gleyic properties within 100 cm of the surface; lacking permafrost within 200 cm of the surface.

Gelic Cambisols (CMi) Cambisols having permafrost within 200 cm of the surface.

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 which is calcareous; lacking the characteristics which are diagnostic for Vertisols or Planosols; lacking salic properties; lacking gleyic properties within 100 cm of the surface.

Haplic Calcisols (CLh) Calcisols lacking an argic B horizon and a petrocalcic horizon.

Luvic Calcisols (CLl) Calcisols having an argic B horizon; lacking a petrocalcic horizon.

Petric Calcisols (CLp) Calcisols having a petrocalcic horizon.

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

Haplic Gypsisols (GYh) Gypsisols lacking an argic B horizon, a calcic horizon and a petrogypsic horizon.

Calcic Gypsisols (GYk) Gypsisols having a calcic or petrocalcic horizon; lacking a petrogypsic horizon.

Luvic Gypsisols (GYl) Gypsisols having an argic B horizon; lacking a calcic horizon and a petrogypsic horizon.

Petric Gypsisols (GYp) Gypsisols having a petrogypsic horizon.

SOLONETZ (SN)

Soils having a natric B horizon.

Haplic Solonetz (SNh) Solonetz having an ochric A horizon; lacking stagnic properties and lacking gleyic properties within 100 cm of the surface.

Mollic Solonetz (SNm) Solonetz having a mollic A horizon; lacking stagnic properties and lacking gleyic properties within 100 cm of the surface.

Calcic Solonetz (SNk) Solonetz having a calcic horizon or concentrations of soft powdery lime within 125 cm of the surface; lacking a gypsic horizon; lacking stagnic properties and lacking gleyic properties within 100 cm of the surface.

Gypsic Solonetz (SNy) Solonetz having a gypsic horizon within 125 cm of the surface overlying or not a calcic horizon; lacking stagnic properties and lacking gleyic properties within 100 cm of the surface.

Stagnic Solonetz (SNj) Solonetz showing stagnic properties; lacking gleyic properties within 100 cm of the surface.

Gleyic Solonetz (SNg) Solonetz showing gleyic properties within 100 cm of the surface.

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 B horizon, a calcic or a gypsic horizon.

Haplic Solonchaks (SCh) Solonchaks having an ochric A horizon; lacking gleyic properties within 100 cm of the surface; lacking permafrost within 200 cm of the surface.

Mollic Solonchaks (SCm) Solonchaks having a mollic A horizon; lacking gleyic properties within 100 cm of the surface; lacking permafrost within 200 cm of the surface.

Calcic Solonchaks (SCk) Solonchaks having a calcic horizon or concentrations of soft powdery lime within 125 cm of the surface; lacking a gypsic horizon; lacking gleyic properties within 100 cm of the surface; lacking permafrost within 200 cm of the surface.

Gypsic Solonchaks (SCy) Solonchaks having a gypsic horizon within 125 cm of the surface; lacking gleyic properties within 100 cm of the surface; lacking permafrost within 200 cm of the surface.

Sodic Solonchaks (SCn) Solonchaks showing sodic properties at least between 20 and 50 cm of the surface; lacking gleyic properties within 100 cm of the surface; lacking permafrost within 200 cm of the surface.

Gleyic Solonchaks (SCg) Solonchaks showing gleyic properties within 100 cm of the surface; lacking permafrost within 200 cm of the surface.

Gelic Solonchaks (SCi) Solonchaks having permafrost within 200 cm of the surface.

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, a petrocalcic 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 present¹.

Haplic Kastanozems (KSh) Kastanozems lacking an argic B horizon, a calcic horizon and a gypsic horizon.

Luvic Kastanozems (KSl) Kastanozems having an argic B horizon; lacking a gypsic horizon.

Calcic Kastanozems (KSk) Kastanozems having a calcic horizon; lacking an argic B horizon and a gypsic horizon.

Gypsic Kastanozems (KSy) Kastanozems having a gypsic horizon.

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 or petrocalcic 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 present¹; lacking uncoated silt and quartz grains on structural ped surfaces.

Haplic Chernozems (CHh) Chernozems lacking an argic B horizon and a calcic horizon; not showing tonguing of the A horizon into a cambic B or into a C horizon.

Calcic Chernozems (CHk) Chernozems having a calcic or petrocalcic horizon; lacking an argic B horizon overlying the calcic horizon; not showing tonguing of the A horizon into a cambic B or into a C horizon.

Luvic Chernozems (CHI) Chernozems having an argic B horizon; a calcic horizon may be present when underlying the B horizon; lacking gleyic properties within 100 cm of the surface.

¹Gleyic properties present within 50 cm of the surface in the absence of an argic B horizon meet the definition of the Mollic Gleysols.

Glossic Chernozems (CHw) Chernozems showing tonguing of the A horizon into a cambic B horizon or into a C horizon; lacking an argic B horizon.

Gleyic Chernozems (CHg) Chernozems having an argic B horizon and showing gleyic properties within 100 cm of the surface.

PHAEOZEMS (PH)

Soils having a mollic A horizon; lacking a calcic horizon, a gypsic horizon, concentrations of soft powdery lime; having a base saturation (by NH_4OAc) 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 present¹; lacking uncoated silt and sand grains on structural ped surfaces when the mollic A horizon has a moist chroma of 2 or less to a depth of at least 15 cm.

Haplic Phaeozems (PHh) Phaeozems lacking an argic B horizon and which are not calcareous from 20 to 50 cm of the surface, lacking gleyic properties within 100 cm of the surface, lacking stagnic properties.

Calcaric Phaeozems (PHc) Phaeozems which are calcareous at least from 20 to 50 cm of the surface; lacking an argic B horizon, lacking gleyic properties within 100 cm of the surface, lacking stagnic properties.

Luvic Phaeozems (PHl) Phaeozems having an argic B horizon; lacking gleyic properties within 100 cm of the surface, lacking stagnic properties.

Stagnic Phaeozems (PHj) Phaeozems showing stagnic properties; lacking gleyic properties within 100 cm of the surface.

Gleyic Phaeozems (PHg) Phaeozems showing gleyic properties within 100 cm of the surface.

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

¹Gleyic properties present within 50 cm of the surface in the absence of an argic B horizon meet the definition of the Mollic Gleysols.

Haplic Greyzems (GRh) Greyzems lacking gleyic properties within 100 cm of the surface.

Gleyic Greyzems (GRg) Greyzems showing gleyic properties within 100 cm of the surface.

LUVISOLS (LV)

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

Haplic Luvisols (LVh) Luvisols having an argic B horizon which is not strong brown to red¹; lacking an albic E horizon; lacking a calcic horizon and concentrations of soft powdery lime within 125 cm of the surface; lacking vertic properties; lacking ferric properties; lacking gleyic and stagnic properties within 100 cm of the surface.

Ferric Luvisols (LVf) Luvisols showing ferric properties within 125 cm of the surface; lacking an albic E horizon; lacking plinthite within 125 cm of the surface; lacking gleyic and stagnic properties within 100 cm of the surface.

Chromic Luvisols (LVx) Luvisols having a strong brown to red¹ argic B horizon; lacking vertic properties; lacking an albic E horizon; lacking a calcic horizon, or concentrations of soft powdery lime within 125 cm of the surface; lacking gleyic and stagnic properties within 100 cm of the surface.

Calcic Luvisols (LVk) Luvisols having a calcic horizon or concentrations of soft powdery lime, or both, within 125 cm of the surface; lacking vertic properties; lacking an albic E horizon; lacking gleyic and stagnic properties within 100 cm of the surface.

Vertic Luvisols (LVv) Luvisols showing vertic properties; lacking an albic E horizon; lacking gleyic and stagnic properties within 100 cm of the surface.

Albic Luvisols (LVa) Luvisols having an albic E horizon; lacking gleyic and stagnic properties within 100 cm of the surface.

Stagnic Luvisols (LVj) Luvisols showing stagnic properties within 50 cm of the surface; lacking gleyic properties within 100 cm of the surface.

¹Rubbed soil has a hue of 7.5YR and a chroma of more than 4, or a hue redder than 7.5 YR.

Gleyic Luvisols (LVg) Luvisols showing gleyic properties within 100 cm of the surface.

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, and lacking a natric or a spodic B horizon.

Eutric Planosols (PLe) Planosols having an ochric A horizon and having a base saturation (by NH_4OAc) of 50 percent or more throughout the slowly permeable horizon within 125 cm of the surface; lacking permafrost within 200 cm of the surface.

Dystric Planosols (PLd) Planosols having an ochric A horizon and having a base saturation (by NH_4OAc) of less than 50 percent in at least a part of the slowly permeable horizon within 125 cm of the surface; lacking permafrost within 200 cm of the surface.

Mollic Planosols (PLm) Planosols having a mollic A horizon or a eutric histic H horizon; lacking permafrost within 200 cm of the surface.

Umbric Planosols (PLu) Planosols having an umbric A horizon or a dystric histic H horizon; lacking permafrost within 200 cm of the surface.

Gelic Planosols (PLi) Planosols having permafrost within 200 cm of the surface.

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.

Eutric Podzoluvisols (PDe) Podzoluvisols having a base saturation (by NH_4OAc) of 50 percent or more throughout the argic B horizon within 125 cm of the surface; lacking gleyic and stagnic properties within 100 cm of the surface; lacking permafrost within 200 cm of the surface.

Dystric Podzoluvisols (PDd) Podzoluvisols having a base saturation (by NH_4OAc) of less than 50 percent in at least a part of the argic B horizon within 125 cm of the surface; lacking gleyic and stagnic properties within 100 cm of the surface; lacking permafrost within 200 cm of the surface.

Stagnic Podzoluvisols (PDj) Podzoluvisols showing stagnic properties within 50 cm of the surface; lacking gleyic

properties within 100 cm of the surface; lacking permafrost within 200 cm of the surface.

Gleyic Podzoluvisols (PDg) Podzoluvisols showing gleyic properties within 100 cm of the surface; lacking permafrost within 200 cm of the surface.

Gelic Podzoluvisols (PDi) Podzoluvisols having permafrost within 200 cm of the surface.

PODZOLS (PZ)

Soils having a spodic B horizon.

Haplic Podzols (PZh) Podzols having a spodic B horizon which in all subhorizons has a ratio of free iron to organic carbon of less than 6, but which contains sufficient free iron to turn redder on ignition; having a continuous albic E horizon that is thicker than 2 cm or a distinct separation within the spodic B horizon of a subhorizon which is visibly more enriched with organic carbon, or both; lacking gleyic properties within 100 cm of the surface; lacking permafrost within 200 cm of the surface.

Cambic Podzols (PZb) Podzols having a spodic B horizon which in all subhorizons has a ratio of free iron to organic carbon of less than 6, but which contains sufficient iron to turn redder on ignition; lacking or having only a thin (2 cm or less) or discontinuous albic E horizon; lacking a subhorizon within the spodic B horizon which is visibly more enriched with organic carbon; lacking gleyic properties within 100 cm of the surface; lacking permafrost within 200 cm of the surface.

Ferric Podzols (PZf) Podzols having a spodic B horizon in which in all subhorizons the ratio of free iron to organic carbon is 6 or more; lacking gleyic properties within 100 cm of the surface; lacking permafrost within 200 cm of the surface.

Carbic Podzols (PZc) Podzols having a spodic B horizon in which a subhorizon¹ contains dispersed organic matter and lacks sufficient free iron to turn redder on ignition²; lacking gleyic properties within 100 cm of the surface; lacking permafrost within 200 cm of the surface.

Gleyic Podzols (PZg) Podzols showing gleyic properties within 100 cm of the surface; lacking permafrost within 200 cm of the surface.

¹If this subhorizon is discontinuous, it should be present in at least half of a soil section large enough to study a full cycle of recurring horizon variations.

²Normally corresponding to less than 0.5 percent Fe in the fine earth fraction.

Gelic Podzols (PZi) Podzols having permafrost within 200 cm of the surface.

LIXISOLS (LX)

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

Haplic Lixisols (LXh) Lixisols lacking an albic E horizon; lacking ferric properties and plinthite within 125 cm of the surface; lacking gleyic and stagnic properties within 100 cm of the surface.

Ferric Lixisols (LXf) Lixisols showing ferric properties within 125 cm of the surface; lacking an albic E horizon; lacking plinthite within 125 cm of the surface; lacking gleyic and stagnic properties within 100 cm of the surface.

Plinthic Lixisols (LXp) Lixisols having plinthite within 125 cm of the surface; lacking an albic E horizon; lacking gleyic and stagnic properties within 100 cm of the surface.

Albic Lixisols (LXa) Lixisols having an albic E horizon; lacking gleyic and stagnic properties within 100 cm of the surface; lacking plinthite within 125 cm of the surface.

Stagnic Lixisols (LXj) Lixisols having stagnic properties within 50 cm of the surface; lacking gleyic properties within 100 cm of the surface; lacking plinthite within 125 cm of the surface.

Gleyic Lixisols (LXg) Lixisols showing gleyic properties within 100 cm of the surface.

ACRISOLS (AC)

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

Haplic Acrisols (ACh) Acrisols which are not strongly humic; lacking ferric properties; lacking plinthite within 125 cm of the surface; lacking gleyic properties within 100 cm of the surface.

Ferric Acrisols (ACf) Acrisols which are not strongly humic; showing ferric properties within 125 cm of the surface; lacking plinthite within 125 cm of the surface; lacking gleyic properties within 100 cm of the surface.

Humic Acrisols (ACu) Acrisols having an umbric or a mollic A horizon and which are strongly humic; lacking plinthite within 125 cm of the surface; lacking gleyic properties within 100 cm of the surface.

Plinthic Acrisols (ACp) Acrisols having plinthite within 125 cm of the surface.

Gleyic Acrisols (ACg) Acrisols showing gleyic properties within 100 cm of the surface; lacking plinthite within 125 cm of the surface.

ALISOLS (AL)

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

Haplic Alisols (ALh) Alisols which are not strongly humic; lacking ferric properties; lacking plinthite within 125 cm of the surface; lacking gleyic and stagnic properties within 100 cm of the surface.

Ferric Alisols (ALf) Alisols which are not strongly humic; showing ferric properties within 125 cm of the surface; lacking plinthite within 125 cm of the surface; lacking gleyic and stagnic properties within 100 cm of the surface.

Humic Alisols (ALu) Alisols having an umbric or a mollic A horizon and which are strongly humic; lacking plinthite within 125 cm of the surface; lacking gleyic and stagnic properties within 100 cm of the surface.

Plinthic Alisols (ALp) Alisols having plinthite within 125 cm of the surface.

Stagnic Alisols (ALj) Alisols showing stagnic properties within 50 cm of the surface; lacking gleyic properties within 100 cm of the surface; lacking plinthite within 125 cm of the surface.

Gleyic Alisols (ALg) Alisols showing gleyic properties within 100 cm of the surface; lacking plinthite within 125 cm of the surface.

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

Haplic Nitisols (NTh) Nitisols which are not strongly humic and have an argic B horizon that is not red to dusky red¹.

Rhodic Nitisols (NTr) Nitisols which are not strongly humic and have a red to dusky red¹ argic B horizon.

Humic Nitisols (NTu) Nitisols having an umbric or a mollic A horizon, and which are strongly humic.

FERRALSOLS (FR)

Soils having a ferralic B horizon.

Haplic Ferralsols (FRh) Ferralsols having a ferralic B horizon that is neither red to dusky red¹ nor yellow to pale yellow²; which are not strongly humic; lacking geric properties throughout the ferralic B horizon within 125 cm of the surface; lacking plinthite within 125 cm of the surface.

Xanthic Ferralsols (FRx) Ferralsols having a yellow to pale yellow² ferralic B horizon; which are not strongly humic; lacking geric properties throughout the ferralic B horizon within 125 cm of the surface; lacking plinthite within 125 cm of the surface.

Rhodic Ferralsols (FRr) Ferralsols having a red to dusky red¹ ferralic B horizon; which are not strongly humic; lacking geric properties throughout the ferralic B horizon within 125 cm of the surface; lacking plinthite within 125 cm of the surface.

Humic Ferralsols (FRu) Ferralsols having an umbric or a mollic A horizon and which are strongly humic; lacking geric properties throughout the ferralic B horizon within 125 cm of the surface; lacking plinthite within 125 cm of the surface.

¹ Rubbed soil has hues redder than 5YR with a moist value of less than 4 and a dry value not more than one unit higher than the moist value.

² Rubbed soil has hues of 7.5YR or yellower with a moist value of 4 or more and a moist chroma of 5 or more.

Geric Ferralsols (FRg) Ferralsols having geric properties in at least some part of the ferralic B horizon within 125 cm of the surface; lacking plinthite within 125 cm of the surface.

Plinthic Ferralsols (FRp) Ferralsols having plinthite within 125 cm of the surface; lacking an albic E horizon or stagnic and gleyic properties within 100 cm of the surface.

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.

Eutric Plinthosols (PTe) Plinthosols having an ochric A horizon and a base saturation (by NH_4OAc) of 50 percent or more in the plinthite horizon; lacking an albic E.

Dystric Plinthosols (PTd) Plinthosols having an ochric A horizon and a base saturation (by NH_4OAc) of less than 50 percent in the plinthite horizon.

Humic Plinthosols (PTu) Plinthosols having an umbric or mollic A horizon or a dystric histic H horizon, and which are strongly humic.

Albic Plinthosols (PTa) Plinthosols having an albic E horizon.

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 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 horizon may be less when it rests on rock or on fragmental material in which the interstices are filled with organic matter.

Folic Histosols (HSI) Histosols that are well drained and are never saturated with water for more than a few days; lacking a sulfuric horizon or sulfidic materials within 125 cm of the surface; lacking permafrost within 200 cm of the surface.

Terric Histosols (HSs) Histosols having highly decomposed organic materials with strongly reduced amounts of visible plant fibres and a very dark grey to black colour to a depth of 35 cm or more from the surface; having an imperfect to very poor drainage; lacking a sulfuric horizon or sulfidic materials within 125 cm of the surface; lacking permafrost within 200 cm of the surface.

Fibric Histosols (HSf) Histosols having raw or weakly decomposed organic materials, the fibre content of which is dominant to a depth of 35 cm or more from the surface; having a very poor drainage or being undrained; lacking a sulfuric horizon or sulfidic materials within 125 cm of the surface; lacking permafrost within 200 cm of the surface.

Thionic Histosols (HSt) Histosols having a sulfuric horizon or sulfidic materials within 125 cm of the surface; lacking permafrost within 200 cm of the surface.

Gelic Histosols (HSi) Histosols having permafrost within 200 cm of the surface.

ANTHROSOLS (AT)

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

Aric Anthrosols (ATa) Anthrosols showing remnants of diagnostic horizons due to deep cultivation.

Cumulic Anthrosols (ATc) Anthrosols showing an accumulation of sediments with a texture which is sandy loam or finer, thicker than 50 cm, resulting from long-continued irrigation or man made raising of the soil surface.

Fimic Anthrosols (ATf) Anthrosols having a fimic A horizon.

Urbic Anthrosols (ATu) Anthrosols having to a depth of more than 50 cm an accumulation of wastes from mines, town refuse, fills from urban developments, etc.

VII. GUIDELINES FOR DISTINGUISHING SOIL SUBUNITS

Since the legend of the Soil Map of the World has been and is being used for mapping at scales larger than 1:5 000 000 the need arises for the separation and definition of soil subunits at a third level. It is not yet possible to draw up a comprehensive list of a third category of subunits at a global scale. They have to be defined in accordance with the specific needs at national or regional level. However, some general principles need to be adhered to for the establishment of soil subunits, in order to keep local applications of the legend from drifting apart.

The examples given below are an attempt to guide the separation of third level subunits. It is realized that further monitoring and guidance will be required to retain uniformity in the FAO-Unesco nomenclature, a main objective of which is to provide a universal tool for communication and exchange of experience.

The different kinds of subunits which can be established are summarized as follows:

1. Subunits which mark intergrades between the major soil groupings at the first level, for example:

gleyi-dystric Fluvisols (FLdg):

Dystric Fluvisols which show gleyic properties within 100 cm of the surface.

areni-albic Lixisols (LXaa):

Albic Lixisols which have a texture that is coarser than sandy loam in the upper 30 cm of the soil.

niti-haplic Acrisols (AChn):

Haplic Acrisols showing nitic properties in some part of the argic B horizon within 125 cm of the surface.

verti-calcaric Phaeozems (PHcv):

Calcaric Phaeozems showing vertic properties within 50 cm of the surface.

andi-humic Ferralsols (FRha):

Humic Ferralsols which show an admixture of material having andic properties in the upper 30 cm of the soil.

acri-xanthic Ferralsols (FRxl):

Xanthic Ferralsols which show textural differentiation within the ferralic B horizon and have a base saturation (by NH_4OAc) of less than 50 percent in at least some part of the B horizon within 125 cm of the surface.

These six subunits are examples of intergrades between, respectively,
Fluvisols and Gleysols
Lixisols and Arenosols
Acrisols and Nitisols
Phaeozems and Vertisols
Ferralsols and Andosols
Ferralsols and Acrisols

2. Subunits which mark intergrades between soil units at the second level, for example:

stagni-gleyic Luvisols (LVgj):

Gleyic Luvisols showing stagnic properties within 50 cm of the surface.

calci-mollic Solonetz (SNmk):

Mollic Solonetz having a calcic horizon within 125 cm of the surface.

ferri-albic Lixisols (LXaf):

Albic Lixisols showing ferric properties.

The intergrades between soil units at the second level make it possible to mark the presence of horizons or properties which, although used to separate soil units within a major grouping, are not specifically mentioned because of the priorities dictated by the key of soil units.

3. Subunits which introduce horizons or properties which, at the level of the soil units (second level) are used only as a phase, for example:

fragi-ferric Luvisols (LVff):

Ferric Luvisols having a fragipan at less than 125 cm from the surface.

duri-haplic Calcisols (CLhd):

Haplic Calcisols having a duripan at less than 125 cm from the surface.

anthraqui-stagnic Solonetz (SNja):

Stagnic Solonetz associated with surface waterlogging due to irrigation.

rudi-calcaric Regosols (RGcr):

Calcaric Regosols which have gravel, stones or boulders in the surface layers or at the surface.

4. Subunits which mark characteristics additional to those used in the definitions of first and second level units, for example:

grumi-eutric Vertisols (VReg):

Eutric Vertisols which, when dry, have a strong fine granular structure in the upper 18 cm of the soil.

mazi-eutric Vertisols (VRem):

Eutric Vertisols which, when dry, have a massive structure and are hard in the upper 18 cm of the soil.

PELLI-dystic Vertisols (VRdp):

Dystic Vertisols which have a moist value of 3 or less and a chroma of 2 or less in the soil matrix throughout the upper 30 cm of the soil.

eutri-haplic Andosols (ANhe):

Haplic Andosols which have a base saturation (by NH_4OAc) of 50 percent or more at least between 20 and 50 cm from the surface.

alumi-humic Acrisols (ACua):

Humic Acrisols having an Al saturation of 50 percent or more in at least some part of the argic B horizon within 125 cm of the surface.

5. Subunits which provide more precise specifications of characteristics which are used in the definition of second level soil units, for example:

hyper-calcaric Cambisols (CMch):

Calcaric Cambisols in which the calcareous material has more than 40 percent CaCO_3 equivalent.

hyper-dystic Planosols (PLdh):

Dystic Planosols which have a base saturation (by NH_4OAc) of less than 20 percent in at least part of the slowly permeable horizon within 125 cm of the surface.

epi-gleyic Podzols (PZge):

Gleyic Podzols which show gleyic properties at less than 50 cm of the surface.

umbri-humic Alisols (Aluu):

Humic Alisols which have an umbric A horizon.

sulfi-thionic Histosols (HSts):

Thionic Histosols which have sulfidic material within 80 cm of the surface.

veti-haplic Ferralsols (FRhv):

Haplic Ferralsols which have a content of extractable bases plus extractable aluminium of less than 6 (but more than 1.5) $\text{cmol}(+)\text{kg}^{-1}$ clay in at least part of the B horizon within 125 cm of the surface.

6. Occasionally, when absolutely necessary, subunits may mark two intergrades or two specifiers in combination, for example:

alumi-andi dystic Nitisols (NTdaa)

Dystic Nitisols which show an admixture of material having andic properties in the upper 30 cm of the soil and which have an Al saturation of 50 percent or more in at least some part of the argic B horizon within 125 cm of the surface.

rudi-mazi calcic Vertisols (VRkmr)

Calcic Vertisols which, when dry, have a massive structure and are hard in the upper 18 cm of the soil, and which have gravel, stones or boulders in the surface layers or at the surface.

rhodi-molli humic Ferralsols (FRhmr)

Humic Ferralsols which have a mollic A horizon and have a red to dusky red ferralic B horizon.

An overall prescription for the separation of soil subunits is that they should be very clearly defined, that their definitions should not overlap and should not conflict with the definitions of the soil units at the first and second level. The symbols used for subunits are those of the relevant soil unit with, in addition, a second lower case letter indicating the third level specification. The choice of letters is limited, and the same letters will need to be used with different meanings.

These guidelines have not yet been worked out in detail. It is the intention to publish a separate publication devoted to the third level soil subunits, as soon as a representative, if not comprehensive, list has been developed.

VIII. PHASES

Phases are limiting factors related to surface or subsurface features of the land. They are not necessarily related to soil formation and generally cut across the boundaries of different soil units. These features may form a constraint to the use of the land. The phases recognized here are : anthraquic, duripan, fragipan, gelundic, gilgai, inundic, lithic, petroferic, phreatic, placic, rudic, salic, skeletal, sodic, takyric and yermic.

The definitions of the petrocalcic and petrogypsic horizons, the petroferic phase (contact), the fragipan and the duripan are those formulated in the Soil Taxonomy of the U.S. Soil Conservation Service (1975). It is to be noted that in Soil Taxonomy the petrocalcic and petrogypsic horizons and the fragipan and duripan are diagnostic for separating different categories of soils. Since the occurrence of these horizons has not been systematically recorded in a number of countries, they are shown as phases on the FAO-Unesco Soil Map of the World where they have been observed.

ANTHRAQUIC PHASE

The anthraquic phase marks soils showing stagneric properties within 50 cm of the surface due to surface waterlogging associated with long continued irrigation, particularly of rice.

DURIPAN PHASE

A duripan is a subsurface horizon that is cemented by silica so that dry fragments do not slake during prolonged soaking in water or in hydrochloric acid. The duripan phase marks soils in which the upper level of a duripan occurs within 100 cm of the surface.

Duripans vary in the degree of cementation by silica and, in addition, they commonly contain accessory cements, mainly iron oxides and calcium carbonate. As a result, duripans vary in appearance but all of them have a very firm or extremely firm moist consistency, and they are always brittle even after prolonged wetting.

FRAGIPAN PHASE

A fragipan is a loamy (uncommonly a sandy) subsurface horizon which has a high bulk density relative to the horizons above it, is hard or very hard and seemingly cemented when dry, is weakly to moderately brittle when moist; when pressure is applied peds or clods tend to rupture suddenly rather than to undergo slow deformation. Dry fragments slake or fracture when placed in water. The fragipan phase marks soils which have the upper level of the fragipan occurring within 100 cm of the surface.

A fragipan is low in organic matter, slowly or very slowly permeable and often shows bleached fracture planes that are

faces of coarse or very coarse polyhedrons or prisms. Clayskins may occur as patches or discontinuous streaks both on the faces and in the interiors of the prisms. A fragipan commonly, but not necessarily, underlies a B horizon. It may be from 15 to 200 cm thick with commonly an abrupt or clear upper boundary, while the lower boundary is mostly gradual or diffuse.

GELUNDIC PHASE

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

GILGAI PHASE

Gilgai is the microrelief typical of clayey soils, mainly Vertisols, that have a high coefficient of expansion with distinct seasonal changes in moisture content. This microrelief consists of either a succession of enclosed microbasins and microknolls in nearly level areas, or of microvalleys and microridges that run up and down the slope. The height of the microridges commonly ranges from a few cm to 100 cm. Rarely does the height attain 200 cm.

INUNDIC PHASE

The inundic phase is used when standing or flowing water is present on the soil surface for more than 10 days during the growing period.

LITHIC PHASE

The lithic phase is used when continuous hard rock occurs within 50 cm of the surface.

PETROFERRIC PHASE

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 indurated layer must either be continuous or, when it is fractured, the average lateral distance between fractures must be 10 cm or more. The petroferric layer differs from a thin iron pan and from an indurated spodic B horizon in containing little or no organic matter.

The petroferric phase marks soils in which the upper part of the indurated layer occurs within 100 cm of the surface.

PHREATIC PHASE

The phreatic phase refers to the occurrence of a groundwater table within 5 m from the surface, the presence of which is not reflected in the morphology of the soil. Therefore the phreatic phase is not shown, for instance, with Fluvisols or Gleysols. 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 groundwater.

PLACIC PHASE

The placic phase refers to the presence of a thin iron pan, a black to dark reddish layer cemented by iron, by iron and manganese, or by an iron-organic matter complex, the thickness of which ranges generally from 2 mm to 10 mm. In spots it may be as thin as 1 mm or as thick as 20 to 40 mm, but this is rare. It may, but not necessarily, be associated with stratification in parent materials. It is in the solum, roughly parallel to the soil surface, and is commonly within the upper 50 cm of the mineral soil. It 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 placic phase marks soils which have a thin iron pan within 100 cm of the surface.

RUDIC PHASE

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. Fragments with a diameter up to 7.5 cm are considered as gravel; larger fragments are called stones or boulders. Though it could not be separated on a small-scale map, this difference is obviously important for soil management purposes.

SALIC PHASE

The salic phase marks soils which, in some horizons within 100 cm of the surface, show electric conductivity values of the saturation extract higher than 4 dS m^{-1} at 25°C . The salic phase is not shown 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 practice.

Though the salic phase indicates present or potential salinization, it should be realized that the effect of salinity varies greatly with the type of salts present, the permeability of the soil, the climatic conditions, and the kind of crops

grown. A further subdivision of the degree of salinity would be required for more detailed mapping.

SKELETIC PHASE

The skeletal phase refers to soil materials which consist of 40 percent or more, by volume, of coarse fragments of oxidic concretions or of hardened plinthite, ironstone or other hard materials, with a thickness of at least 25 cm, the upper part of which occurs within 50 cm of the surface. The difference from the petroferric phase is that the concretionary layer of the skeletal phase is not continuously cemented.

SODIC PHASE

The sodic phase marks soils which have more than 6 percent saturation with exchangeable sodium at least in some horizons within 100 cm of the surface. The sodic phase is not shown for soil units which have a natric B horizon or which have sodic properties since a high percentage of sodium saturation is already implied in their definition.

TAKYRIC PHASE

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

YERMIC PHASE

The yermic phase applies to soils which have less than 0.6 percent organic carbon in the surface 18 cm when mixed, or less than 0.20 percent organic carbon¹ if the texture is coarser than sandy loam, and which show one or more of the following features connotative of arid conditions:

1. presence in the surface horizon of gravels or stones shaped by the wind or showing desert varnish (manganese oxide coating at the upper surface) or both. When the soil is not ploughed these gravels or stones usually form a surface pavement; they may show calcium carbonate or gypsum accumulating immediately under the coarse material.
2. presence in the surface horizon of pitted and rounded quartz grains showing a matte surface which constitute 10 percent or more of the sand fraction having a diameter of 0.25 mm or more.
3. presence of 2 percent or more palygorskite in the clay fraction in at least some subhorizon within 50 cm of the surface.

¹The organic carbon conditions are waived if the soil meets the requirements of the salic phase.

4. surface cracks filled with in-blown sand or silt; when the soil is ploughed this characteristic may be obliterated, however, cracks may extend below the plough layer.
5. a platy surface horizon which frequently shows vesicular pores and which may be indurated but not cemented.
6. accumulation of blown sand on a stable surface.

IX. CLIMATIC ZONES

As has been recognised since the earliest days of soil science, climate is one of the major features controlling the development of soils. The regional distribution of some major soil groupings can be related to climatic conditions. The main effects of climatic influence on the processes occurring in the soil are evident from the soil characteristics. Therefore in the Legend of the Soil Map of the World, climatic characteristics are not used as keying (diagnostic) properties in the definition of major soil groupings and soil units.

Soil temperature and soil moisture regimes are important soil properties which affect the comportment of the soil. They are also important factors of plant growth, but must be supplemented by the standard climatic data in order to predict plant production potential. They are measured at meteorological stations but are commonly inferred or extrapolated from general climatic data.

Climatic conditions, particularly of available moisture and air temperatures, are important factors of production. Therefore, for interpretation and evaluation for management and development, soils occurring under different climatic conditions should be separated even if otherwise similar.

Temperature and water availability, to take the two most prominent features, act to different degrees as constraints to year-round rainfed crop production. In warm tropical regions the major constraint is seasonal water availability, whereas in sub-tropical regions with winter rainfall, low temperatures in winter and drought in summer may both limit crop growth.

Some major climate-related soils features can be shown on the Soil Map of the World, for example the presence of permafrost, or the regions where rainfall is insufficient to produce a field crop, or the regions where soils are continuously wet. To facilitate predictions of biomass production or crop responses, more detailed climatic information needs to be superimposed on the soil map. There is, at present, no generally agreed classification of soil thermal and moisture regimes, nor of climatic conditions for plant growth, to use as an adjunct to the soil units. Some recent work is described below.

A climatic inventory was developed for the countries of the developing world by the FAO Agro-ecological Zones Project (FAO, 1978-1981). It places equal emphasis on temperature and available moisture in order to compute the *growing period*, which is the continuous period when temperature is high enough, and water is available to permit crop growth.

Zones with similar lengths of growing period were delineated by isolines at intervals of 30 days e.g. 90-119 days, 120-149 days, 150-179 days, etc. The 75 day isoline was added to cover production of short duration cultivars of pearl

millet, and the 365+ isoline for excessively wet climates which limit production opportunities.

To take into account crop temperature requirements that limit the potential distribution of the crops, prevailing temperature regimes have been inventoried by identification of thermal zones. To delineate the thermal zones, first the effect of latitude, in space and time, on mean temperature was taken into account. To inventory this, monthly mean temperatures were reduced to sea level temperatures, and areas with mean temperatures of all months greater than 18°C were separated from those with a period with monthly mean temperatures less than 18°C. The former were designated the tropics. In the latter case areas with mean temperatures of all months greater than 5°C were separated from those with a period with monthly mean temperatures less than 5°C. These two areas were designated the sub-tropics and the temperate respectively. The sub-tropics were separated into areas where the rainfall was concentrated in the cooler part of the year (i.e. sub-tropics with winter rainfall) and where it was concentrated in the warmer part of the year (i.e. sub-tropics with summer rainfall). To take into account the effect of altitude on mean temperatures during the growing period (and therefore on potential crop distribution), the tropics and the sub-tropics with summer rainfall were each divided into four thermal zones, i.e. warm (>20°C), moderately cool (15°-20°C), cool (5°-15°C) and cold (<5°C). The sub-tropics with winter rainfall and the temperate were each divided into two thermal zones. This led to recognition of the thermal zones for the developing world.

Once the temperature requirements of a crop are met, production mainly depends on an adequate supply of moisture. To assess this the growing period is defined as the continuous period (with high enough temperature) when rainfall exceeds half potential evapotranspiration (calculated by the Penman method) plus the days required to evaporate an assumed 100 mm of stored soil moisture. 'Normal' growing periods have a humid phase when rainfall exceeds potential evapotranspiration. 'Intermediate' growing periods are recognised where rainfall is less than potential evapotranspiration but more than half of it (so plants can grow but under stress).

Other climatic features can be introduced such as seasonal variability, the distribution pattern of different lengths of growing period, or other locally important climatic features.

For more complete information reference should be made to the four volumes of the FAO Agro-ecological Zones Project (FAO, 1978-81) and to later publications on the agro-ecological zones approach to the application of climatic parameters to the assessment of the production potential of land for specific types of use.

X. KEY TO MAJOR SOIL GROUPINGS AND SOIL UNITS

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 when it rests on rocks or on fragmental material of which the interstices are filled with organic matter.

HISTOSOLS (HS)

Histosols having permafrost within 200 cm of the surface.

Gelic Histosols (HSi)

Other Histosols having a sulfuric horizon or sulfidic materials at less than 125 cm from the surface.

Thionic Histosols (HSt)

Other Histosols that are well drained and are never saturated with water for more than a few days.

Folic Histosols (HSI)

Other Histosols having raw or weakly decomposed organic materials, the fiber content of which is dominant to a depth of 35 cm or more from the surface; having very poor drainage or are undrained.

Fibric Histosols (HSf)

Other Histosols. These Histosols have highly decomposed organic materials with only small amounts of visible plant fibers and a very dark grey to black colour to a depth of 35 cm or more from the surface, having an imperfect to very poor drainage.

Terrie Histosols (HSs)

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

ANTHROSOLS (AT)

Anthrosols showing remnants of diagnostic horizons due to deep cultivation.

Aric Anthrosols (ATa)

Other Anthrosols having a fimic A horizon.

Fimic Anthrosols (ATf)

Other Anthrosols showing an accumulation of fine sediments, thicker than 50 cm, resulting from long-continued irrigation or man-made raising of the soil surface.

Cumulic Anthrosols (ATc)

Other Anthrosols. These Anthrosols have, to a depth of more than 50 cm, an accumulation of wastes from mines, town refuse, fills from urban developments, etc.

Urbic Anthrosols (ATu)

Other soils which are limited in depth by continuous hard rock or highly calcareous materials (calcium carbonate equivalent of more than 40 percent) or a continuous cemented layer within 30 cm of the surface or having less than 20 percent of fine earth over a depth of 75 cm from the surface. Diagnostic horizons may be present.

LEPTOSOLS (LP)

Leptosols which are limited in depth by continuous hard rock or a continuous cemented layer within 10 cm of the surface.

Lithic Leptosols (LPq)

Other Leptosols having permafrost within 200 cm of the surface.

Gelic Leptosols (LPi)

Other Leptosols having a mollic A horizon which contains or immediately overlies calcareous material with a calcium carbonate equivalent of more than 40 percent.

Rendzic Leptosols (LPk)

Other Leptosols having a mollic A horizon.

Mollic Leptosols (LPm)

Other Leptosols having an umbric A horizon.

Umbric Leptosols (LPu)

Other Leptosols having a base saturation (by NH_4OAc) of less than 50 percent.

Dystric Leptosols (LPd)

Other Leptosols.

Eutric Leptosols (LPe)

Other soils having, after the upper 18 cm have been mixed, 30 per cent 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)

Vertisols having a gypsic horizon within 125 cm of the surface.

Gypsic Vertisols (VRy)

Other Vertisols having a calcic horizon or concentrations of soft powdery lime within 125 cm of the surface.

Calcic Vertisols (VRk)

Other Vertisols having a base saturation (by NH_4OAc) of less than 50 percent at least from 20 to 50 cm from the surface.

Dystric Vertisols (VRd)

Other Vertisols.

Eutric Vertisols (VRe)

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

FLUVISOLS (FL)

Fluvisols having a sulfuric horizon or sulfidic material, or both, at less than 125 cm from the surface.

Thionic Fluvisols (FLt)

Other Fluvisols showing salic properties.

Salic Fluvisols (FLs)

Other Fluvisols having a mollic A horizon or a eutric histic H horizon.

Mollic Fluvisols (FLm)

Other Fluvisols which are calcareous at least between 20 and 50 cm from the surface.

Calcaric Fluvisols (FLc)

Other Fluvisols having an umbric A horizon or a dystric histic H horizon.

Umbric Fluvisols (FLu)

Other Fluvisols having a base saturation (by NH_4OAc) of less than 50 percent, at least from 20 to 50 cm from the surface.

Dystric Fluvisols (FLd)

Other Fluvisols

Eutric Fluvisols (FLe)

Other soils showing salic properties and having no diagnostic horizons other than an ochric, umbric or mollic A horizon, a histic H horizon, a cambic B horizon, a calcic or a gypsic horizon.

SOLONCHAKS (SC)

Solonchaks having permafrost within 200 cm of the surface.

Gelic Solonchaks (SCi)

Other Solonchaks showing gleyic properties within 100 cm of the surface.

Gleyic Solonchaks (SCg)

Other Solonchaks having a mollic A horizon.

Mollic Solonchaks (SCm)

Other Solonchaks having a gypsic horizon within 125 cm of the surface.

Gypsic Solonchaks (SCy)

Other Solonchaks having a calcic horizon within 125 cm of the surface.

Calcic Solonchaks (SCk)

Other Solonchaks showing sodic properties at least between 20 and 50 cm of the surface.

Sodic Solonchaks (SCn)

Other Solonchaks.

Haplic Solonchaks (SCH)

Other soils, exclusive of coarse textured materials (except when a Histic H horizon is present), 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 sulfuric, a calcic or a gypsic horizon; lacking plinthite within 125 cm of the surface.

GLEYSOLS (GL)

Gleysols having permafrost within 200 cm from the surface.

Gelic Gleysols (GLi)

Other Gleysols having a sulfuric horizon or sulfidic material at less than 125 cm from the surface.

Thionic Gleysols (GLt)

Other Gleysols having andic properties.

Andic Gleysols (GLa)

Other Gleysols having a mollic A horizon or a eutric histic H horizon.

Mollic Gleysols (GLm)

Other Gleysols having an umbric A horizon or a dystric histic H horizon.

Umbric Gleysols (GLu)

Other Gleysols having a calcic horizon within 125 cm of the surface.

Calcic Gleysols (GLk)

Other Gleysols having a base saturation (by NH_4OAc) of less than 50 percent, at least from 20 to 50 cm from the surface.

Dystic Gleysols (GLd)

Other Gleysols.

Eutric Gleysols (GLE)

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)

Andosols having permafrost within 200 cm of the surface.

Gelic Andosols (ANi)

Other Andosols showing gleyic properties within 100 cm of the surface.

Gleyic Andosols (ANg)

Other Andosols lacking a smeary consistence, or a texture which is silt loam or finer on the weighted average for all horizons within 100 cm of the surface, or both.

Vitric Andosols (ANz)

Other Andosols having a mollic A horizon.

Mollic Andosols (ANm)

Other Andosols having an umbric A horizon.

Umbric Andosols (ANu)

Other Andosols.

Haplic Andosols (ANh)

Other soils which are coarser than sandy loam to a depth of at least 100 cm from the surface, having less than 35 per cent of rock fragments or other coarse fragments in all subhorizons within 100 cm of the surface, having no diagnostic horizons other than an ochric A horizon or an albic E horizon.

ARENOSOLS (AR)

Arenosols showing gleyic properties within 100 cm of the surface.

Gleyic Arenosols (ARg)

Other Arenosols having an albic E horizon with a minimum thickness of 50 cm within 125 cm of the surface.

Albic Arenosols (ARa)

Other Arenosols which are calcareous at least between 20 and 50 cm from the surface.

Calcaric Arenosols (ARc)

Other Arenosols showing an increase of 3 per cent clay or more or lamellae of clay accumulation within 125 cm of the surface.

Luvic Arenosols (ARl)

Other Arenosols showing ferralic properties within 125 cm of the surface and colouring of the horizon immediately underlying the A horizon expressed by chroma of 5 or more or hues redder than 10YR.

Ferralic Arenosols (ARo)

Other Arenosols showing colouring or alteration characteristic of a cambic B horizon.

Cambic Arenosols (ARb)

Other Arenosols.

Haplic Arenosols (ARh)

Other soils having no diagnostic horizons other than an ochric or umbric A horizon; *lacking soft powdery lime*.

REGOSOLS (RG)

Regosols having permafrost within 200 cm of the surface.

Gelic Regosols (RGi)

Other Regosols having an umbric A horizon.

Umbric Regosols (RGu)

Other Regosols which are gypsiferous at least between 20 and 50 cm from the surface.

Gypsic Regosols (RGy)

Other Regosols which are calcareous at least from 20 to 50 cm from the surface.

Calcaric Regosols (RGc)

Other Regosols having a base saturation (by NH_4OAc) of less than 50 percent, at least from 20 to 50 cm from the surface.

Dystric Regosols (RGd)

Other Regosols.

Eutric Regosols (RGe)

Other soils having a spodic B horizon.

PODZOLS (PZ)

Podzols having permafrost within 200 cm of the surface.

Gelic Podzols (PZi)

Other Podzols showing gleyic properties within 100 cm of the surface.

Gleyic Podzols (PZg)

Other Podzols having a B horizon in which a subhorizon contains dispersed organic matter and lacks sufficient free iron to turn redder on ignition.

Carbic Podzols (PZc)

Other Podzols in which the ratio of percentage of free iron to percentage of organic carbon is 6 or more in all subhorizons of the B horizon.

Ferric Podzols (PZf)

Other Podzols lacking or having only a thin (2 cm or less) and discontinuous albic E horizon; lacking a subhorizon within the B horizon which is visibly more enriched with organic carbon.

Cambic Podzols (PZb)

Other Podzols.

Haplic Podzols (PZh)

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 when 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)

Plinthosols having an albic E horizon.

Albic Plinthosols (PTa)

Other Plinthosols having an umbric A horizon or a dystric histic H horizon and which are strongly humic.

Humic Plinthosols (PTu)

Other Plinthosols having an ochric A horizon and a base saturation (by NH_4OAc) of less than 50 percent throughout the upper 50 cm of the plinthite horizon.

Dystric Plinthosols (PTd)

Other Plinthosols.

Eutric Plinthosols (PTe)

Other soils having a ferralic B horizon.

FERRALSOLS (FR)

Ferralsols having plinthite within 125 cm of the surface.

Plinthic Ferralsols (FRp)

Other Ferralsols having geric properties in at least some part of the ferralic B horizon within 125 cm of the surface.

Geric Ferralsols (FRg)

Other Ferralsols which are strongly humic, having an umbric A horizon, or a mollic A horizon and a base saturation (by NH_4OAc) of less than 50 percent in at least a part of the B horizon within 100 cm of the surface.

Humic Ferralsols (FRu)

Other Ferralsols having a red to dusky red B horizon (rubbed soil has hues redder than 5YR with a moist value of less than 4 and a dry value not more than one unit higher than the moist value).

Rhodic Ferralsols (FRr)

Other Ferralsols having a yellow to pale yellow B horizon (rubbed soil has hues of 7.5 YR or yellower with a moist value of 4 or more and a moist chroma of 5 or more).

Xanthic Ferralsols (FRx)

Other Ferralsols

Haplic Ferralsols (FRh)

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, and lacking a natric or a spodic B horizon.

PLANOSOLS (PL)

Planosols having permafrost within 200 cm of the surface.

Gelic Planosols (PLi)

Other Planosols having a mollic A horizon or a eutric histic H horizon.

Mollic Planosols (PLm)

Other Planosols having an umbric A horizon or a dystrophic H horizon.

Umbric Planosols (PLu)

Other Planosols having a base saturation (by NH_4OAc) of less than 50 percent in at least a part of the slowly permeable horizon within 125 cm of the surface.

Dystrophic Planosols (PLd)

Other Planosols.

Eutric Planosols (PLe)

Other soils having a natric B horizon.

SOLONETZ (SN)

Solonetz showing gleyic properties within 100 cm of the surface.

Gleyic Solonetz (SNg)

Other Solonetz showing stagnic properties within 50 cm of the surface.

Stagnic Solonetz (SNj)

Other Solonetz having a mollic A horizon.

Mollic Solonetz (SNm)

Other Solonetz having a gypsic horizon within 125 cm of the surface.

Gypsic Solonetz (SNy)

Other Solonetz having a calcic horizon *or soft powdery lime* within 125 cm of the surface.

Calcic Solonetz (SNk)

Other Solonetz.

Haplic Solonetz (SNh)

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 sand grains on structural ped surfaces; having an argic B horizon.

GREYZEMS (GR)

Greyzems showing gleyic properties within 100 cm of the surface.

Gleyic Greyzems (GRg)

Other Greyzems.

Haplic Greyzems (GRh)

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 or petrocalcic horizon, or concentrations of soft powdery lime within 125 cm of the surface, or both.

CHERNOZEMS (CH)

Chernozems having an argic B horizon and showing gleyic properties within 100 cm of the surface.

Gleyic Chernozems (CHg)

Other Chernozems having an argic B horizon; a calcic horizon may underlie the B horizon.

Luvic Chernozems (CHl)

Other Chernozems showing tonguing of the A horizon into a cambic B or into a C horizon.

Glossic Chernozems (CHw)

Other Chernozems having a calcic or petrocalcic horizon.

Calcic Chernozems (CHk)

Other Chernozems.

Haplic Chernozems (CHh)

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, petrocalcic or gypsic horizon, or concentrations of soft powdery lime within 125 cm of the surface.

KASTANOZEMS (KS)

Kastanozems having a gypsic horizon.

Gypsic Kastanozems (KSy)

Other Kastanozems having an argic B horizon; a calcic horizon may underlie the B horizon.

Luvic Kastanozems (KSl)

Other Kastanozems having a calcic or petrocalcic horizon.

Calcic Kastanozems (KSk)

Other Kastanozems.

Haplic Kastanozems (KSh)

Other soils having a mollic A horizon; having a base saturation (by NH_4OAc) of 50 percent or more throughout the upper 125 cm of the soil.

PHAEZEMS (PH)

Phaeozems showing gleyic properties within 100 cm of the surface.

Gleyic Phaeozems (PHg)

Other Phaeozems showing stagnic properties within 50 cm of the surface.

Stagnic Phaeozems (PHj)

Other Phaeozems having an argic B horizon.

Luvic Phaeozems (PHl)

Other Phaeozems that are calcareous at least from 20 to 50 cm of the surface.

Calcaric Phaeozems (PHc)

Other Phaeozems.

Haplic Phaeozems (PHh)

Other 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 have redder hues and stronger chromas than the interiors.

PODZOLUVISOLS (PD)

Podzoluvisols having permafrost within 200 cm of the surface.

Gelic Podzoluvisols (PDi)

Other Podzoluvisols showing gleyic properties within 100 cm of the surface.

Gleyic Podzoluvisols (PDg)

Other Podzoluvisols showing stagnic properties within 50 cm of the surface.

Stagnic Podzoluvisols (PDj)

Other Podzoluvisols having a base saturation (by NH_4OAc) of less than 50 percent in at least a part of the B horizon within 125 cm of the surface.

Dystic Podzoluvisols (PDd)

Other Podzoluvisols.

Eutric Podzoluvisols (PDe)

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 permeated with gypsum or calcium carbonate, a calcic or a petrocalcic horizon.

GYPSISOLS (GY)

Gypsisols having a petrogypsic horizon, the upper part of which occurs within 100 cm of the surface.

Petric Gypsisols (GYp)

Other Gypsisols having a calcic or petrocalcic horizon.
Calcic Gypsisols (GYk)

Other Gypsisols having an argic B horizon.
Luvic Gypsisols (GYl)

Other Gypsisols.
Haplic Gypsisols (GYh)

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 which is calcareous.

CALCISOLS (CL)

Calcisols having a petrocalcic horizon, the upper part of which occurs within 100 cm of the surface.
Petric Calcisols (CLp)

Other Calcisols having an argic B horizon.
Luvic Calcisols (CLl)

Other Calcisols.
Haplic Calcisols (CLh)

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)

Nitisols which are strongly humic, having an umbric A horizon, or a mollic A horizon and a base saturation (by NH_4OAc) of less than 50 percent in at least a part of the B horizon within 125 cm of the surface.
Humic Nitisols (NTu)

Other Nitisols having a red to dusky red argic B horizon (rubbed soil having hues redder than 5 YR with a moist value of less than 4 and a dry value not more than one unit higher than the moist value).
Rhodic Nitisols (NTr)

Other Nitisols.
Haplic Nitisols (NTh)

Other soils having an argic B horizon which has a cation exchange capacity equal to or more than 24 cmol(+) kg⁻¹ clay and a base saturation (by NH₄OAc) of less than 50 percent in at least some part of the B horizon within 125 cm of the surface.

ALISOLS (AL)

Alisols having plinthite within 125 cm of the surface.

Plinthic Alisols (ALp)

Other Alisols showing gleyic properties within 100 cm of the surface.

Gleyic Alisols (ALg)

Other Alisols showing stagnic properties within 50 cm of the surface.

Stagnic Alisols (ALj)

Other Alisols which are strongly humic.

Humic Alisols (ALu)

Other Alisols showing ferric properties.

Ferric Alisols (ALf)

Other Alisols.

Haplic Alisols (ALh)

Other soils having an argic B horizon which has a cation exchange capacity of less than 24 cmol(+) kg⁻¹ clay and a base saturation (by NH₄OAc) of less than 50 percent in at least some part of the B horizon within 125 cm of the surface.

ACRISOLS (AC)

Acrisols having plinthite within 125 cm of the surface.

Plinthic Acrisols (ACp)

Other Acrisols showing gleyic properties within 100 cm of the surface.

Gleyic Acrisols (ACg)

Other Acrisols which are strongly humic, having an umbric or a mollic A horizon.

Humic Acrisols (ACu)

Other Acrisols showing ferric properties.

Ferric Acrisols (ACf)

Other Acrisols.

Haplic Acrisols (ACH)

Other soils having an argic B horizon which has a cation exchange capacity equal to or more than 24 cmol(+) kg⁻¹ clay and a base saturation (by NH₄OAc) of 50 percent or more throughout the B horizon to a depth of 125 cm.

LUVISOLS (LV)

Luvisols showing gleyic properties within 100 cm of the surface.

Gleyic Luvisols (LVg)

Other Luvisols showing stagnic properties within 50 cm of the surface.

Stagnic Luvisols (LVj)

Other Luvisols having an albic E horizon.

Albic Luvisols (LVa)

Other Luvisols showing vertic properties.

Vertic Luvisols (LVv)

Other Luvisols having a calcic horizon or concentrations of soft powdery lime within 125 cm of the surface.

Calcic Luvisols (LVk)

Other Luvisols showing ferric properties.

Ferric Luvisols (LVf)

Other Luvisols having a strong brown to red B horizon (rubbed soil has a hue of 7.5YR and a chroma of more than 4, or a hue redder than 7.5YR).

Chromic Luvisols (LVx)

Other Luvisols.

Haplic Luvisols (LVh)

Other soils having an argic B horizon which has a cation exchange capacity of less than 24 cmol(+) kg⁻¹ clay and a base saturation (by NH₄OAc) of 50 percent or more throughout the B horizon to a depth of 125 cm.

LIXISOLS (LX)

Lixisols having plinthite within 125 cm of the surface.

Plinthic Lixisols (LXp)

Other Lixisols showing gleyic properties within 100 cm of the surface.

Gleyic Lixisols (LXg)

Other Lixisols showing stagnic properties within 50 cm of the surface.

Stagnic Lixisols (LXj)

Other Lixisols having an albic E horizon.

Albic Lixisols (LXa)

Other Lixisols showing ferric properties.

Ferric Lixisols (LXf)

Other Lixisols.

Haplic Lixisols (LXh)

Other soils having a cambic B horizon.

CAMBISOLS (CM)

Cambisols having permafrost within 200 cm of the surface.

Gelic Cambisols (CMi)

Other Cambisols showing gleyic properties within 100 cm of the surface.

Gleyic Cambisols (CMg)

Other Cambisols showing vertic properties.

Vertic Cambisols (CMv)

Other Cambisols having an umbric A horizon or a mollic A horizon overlying a cambic B horizon with a base saturation (by NH_4OAc) of less than 50 percent *in at least some part of the B horizon*.

Humic Cambisols (CMu)

Other Cambisols which are calcareous at least between 20 and 50 cm from the surface.

Calcaric Cambisols (CMc)

Other Cambisols having a cambic B horizon with ferralic properties.

Ferralic Cambisols (CMo)

Other Cambisols having a base saturation of less than 50 percent (by NH_4OAc) at least in some part of the B horizon.

Dystric Cambisols (CMd)

Other Cambisols which have a strong brown to red B horizon (rubbed soil has a hue of 7.5YR and a chroma of more than 4, or a hue redder than 7.5YR).

Chromic Cambisols (CMx)

Other Cambisols.

Eutric Cambisols (CMe)

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Appendix 1

SOIL HORIZON DESIGNATIONS

This chapter has been taken from: Guidelines for soil description, 3rd edition (revised) FAO, Rome, 1990

HORIZON SYMBOL

Horizon symbols consist of one or two capital letters for the master horizon and lower case letter suffixes for subordinate distinctions, with or without a figure suffix. For the presentation and understanding of the soil profile description, it is essential that correct horizon symbols are given.

(i) MASTER HORIZONS AND LAYERS

The capital letters **H**, **O**, **A**, **E**, **B**, **C** and **R** represent the master horizons and layers of soils. The capital letters are the base symbols to which other characters are added to complete the designation. Most horizons and layers are given a single capital letter symbol, but some require two.

Currently seven master horizons and layers and seven transitional horizons are recognized. The master horizons correspond to the SSM master horizons except for the **H** horizon, which is part of the **O** horizon in SSM.

The master horizons and their subdivisions represent layers which show evidence of change and some layers which have not been changed. Most are genetic soil horizons, reflecting a qualitative judgement about the kind of changes which have taken place. Genetic horizons are not equivalent to diagnostic horizons (see section 2.1.3), although they may be identical in soil profiles. Diagnostic horizons are quantitatively defined features used in classification.

H horizons or layers: Layers dominated by organic material, formed from accumulations of undecomposed or partially decomposed organic material at the soil surface which may be underwater. All **H** horizons are saturated with water for prolonged periods or were once saturated but are now artificially drained. An **H** horizon may be on top of mineral soils or at any depth beneath the surface if it is buried.

O horizons or layers: Layers dominated by organic material, consisting of undecomposed or partially decomposed litter, such as leaves, needles, twigs, moss, and lichens, which has accumulated on the surface; they may be on top of either mineral or organic soils. **O** horizons are not saturated with water for prolonged periods. The mineral fraction of such material is only a small percentage of the volume of the material and generally is much less than half of the weight.

An **O** layer may be at the surface of a mineral soil or at any depth beneath the surface if it is buried. An horizon formed by illuviation of organic material into a mineral subsoil is not an **O** horizon, though some horizons formed in this manner contain much organic matter.

A horizons: Mineral horizons which formed at the surface or below an **O** horizon, in which all or much of the original rock

structure has been obliterated and which are characterized by one or more of the following:

- an accumulation of humified organic matter intimately mixed with the mineral fraction and not displaying properties characteristic of **E** or **B** horizons (see below);
- properties resulting from cultivation, pasturing, or similar kinds of disturbance; or
- a morphology which is different from the underlying **B** or **C** horizon, resulting from processes related to the surface.

If a surface horizon (or epipedon) has properties of both **A** and **E** horizons but the dominant feature is an accumulation of humified organic matter, it is designated an **A** horizon. In some places such as warm arid climates, the undisturbed surface horizon is less dark than the adjacent underlying horizon and contains only small amounts of organic matter. It has a morphology distinct from the **C** layer, though the mineral fraction may be unaltered or only slightly altered by weathering. Such an horizon is designated **A** because it is at the surface. Examples of epipedons which may have a different structure or morphology due to surface processes are Vertisols, soils in pans or playas with little vegetation, and soils in deserts. However, recent alluvial or aeolian deposits that retain fine stratification are not considered to be an **A** horizon unless cultivated.

E horizons: Mineral horizons in which the main feature is loss of silicate clay, iron, aluminum, or some combination of these, leaving a concentration of sand and silt particles, and in which all or much of the original rock structure has been obliterated.

An **E** horizon is usually, but not necessarily, lighter in colour than an underlying **B** horizon. In some soils the colour is that of the sand and silt particles, but in many soils coatings of iron oxides or other compounds mask the colour of the primary particles. An **E** horizon is most commonly differentiated from an underlying **B** horizon in the same soil profile by colour of higher value or lower chroma, or both; by coarser texture; or by a combination of these properties. An **E** horizon is commonly near the surface, below an **O** or **A** horizon and above a **B** horizon, but the symbol **E** may be used without regard to position in the profile for any horizon that meets the requirements and that has resulted from soil genesis.

B horizons: Horizons that formed below an **A**, **E**, **O** or **H** horizon, and in which the dominant features are the obliteration of all or much of the original rock structure, together with one or a combination of the following:

- illuvial concentration, alone or in combination, of silicate clay, iron, aluminum, humus, carbonates, gypsum or silica;
- evidence of removal of carbonates;
- residual concentration of sesquioxides;
- coatings of sesquioxides that make the horizon conspicuously lower in value, higher in chroma, or redder in hue than overlying and underlying horizons without apparent illuviation of iron;

- alteration that forms silicate clay or liberates oxides or both and that forms a granular, blocky, or prismatic structure if volume changes accompany changes in moisture content; or
- brittleness.

All kinds of **B** horizons are, or were originally, subsurface horizons. Included as **B** horizons are layers of illuvial concentration of carbonates, gypsum, or silica that are the result of pedogenetic processes (these layers may or may not be cemented) and brittle layers that have other evidence of alteration, such as prismatic structure or illuvial accumulation of clay.

Examples of layers that are not **B** horizons are layers in which clay films either coat rock fragments or are on finely stratified unconsolidated sediments, whether the films were formed in place or by illuviation; layers into which carbonates have been illuviated but that are not contiguous to an overlying genetic horizon; and layers with gleying but no other pedogenetic changes.

C horizons or layers: Horizons or layers, excluding hard bedrock, that are little affected by pedogenetic processes and lack properties of **H**, **O**, **A**, **E**, or **B** horizons. Most are mineral layers, but some siliceous and calcareous layers such as shells, coral and diatomaceous earth, are included. The material of **C** layers may be either like or unlike that from which the solum presumably formed. A **C** horizon may have been modified even if there is no evidence of pedogenesis. Plant roots can penetrate **C** horizons, which provide an important growing medium.

Included as **C** layers are sediments, saprolite, and unconsolidated bedrock and other geologic materials that commonly slake within 24 hours when air dry or drier chunks are placed in water and when moist can be dug with a spade. Some soils form in material that is already highly weathered, and such material that does not meet the requirements of **A**, **E** or **B** horizons is designated **C**. Changes not considered pedogenetic are those not related to overlying horizons. Layers having accumulations of silica, carbonates, or gypsum, even if indurated, may be included in **C** horizons, unless the layer is obviously affected by pedogenetic processes; then it is a **B** horizon.

R layers: Hard bedrock underlying the soil.

Granite, basalt, quartzite and indurated limestone or sandstone are examples of bedrock that are designated **R**. Air dry or drier chunks of an **R** layer when placed in water will not slake within 24 hours. The **R** layer is sufficiently coherent when moist to make hand digging with a spade impractical, although it may be chipped or scraped. Some **R** layers can be ripped with heavy power equipment. The bedrock may contain cracks, but these are so few and so small that few roots can penetrate. The cracks may be coated or filled with clay or other material.

(ii) TRANSITIONAL HORIZONS

There are two kinds of transitional horizons: those with properties of two horizons superimposed and those with the two properties separate.

For horizons dominated by properties of one master horizon but having subordinate properties of another, two capital letter symbols are used, such as **AB**, **EB**, **BE** and **BC**. The master horizon symbol that is given first designates the kind of horizon whose properties dominate the transitional horizon. An **AB** horizon, for example, has characteristics of both an overlying **A** horizon and an underlying **B** horizon, but is more like the **A** than like the **B**.

In some cases, a horizon can be designated as transitional even if one of the master horizons to which it is apparently transitional is not present. A **BE** horizon may be recognized in a truncated soil if its properties are similar to those of a **BE** horizon in a soil in which the overlying **E** horizon has not been removed by erosion. An **AB** or a **BA** horizon may be recognized where bedrock underlies the transitional horizon. A **BC** horizon may be recognized even if no underlying **C** horizon is present; it is transitional to assumed parent material. A **CR** horizon can be used for weathered bedrock which can be dug with a spade though roots cannot penetrate except along fracture planes.

Horizons in which distinct parts have recognizable properties of two kinds of master horizons are indicated as above, but the two capital letters are separated by a virgule (/), as **E/B**, **B/E**, **B/C** or **C/R**. Commonly most of the individual parts of one of the components are surrounded by the other.

(iii) SUBORDINATE CHARACTERISTICS WITHIN MASTER HORIZONS AND LAYERS

Designations of subordinate distinctions and features within the master horizons and layers are based on profile characteristics observable in the field and are applied during the description of the soil at the site. Lower case letters are used as suffixes to designate specific kinds of master horizons and layers, and other features.

Symbols a,d,e,i,l are not used

- b Buried genetic horizon:** Used in mineral soils to indicate identifiable buried horizons with major genetic features that were formed before burial. Genetic horizons may or may not have formed in the overlying material, which may be either like or unlike the assumed parent materials of the buried soil. The symbol is not used in organic soils or to separate an organic layer from a mineral layer.
- c Concretions or nodules:** Indicates a significant accumulation of concretions or of nodules. The nature and consistence of the nodules is specified by other suffixes and in the horizon description.
- f Frozen soil:** Designates horizons or layers that contain permanent ice or are perennially colder than 0°C. It is not

used for seasonally frozen layers nor for bedrock layers (R).

- g Gleying:** Designates horizons in which a distinct pattern of mottling occurs which reflects alternating conditions of oxidation and reduction of sesquioxides (caused by seasonal waterlogging).
- h Accumulation of organic matter:** Designates the accumulation of organic matter in mineral horizons. The accumulation may occur in surface horizons, or in subsurface horizons through illuviation.
- j Jarosite mottles:** Indicates the presence of jarosite mottles.
- k Accumulation of carbonates:** Indicates an accumulation of alkaline earth carbonates, commonly calcium carbonate.
- m Cementation or induration:** Indicates continuous or nearly continuous cementation, and is used only for horizons that are more than 90% cemented, though they may be fractured. The layer is root restrictive and roots do not enter except along fracture planes. The single predominant or codominant cementing agent may be indicated using defined letter suffices singly or in pairs. If the horizon is cemented by carbonates **km** is used; by silica, **qm**; by iron, **sm**; by gypsum, **ym**; by both lime and silica, **kqm**; by salts more soluble than gypsum, **zm**.
- n Accumulation of sodium:** Indicates an accumulation of exchangeable sodium.
- o Residual accumulation of sesquioxides:** Indicates residual accumulation of sesquioxides and differs from the use of symbol **s**, which indicates illuvial accumulation of organic matter and sesquioxide complexes.
- p Ploughing or other disturbance:** Indicates disturbance of the surface layer by ploughing or any other tillage practice. A disturbed organic horizon is designated **Op** or **Hp**. A disturbed mineral horizon, even though clearly once an **E**, **B** or **C**, is designated **Ap**.
- q Accumulation of silica:** Indicates an accumulation of secondary silica. If silica cements the layer and cementation is continuous or nearly continuous, **qm** is used.
- r Strong reduction:** Indicates that iron has been reduced during soil formation, or that continuous saturation with stagnant water has preserved a reduced state. If **r** is used with **B**, pedogenetic change in addition to reduction is implied; if no other change has taken place, the horizon is designated **Cr**.
- s Illuvial accumulation of sesquioxides:** Used with **B** to indicate the accumulation of illuvial, amorphous, dispersible organic matter-sesquioxide complexes if the value and chroma of the horizon are more than 3. The symbol is also used in combination with **h** as **Bhs** if both the organic matter and sesquioxides components are significant and both value and chroma are approximately 3 or less.

- t Accumulation of silicate clay:** Used with **B** or **C** to indicate an accumulation of silicate clay that either has formed in the horizon or has been moved into it by illuviation, or both. At least some part should show evidence of clay accumulation in the form of coatings on ped surfaces or in pores, as lamellae, or as bridges between mineral grains.
- u Unspecified:** this suffix is used in connexion 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 had a genetic connotation. If no subdivision using figure suffixes is needed, the symbols **A** and **B** can be used without **u**.
- v Occurrence of plinthite:** Indicates the presence of iron-rich, humus-poor material that is firm or very firm when moist and that hardens irreversibly when exposed to the atmosphere. When hardened, it is no longer called plinthite but a hardpan, ironstone, a petroferric or a skeletal phase.
- w Development of colour or structure:** Used with **B** to indicate development of colour or structure, or both. It should not be used to indicate a transitional horizon.
- x Fragipan character:** Used to indicate genetically developed firmness, brittleness or high bulk density. These features are characteristic of fragipans, but some horizons designated **x** do not have all the properties of a fragipan.
- y Accumulation of gypsum:** Indicates an accumulation of gypsum.
- z Accumulation of salts more soluble than gypsum:** Indicates an accumulation of salts more soluble than gypsum.

(iv) CONVENTIONS FOR USING LETTER SUFFIXES

Many master horizons and layers that are symbolized by a single capital letter will have one or more lowercase letter suffixes. More than three suffixes are rarely used. The following rules apply:

Letter suffixes should immediately follow the capital letter.

When more than one suffix is needed, the following letters, if used, are written first: **r**, **s**, **t**, and **w**. Except for the **Bhs** or **Crt** horizons, these letters are rarely used in combination in a single horizon.

If more than one suffix is needed and the horizon is not buried, these symbols, if used, are written last: **c**, **f**, **g**, **m**, **u**, **v**, and **x**. Some examples: **Btc**, **Bkm**, and **Bsv**.

If a horizon is buried, the suffix **b** is written last.

A **B** horizon that has significant accumulation of clay and also shows evidence of development of colour or struc-

ture, or both, is designated **Bt** (**t** has precedence over **w**, **s**, and **h**). A **B** horizon that is gleyed or that has accumulations of carbonates, sodium, silica, gypsum, salts more soluble than gypsum, or residual accumulation or sesquioxides carries the appropriate symbol **g**, **k**, **n**, **q**, **y**, **z**, or **o**. If illuvial clay is also present, **t** precedes the other symbol: **Bto**.

Suffixes **h**, **s**, and **w** are normally not used with **g**, **k**, **n**, **q**, **y**, **z**, or **o** unless needed for explanatory purposes.

Unless otherwise indicated, suffixes are listed alphabetically.

(v) VERTICAL SUBDIVISIONS

Horizons or layer designated by a single combination of letter symbols can be subdivided using arabic numerals which follow all the letters. Within a **C**, for example, successive layers could be **C1**, **C2**, **C3**, etc.; or if the lower part is gleyed and the upper part is not, the designations could be **C1-C2-Cg1-Cg2** or **C-Cg1-Cg2-R**.

These conventions apply whatever the purpose of subdivision. A horizon identified by a single set of letter symbols may be subdivided on the basis of evident morphological features, such as structure, colour, or texture. These subdivisions are numbered consecutively. The numbering starts with 1 at whatever level in the profile. Thus **Bt1-Bt2-Btk1-Btk2** is used, not **Bt1-Bt2-Btk3-Btk4**. The numbering of vertical subdivisions within a horizon is not interrupted at a discontinuity (indicated by a numerical prefix) if the same letter combination is used in both materials: **Bs1-Bs2-2Bs3-2Bs4** is used, not **Bs1-Bs2-2Bs1-2Bs2**. **A** and **E** horizons can be subdivided similarly, for example **Ap**, **A1**, **A2**; **Ap1**, **Ap2**; **A1**, **A2**, **A3**; and **E1**, **E2**, **Eg1**, **Eg2**.

(vi) DISCONTINUITIES

In mineral soils, arabic numerals are used as prefixes to indicate discontinuities. Wherever needed, they are used preceding **A**, **E**, **B**, **C** and **R**. These prefixes are distinct from arabic numerals used as suffixes to denote vertical subdivisions.

A discontinuity is a significant change in particle size distribution or mineralogy that indicates a difference in the material from which the horizons formed or a significant difference in age or both, unless that difference in age is indicated by the suffix **b**. Symbols to identify discontinuities are used only when they will contribute substantially to the reader's understanding of relationships among horizons. The stratification common in soils formed in alluvium is not designated as discontinuities unless particle size distribution differs markedly from layer to layer even though genetic horizons have formed in the contrasting layers.

Where a soil has formed entirely in one kind of material, a prefix is omitted from the symbol; the whole profile is material **1**. Similarly, the uppermost material in a profile having two or more contrasting materials is understood to be material **1**, but the number is omitted. Numbering starts with

the second layer of contrasting material, which is designated 2. Underlying contrasting layers are numbered consecutively. Even though a layer below material 2 is similar to material 1, it is designated 3 in the sequence. The numbers indicate a change in the material, not the type of material. Where two or more consecutive horizons formed in one kind of material, the same prefix number applied to all of the horizon designations in that material: **Ap-E-Bt1-2Bt2-2Bt3-2bC**. The number suffixes designating subdivisions of the **Bt** horizon continue in consecutive order across the discontinuity.

If an **R** layer is below a soil that formed in residuum and the material of the **R** layer is judged to be like that from which the material of the soil weathered, the arabic number prefix is not used. If the **R** layer would not produce material like that in the solum, the number prefix is used, as in **A-Bt-C-2R** or **A-Bt-2R**. If part of the solum formed in residuum, **R** is given the appropriate prefix: **Ap-Bt1-2Bt2-2Bt3-2C1-2C2-2R**.

Buried horizons (designated **b**) are special problems. A buried horizon is obviously not the same deposit as horizons in the overlying deposit. Some buried horizons, however, formed in material lithologically like that of the overlying deposit. A prefix is not used to distinguish material of such buried horizons. If the material in which a horizon of a buried soil formed is lithologically unlike that of the overlying material, the discontinuity is designated by number prefixes and the symbol for a buried horizon is used as well: **Ap-Bt1-Bt2-BC-C-2ABb-2Btb1-2Btb2-2C**.

In organic soils, discontinuities between different kinds of layers are not identified. In most cases the differences are shown by the letter suffix designations, if the different layers are organic, or by the master symbol if the different layers are mineral.

(vii) USE OF THE PRIME

Identical designations may be appropriate for two or more horizons or layers separated by at least one horizon or layer of a more different kind in the same pedon. The sequence **A-E-Bt-E-Btx-C** is an example: the soil has two **E** horizons. To make communication easier, a prime is used with the master horizon symbol of the lower of two horizons having identical letter designations: **A-E-Bt-E'-Btx-C**. The prime is applied to the capital letter designation, and any lower case symbol follows it: **B t**. The prime is not used unless all letters of the designations of two different layers are identical. Rarely, three layers have identical letter symbols; a double prime can be used: **E''**.

The same principle applies in designating layers of organic soils. The prime is used only to distinguish two or more horizons that have identical symbols: **O-C-C'-C**. The prime is added to the lower **C** layer to differentiate it from the upper.

Appendix 2

GUIDELINES FOR MAPPING

SOURCES OF INFORMATION

The FAO/Unesco Soil Map of the World is based to the maximum extent possible on factual information derived from actual surveys. As this material is compiled from surveys of different intensity it is not of equal precision and reliability. The sources of the material used are therefore indicated on each sheet by means of a small-scale inset map, which specifies whether the information was derived from systematic soil surveys, reconnaissance surveys, or general information.

Where the soil map is based on systematic soil surveys, the boundaries of the mapping units are plotted from field observations, the density of which depends on the scale of the original maps used.

Where the map is compiled from soil reconnaissance, the boundaries are based to a large extent on topographic, geological, vegetational and climatic data. Information regarding the composition of soil associations results from field observations, the density of which, however, is not sufficient to enable the boundaries of the mapping units to be checked systematically.

For those parts of the soil map compiled from general information, both the boundaries of the mapping units and the composition of the soil associations are largely based on the interpretation of data on land forms, geology, vegetation and climate. Only occasional field observations have been made, and these are insufficient to supply detailed information on the distribution of the different soils throughout the area.

Approximately 600 soil maps of different scales and legends have been compiled to form the Soil Map of the World. They were selected from a collection at FAO of 11 000 maps related not only to soils but also to physiography, vegetation, climate, geology and land use. Many of these maps were used for correlation purposes and for filling maps where direct observation had not been made. Intensive use was also made of first-hand information supplied by FAO field staff engaged in development surveys.

TOPOGRAPHIC BASE

The Soil Map of the World was prepared on the base of the topographic map series of the American Geographical Society of New York at a nominal scale of 1:5 000 000. This scale was considered to be the largest possible for presenting a comprehensive picture of the world's soil resources, taking into account the amount of knowledge available. Grateful acknowledgement is made of the permission given by the American Geographical Society to use this map.

The Americas are compiled on a bipolar oblique conformal projection. The sheets covering Europe, Africa,

Asia and Australasia are based on the Miller oblated stereographic projection, a system consisting of three conformal projections centred on Africa, Central Asia and Australasia, joined together in a continuous fashion by so-called 'fill-in' projections. These fill-in areas, mostly covering the oceans, although not conformal have the property of a conformal match at their boundaries with the adjacent strictly conformal projections. As a result there is complete angular continuity between all sheets.

Consideration was given in the early stages to the use of an equal area projection so that the size of the mapping units could be directly measured. An equal area projection has the disadvantage, however, of introducing unnecessarily large distortion. It was felt more important to represent the topographic features and soil patterns in their true shape. The conformal projection, by which parallels and meridians cut each other at right angles, has the additional advantage of facilitating the compilation into one document of large-scale sectional maps and it therefore simplifies considerably the process of reduction. Areas and distances measured directly on the map are subject to variations related to the projection. However, accuracy can be obtained by use of the conversion tables based on the mean-scale departure ratios published by the American Geographical Society.

SHEET DISTRIBUTION

The base map of the American Geographical Society of New York comprises 16 sheets. For the purpose of the Soil Map of the World redistribution has been made over 18 sheets in order to obtain an equal sheet size of 76 x 110 cm frame, and with a view to showing as many countries as possible in full on at least one of the sheets. A nineteenth sheet is devoted to the legend.

The map sheets have been grouped into major regions, each of which is described in a separate volume as follows:

- I. Legend (1 sheet)
- II. North America (2 sheets)
- III. Mexico and Central America (1 sheet)
- IV. South America (2 sheets)
- V. Europe (2 sheets)
- VI. Africa (3 sheets)
- VII. South Asia (2 sheets)
- VIII. North and Central Asia (3 sheets)
- IX. Southeast Asia (1 sheet)
- X. Australasia (2 sheets)

The distribution of the map is shown on the sheet index reproduced on the legend sheet and on each map sheet.

MAP UNITS

Map units of a world soil map must be sufficiently broad to have universal validity but must contain sufficient elements to reflect as precisely as possible the soil pattern of large regions. The legend of the Soil Map of the World comprises an estimated 5000 different map units, which consist of soil units or associations of soil units occurring within the limits of a mappable physiographic entity¹.

When a map unit is not homogeneous - that is, when it does not consist of just one soil unit, which is generally the case on a small-scale map - it is composed of a dominant soil and of associated soils, the latter covering at least 20 percent of the area; important soils which cover less than 20 percent of the area are added as inclusions. The textural class of the dominant soil and the slope class are given for each association. Phases are used where indurated layers or hard rock occur at shallow depth or in order to indicate stoniness, salinity or alkalinity. Climatic variants need to be considered for interpretation purposes.

The different elements of the legend are defined below.

SOILS

The soil units which compose the legend of the Soil Map of the World are presented on the legend sheet in an order which reflects the general processes of soil formation. The basic principles which underlie the separation of these soil units and their definitions are discussed in Chapter V. Areas of 'non soil' are shown on the map as miscellaneous land units.

For easy reference the list of soil units is given on pages 16-19 and 137-140.

TEXTURAL CLASSES

Textural classes reflect the relative proportions of clay (fraction less than 2 μm), silt (2-50 μm) and sand (50-2 000 μm) in the soil.

¹ The number of map units for North America (sheets II 1-2), Mexico and Central America (sheet III), South America (sheets IV 1-2), Europe (sheets V 1-2), Africa (sheets VI 1-2-3), South Asia (sheets VII 1-2), North and Central Asia (sheets VIII 1-2-3), Southeast Asia (sheet IX) and Australasia (sheets X 1-2) is 596, 301, 469, 777, 1509, 383, 442, 195 and 478 respectively. Certain map units are common to different map sheets. It is estimated that a total of about 5 000 map units cover the whole world.

The texture of a 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.

The textural class is given for the dominant soil of each soil association. It refers to the texture of the upper 30 cm of the soil, which are important for tillage and water retention. Marked changes in texture within the soil resulting from profile development are indicated in the definitions of the soil units (for example, the presence of argic or natric B horizons or the occurrence of an abrupt textural change).

Because of the scale of the map the textural classes shown are limited to three. It is obvious that for management purposes soil texture has to be defined more precisely.

SLOPE CLASSES

Slope is an integral part of the land surface. It influences drainage, run-off, erosion, exposure, accessibility. The slope classes referred 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.

The effect of slope, for example on run-off and erosion, differs with the soil group and with climate. The separation of the three classes, however, gives a general indication which can be interpreted in relation to the other soil characteristics. The limit of 8 percent is considered significant for purposes of mechanization. Class a is obviously too broad - for example to delimit irrigable areas - but small scale maps do not allow a more refined subdivision. Nevertheless the slope classes supply an indication of development potential.

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 textures 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.

If insufficient information is available to specify the dominant soil unit, the group of units as a whole is marked by the colour of the first unit mentioned in the list. For example, the colour of the Haplic Ferralsols is used to show Ferralsols in general, the colour of the Haplic Podzols to show Podzols and the colour of the Haplic Andosols to show Andosols.

Associations dominated by Leptosols (Lithosols) are shown by a striped pattern of the colours of the associated soils. If no associated soils are recognized, because they occupy less than 20 percent of the area or because specific information is lacking, the colour of the Eutric Leptosols unit is applied uniformly with a hatched overprint.

The analytical colour chart of the legend sheet indicates how the different soil colours are composed. Each of the 18 base colours which have been used can be produced in four densities: in full (100 percent), in crossed grid (75 percent), horizontal grid (50 percent) or in dotted grid (25 percent).

The colour chart shows which combinations of base colours and densities have been used to compose each of the colours representing the soil units. This chart should facilitate the reproduction of these colours and possibly at some stage allow for the standardization of the colour schemes used for representing major soil groups.

Overprints

Phases which indicate land characteristics 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, petroferic, phreatic, placic, rudic, salic, skeletal, sodic, takyric and yermic. Phases are normally shown only when they apply to the whole area covered by a map unit. They

may be given for only a part of a map unit when the area to which they apply can be delimited.

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. Where the extent of the land unit is large enough to be shown separately the sign may be printed over a blank background. When a land unit occurs in combination with a soil association the sign may be printed over the soil colour. Boundaries of permafrost and intermittent permafrost are indicated separately from those map 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. It should be pointed out that the systems used for describing environmental factors are not the same in all volumes. For climate and vegetation no generally accepted classifications are in use, so that the selection of the system to be used was left to the discretion of the authors.

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. In certain regions it has not been possible to collect all the information required, so that only part of it is given.

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.

It should be stressed that the explanatory texts to the Soil Map of the World are not monographs on the soils of a given region but are intended to facilitate the use and interpretation of the map.

Appendix 3

UPDATING OF THE SOIL MAP OF THE WORLD

During the preparation of the Soil Map of the World it was apparent that knowledge of the soils of extensive areas was inadequate. Even then it was envisaged that, as information became available, the soil map would be made more reliable and more detailed. The unique collection of soil maps which provided the data base for the original cartography has been continuously added to ever since. Although by no means all the latest maps have been acquired as yet, the collection contains more precise information than is shown on the published maps.

The world soil map is constantly referred to for basic statistical and geographical information about soils. It should provide the most up-to-date data possible rather than remaining frozen at the level of knowledge in the 1970's. Updating is necessary to enhance reliability for the new uses which are being made of the soil data, the map and the map legend, to promote agro-technology transfer and facilitate planning. Redrawing the world soil map is a huge task; fortunately it is now possible to take advantage of modern cartographic methods which make such up-dating feasible, within the limited resources available.

To make generally available the wealth of new information on the latest national soil maps, they have to be collected, made compatible with one another, and combined into a uniform soil map. This is the same process as was undertaken for the original map which took 20 years to complete. However, it will be a less daunting task now for two reasons: soils on most of the national maps are already classified according to the FAO/Unesco legend, or can easily be; and computer-assisted map making is now practical. Digitized cartography facilitates the necessary transformation, automatically provides area measurements, makes boundary changes and adjustments relatively easy, and provides printed outputs rapidly. This new technology enables improved country maps to be inserted when available, and constantly improved World Soil Map sheets to be printed as required.

However, before beginning to amend the mapping boundaries it is essential to refashion the legend to take account of the improved knowledge and understanding of soil conditions and changed concepts of soil taxonomy. The original legend has served well and no radical changes are anticipated. The amendments to the draft legend are based on suggestions collected over the years, published proposals and a broad discussion among experienced users of the legend. Further suggestions, for refinement based on experience with using the legend in the field, will be welcome. However, it is anticipated that the legend now established will be stable for a number of years.

The original Soil Map of the World has already been digitized using the ARC/INFO system. Updating it by the input of national soil maps, with adaptations for small scale global coverage (1:1 000 000 to 1:10 000 000 scales), will be undertaken as resources permit, and in relation to requirements for development. A part of Africa has already been adapted for the 1:1 M scale using the new legend. The digitized maps form part of the new geographic information system. The different scales and projections of national maps can be handled provided that complete information about them is given.

To ensure that the Soil Map of the World contains the most up-to-date information requires the support of soil science institutions everywhere. National soil maps suitable for incorporation, together with the legends and if possible the classification according to the FAO/Unesco legend, should be sent to the Land and Water Development Division of FAO. Proposals for changes and accounts of uses made of the Soil Map of the World and its legend will also be welcome.

Appendix 4

MAIN CHANGES IN THE REVISED LEGEND

Diagnostic horizons, diagnostic properties and phases are listed to indicate whether they are unchanged, have a changed definition, have been added, or deleted with an indication of the reason. For details of the definitions reference should be made to the relevant section.

1. Changes in diagnostic horizons

Diagnostic horizons	Changes or comments
Albic E	amended definition
Argic B	new: replaces 'argillic B', with changed name and definition
Argillic B	deleted: replaced by 'argic B'
Calcic	unchanged
Cambic B	amended definition
Ferralic B	new: replaces 'oxic B', with changed name and definition
Fimic A	new
Gypsic	unchanged
Histic H	unchanged
Mollic A	unchanged
Natric B	amended definition (as 'argic B')
Ochric A	unchanged
Oxic B	deleted: replaced by 'ferralic B'
Petrocalcic	new: replaces 'petrocalcic phase'
Petrogypsic	new: replaces 'petrogypsic phase'
Spodic B	unchanged
Sulfuric	unchanged
Umbric A	unchanged

2. Changes in diagnostic properties

Diagnostic properties	Changes or comments
Abrupt textural change	amended definition
Albic material	deleted
Andic properties	new: replaces 'exchange complex dominated by amorphous materials'
Aridic moisture regime	deleted
Calcareous	new
Calcaric	new
Continuous hard rock	amended: 'coherent' deleted
Ferralic properties	unchanged, except NH_4OAC substituted for NH_4Cl
Ferric properties	amended definition
Fluvic properties	new
Geric properties	new
Gilgai microrelief	deleted: replaced by 'gilgai phase'
Gleyic and Stagnic properties	new: replaces 'hydromorphic properties'
Gypsiferous	new

High organic matter in the B horizon	deleted: replaced by 'strongly humic'
High salinity	deleted: replaced by 'salic properties'
Hydromorphic properties	deleted: replaced by 'gleyic and stagnic properties'
Interfingering	unchanged
Nitic properties	new
Organic soil materials	new
Permafrost	unchanged
Plinthite	amended definition
Salic properties	new: replaces 'high salinity'
Slickensides	unchanged
Smeary consistence	unchanged
Sodic properties	new
Soft powdery lime	unchanged
Strongly humic	new
Sulfidic materials	unchanged
Takyr features	deleted: replaced by 'takyr phase'
Thin iron pan	deleted: replaced by 'placic phase'
Tonguing	unchanged
Vertic properties	unchanged
Weatherable minerals	unchanged

3. Changes in phases

Phases	Changes or comments
Anthraquic	new
Cerrado	deleted
Climatic variants	deleted
Duripan	amended definition
Fragipan	amended definition
Gelundic	new
Gilgai	new
Inundic	new
Lithic	amended: 'coherent' deleted
Petric	deleted: replaced by 'skeletal phase'
Petrocalcic	deleted
Petroferric	amended definition
Petrogypsic	deleted
Phreatic	amended definition
Placic	new: replaces 'thin iron pan'
Rudic	new: replaces 'stony phase'
Salic	new: replaces 'salic phase'; amended definition
Saline	deleted, replaced by salic phase
Skeletal	new: replaces 'petric phase'
Sodic	unchanged
Stony	deleted, replaced by rudic phase
Takyr	new: replaces 'takyr properties'
Yermic	new

4. Main changes in the major soil groupings and soil units

1. Major soil groupings of the 1974-Legend deleted in the Revised Legend: Lithosols, Rendzinas and Rankers now grouped within the Leptosols; Yermosols and Xerosols, previously classified on the basis of an aridic soil moisture regime, are now incorporated in other groups and a yermic phase is indicated where appropriate.
2. Major soil groupings added in the Revised Legend: Leptosols, Calcisols, Gypsisols, Lixisols, Alisols, Plinthosols, Anthrosols.
3. 1974-Legend : 26 major soil groupings with 106 soil units.
Revised Legend : 28 major soil groupings with 153 soil units.
4. The symbols of major soil groupings and soil units have been changed in order to avoid confusion between the 1974 Legend and the Revised one.

Level 1 Major soil groupings	Changes in definitions or comments	Level 2 Soil units	Changes in definitions or comments
Fluvisols (FL)	- mollic or umbric A horizon	Eutric Fluvisols (FLe) allowed as a diagnostic horizon - fluvic properties replace 'recent alluvial deposits' - salic properties allowed	Calcic Fluvisols (FLc) Dystric Fluvisols (FLd) Mollic Fluvisols (FLm) Umbric Fluvisols (FLu) Thionic Fluvisols (FLt) Salic Fluvisols (FLs)
			- new - new - new

Gleysols (GL)

- addition: 'exclusive of coarse textured materials' (a gleyic unit is now included in the Arenosols) and exclusive of alluvial deposits which show fluvic properties (which are grouped with the Fluvisols)
- plinthite within 125 cm of the surface not allowed (these soils are now grouped under Plinthosols)

Eutric Gleysols (GLE)
Calcic Gleysols (GLk)
Dystric Gleysols (GLd)
Andic Gleysols (GLa)
Mollic Gleysols (GLm)
Umbric Gleysols (GLu)
Thionic Gleysols (GLt)
Gellic Gleysols (GLi)
(Plinthic Gleysols)

- new

- formerly Humic Gleysols

- new

- deleted: now Plinthosols

Regosols (RG)

- coarse textured and very stony materials are excluded; these soils are now grouped under Arenosols and Leptosols.

Eutric Regosols (RGe)
Calcic Regosols (RGc)
Gypsic Regosols (RGy)
Dystric Regosols (RGd)
Umbric Regosols (RGu)
Gellic Regosols (RGi)

- new

- new

Leptosols (LP)	<ul style="list-style-type: none"> - new major grouping; groups the former Rankers, Rendzinas and Lithosols. 	<ul style="list-style-type: none"> - new - new - formerly Rendzinas - new - formerly Rankers - formerly Lithosols - new 	<ul style="list-style-type: none"> - new (only ochric A horizon) - clay increase also without lamellae is diagnostic - albic E horizon (125 cm) replaces albic material - new - new
Arenosols (AR)	<ul style="list-style-type: none"> - fluvic and andic properties excluded - 'albic material between at least 0-50 cm or characteristics of argic, cambic or ferralic B horizons without textural requirements' deleted - albic E horizon allowed 	<ul style="list-style-type: none"> - new - new - formerly Rendzinas - new - formerly Rankers - formerly Lithosols - new 	<ul style="list-style-type: none"> - new (only ochric A horizon) - clay increase also without lamellae is diagnostic - albic E horizon (125 cm) replaces albic material - new - new

Andosols (AN)	- soils showing andic properties (instead of specification on bulk density and vitric material)	Haplic Andosols (ANh) Mollic Andosols (ANm) Umbric Andosols (ANu) Vitric Andosols (ANz) Gleyic Andosols (ANG) Gellic Andosols (ANi)	- formerly Ochric Andosols - formerly Humic Andosols - new - new
Vertisols (VR)		Eutric Vertisols (VRe) Dystric Vertisols (VRd) Calcic Vertisols (VRk) Gypsic Vertisols (VRy)	- new: former subdivisions based on chroma (Pellic and Chromic) replaced by base saturation, presence/absence of calcic or gypsic horizon
Cambisols (CM)	- 'calcic or gypsic horizon' deleted (such soils being now included in Calcisols or Gypsisols) - 'lacking an aridic moisture regime' deleted	Eutric Cambisols (CMe) Dystric Cambisols (CMd) Humic Cambisols (CMu) Calcic Cambisols (CMc) Chromic Cambisols (CMx) Vertic Cambisols (CMv) Ferralic Cambisols (CMo) Gleyic Cambisols (CMg) Gellic Cambisols (CMi)	- formerly in Calcic Cambisols

Calcisols (CL)	- new major soil grouping	Haplic Calcisols (CLh) Luvic Calcisols (CLl) Petric Calcisols (CLp)	
Gypsisols (GY)	- new major soil grouping	Haplic Gypsisols (GYh) Calcic Gypsisols (GYk) Luvic Gypsisols (GYl) Petric Gypsisols (GYp)	
Solonetz (SN)	- 'lacking an albic E horizon with hydromorphic properties in a part of the horizon and an abrupt textural change' deleted	Haplic Solonetz (SNh) Mollic Solonetz (SNm) Calcic Solonetz (SNk) Gypsic Solonetz (SNy) Stagnic Solonetz (SNj) Gleyic Solonetz (SNG)	- formerly Orthic Solonetz; lacking gleyic or stagnic properties - new - new - new - gleyic properties between 0-100 cm (was 0-50 cm)

Solonchaks (SC)	- defined in terms of 'salic properties' which require salinity within the upper 30 cm at least during part of the year	Haplic Solonchaks (Sch) Mollic Solonchaks (SCm) Calcic Solonchaks (SCK) Gypsic Solonchaks (SCy) Sodic Solonchaks (SCn) Gleyic Solonchaks (SCg) Gelic Solonchaks (SCi) (Takyric Solonchaks)	- formerly Orthic Solonchaks - lacking gleyic or stagnic properties - new - new - new - gleyic properties between 0-100 cm (was 0-50 cm) - new - deleted
Kastanozems (KS)		Haplic Kastanozems (KSh) Luvic Kastanozems (KSI) Calcic Kastanozems (KSk) Gypsic Kastanozems (KSy)	- soils with gypsic horizon excluded - new
Chernozems (CH)	- 'gypsic horizon' deleted (considering that a gypsic horizon is unlikely to develop under the climate prevailing in Chernozem environment)	Haplic Chernozems (CHh) Calcic Chernozems (CHk) Luvic Chernozems (CHI) Glossic Chernozems (CHw) Gleyic Chernozems (CHg)	- added: lacking gleyic properties within 100 cm of the surface - new

Phaeozems (PH)	- addition: 'having a base saturation (by NH_4OAc) of 50 percent or more throughout 125 cm of the surface'	Haplic Phaeozems (PHh) Calcic Phaeozems (PHc) Luvic Phaeozems (PHl) Stagnic Phaeozems (PHj) Gleyic Phaeozems (PHg)	- lacking gleyic properties between 0-100 cm (was 0-50 cm) - new - gleyic properties between 0-100 cm (was 0-50 cm)
Greyzems (GR)	- 'bleached coatings' replaced by 'uncoated silt and sand grains'; - addition: having an argic B horizon	Haplic Greyzems (GRh) 0-100 cm (was 0-50 cm) Gleyic Greyzems (GRg)	- formerly Orthic Greyzems; lacking gleyic properties between 0-100 cm (was 0-50cm) - gleyic properties between 0-100 cm (was 0-50cm)

Luvvisols (LV)	<p>- addition: 'argic B horizon which has a CEC equal or more than 24 cmol(+) kg⁻¹ clay' (high activity clays)</p> <p>- soils with plinthite are included with Plinthosols</p> <p>- 'lacking an aridic moisture regime' deleted</p>	<p>Haplic Luvvisols (LVh)</p> <p>Ferric Luvvisols (LVf)</p> <p>Chromic Luvvisols (LVx)</p> <p>Calcic Luvvisols (LVk)</p> <p>Vertic Luvvisols (LVv)</p> <p>Albic Luvvisols (LVa)</p> <p>Stagnic Luvvisols (LVj)</p> <p>Gleyic Luvvisols (LVg)</p>	<p>- formerly Orthic Luvvisols lacking gleyic properties between 0-100 cm (was 0-50 cm)</p> <p>- new</p> <p>- gleyic properties between 0-100 cm (was 0-50 cm)</p>
Lixisols (LX)	<p>- new major soil grouping</p> <p>'argic B horizon which has a CEC of less than 24 cmol(+) kg⁻¹ clay' (low activity clays)</p>	<p>Haplic Lixisols (LXh)</p> <p>Ferric Lixisols (LXf)</p> <p>Plinthic Lixisols (LXp)</p> <p>Albic Lixisols (LXa)</p> <p>Stagnic Lixisols (LXj)</p> <p>Gleyic Lixisols (LXg)</p>	

Planosols (PL)

Eutric Planosols (PLe)
 Dystric Planosols (PLd)
 Mollic Planosols (PLm)
 Umbric Planosols (PLu)
 Gelic Planosols (PLi)
 (Solodic Planosols)

- formerly Humic Planosols

- deleted

Podzoluvisols (PD)

Eutric Podzoluvisols (PDe)
 Dystric Podzoluvisols (PDd)
 Stagnic Podzoluvisols (PDj)
 Gleyic Podzoluvisols (PDg)
 Gelic Podzoluvisols (PDi)

- lacking gleyic properties between
 0-100 cm (was 0-50 cm)

- new

- gleyic properties between 0-100 cm (was 0-50 cm)

- new

Podzols (PZ)	<ul style="list-style-type: none"> - reference to 'thin iron pan' deleted (thin iron pan is now shown as a placic phase) 	<ul style="list-style-type: none"> Haplic Podzols (PZh) Cambic Podzols (PZb) Ferric Podzols (PZf) Carbic Podzols (PZc) Gleyic Podzols (PZg) Gelic Podzols (PZi) (Placic Podzols) 	<ul style="list-style-type: none"> - formerly Orthic Podzols - formerly Leptic Podzols - formerly Humic Podzols - gleyic properties between 0-100 cm (was 0-50cm) - new - deleted
Acrisols (AC)	<ul style="list-style-type: none"> - addition: 'argic B horizon which has a CEC of less than 24 cmol(+) kg⁻¹ clay' (low activity clays) - 'lacking an aridic moisture 	<ul style="list-style-type: none"> Haplic Acrisols (ACh) Ferric Acrisols (ACf) Humic Acrisols (ACu) Plinthic Acrisols (ACp) Gleyic Acrisols (ACg) 	<ul style="list-style-type: none"> - formerly Orthic Acrisols - definition revised - gleyic properties between 0-100 cm regime' deleted (was 0-50 cm)
Alisols (AL)	<ul style="list-style-type: none"> - new major soil grouping 'former Acrisols with a CEC in the argic B horizon equal or higher than 24 cmol(+) kg⁻¹ clay' (high activity clays) 	<ul style="list-style-type: none"> Haplic Alisols (ALh) Ferric Alisols (ALf) Humic Alisols (ALu) Plinthic Alisols (ALp) Stagnic Alisols (ALj) Gleyic Alisols (ALg) 	

Nitisols (NT)	<ul style="list-style-type: none"> - formerly Nitisols; with added requirements on horizon boundaries, clay content and nitic properties - 'lacking an aridic moisture regime' deleted 	Haplic Nitisols (NTh) Rhodic Nitisols (NTr) Humic Nitisols (NTu)	<ul style="list-style-type: none"> - substitutes the former subdivision in Eutric Nitisols and Dystric Nitisols - definition revised
Ferralsols (FR)	<ul style="list-style-type: none"> - 'ferralic horizon' replaces 'oxic horizon' 	Haplic Ferralsols (FRh) Xanthic Ferralsols (FRx) Rhodic Ferralsols (FRr) Humic Ferralsols (FRu) Geric Ferralsols (FRg) Plinthic Ferralsols (FRp)	<ul style="list-style-type: none"> - formerly Orthic Ferralsols - definition revised - formerly Acric Ferralsols; 'geric properties' replaces part of definition - addition: 'lacking an albic E horizon or a horizon which shows gleyic properties within 100 cm of the surface'
Plinthosols (PT)	<ul style="list-style-type: none"> - new major soil grouping (soils previously grouped with the Ferralsols or Gleysols) 	Eutric Plinthosols (PTe) Dystric Plinthosols (PTd) Humic Plinthosols (PTu) Albic Plinthosols (PTa)	

Histosols (HS)			
	Folic Histosols (HSI) Terric Histosols (HSs) Fibric Histosols (HSf) Thionic Histosols (HSi) Gellic Histosols (HSi)		- new; definition of soil units based on degree of decomposition of plant materials and on drainage; substitutes the former separation, Eutric and Dystric, which can be taken care of at the third level
Anthrosols (AT)		Aric Anthrosols (ATa) Fimic Anthrosols (ATf) Cumulic Anthrosols (ATc) Urbic Anthrosols (ATu)	- soils with a plaggen or an anthropic epipedon according to the USDA Soil Taxonomy (1975)
			- new major soil grouping (man-influenced soils)

Appendix 5

PROCEDURES FOR SOIL ANALYSIS

The procedures for soil analysis are those described in soil survey laboratory methods and procedures for collecting soil samples (US Department of Agriculture, 1984) supplemented by those adopted by ISRIC (ISRIC, 1987). For ease of reference the procedures used are summarized below, however, reference should be made to the two publications mentioned above for more complete information.

The units used in the present legend are those of the International System of Units (SI). In order to facilitate comparison with the original legend (FAO, 1974) the equivalents between SI units and those used previously are given below:

SI units	superseded
1 cmol(+) kg ⁻¹	=1 meq/100 g
1 dS m ⁻¹	=1 mmho/cm
33 kPa	=1/3 bar
1 M (Mol)	=1 N (Normal)
1 µm (micrometer)	=1 µ (micron)
1 mg kg ⁻¹	=1 ppm
1 Mg m ⁻³	=1 g/cm ³

Physical analysis

Particle size distribution

The sample is pretreated with hydrogen peroxide to remove organic matter. Prior to this, if carbonates are present, the sample is pretreated with 1 M hydrochloric acid. Dispersion is with sodium hexametaphosphate/sodium carbonate and shaking overnight. Clay and silt are separated from sand by wet sieving (50 µm) and determined by the pipette method. Sand is fractionated by dry sieving.

Note: Clay-size carbonates have physico-chemical properties that differ from those of clay minerals. For this reason, in the definition of particle size classes, carbonates in the clay fraction accrue to the silt fraction. This requires a simple carbonate determination on the clay fraction obtained during particle size analysis. In many laboratories, however, it is routine practice to remove carbonates as a pretreatment in particle size analysis to obtain maximum dispersion of primary particles (in addition to removal of organic matter). Obviously, in this case no carbonate is found in the clay fraction. Therefore, adding the total percentage of carbonates in the

whole soil to the silt fraction could result in an overestimation of this fraction with sand-size carbonates. Since particle size analysis may serve different purposes there is as yet no standardized procedure. Pretreatments in most laboratory manuals are optional. It is clear that both options, to either remove or not to remove carbonates, have advantages and disadvantages. At relatively low carbonate contents (less than 10-15 percent) the advantage of carbonate removal in increased dispersion outweighs the disadvantage of loss of information on the distribution of carbonates. By contrast, in highly calcareous soils the carbonate particles constitute such a substantial part of the soil matrix that removal ought to be omitted. A possible error by incomplete dispersion of the clay particles is then implied. It is always worthwhile to carry out comparative tests to gauge the influence of pretreatments and dispersion methods.

Ref.: Gee, G.W. and Bauder, J.W. (1986). Particle size analysis. In: Klute, A. (ed.) *Methods of soil analysis. Part 1. Physical and mineralogical methods*. Second ed. Agronomy Series no. 9, ASA, SSSA, Madison, Wis., USA, p. 383-411.

Water-dispersible clay

This is the clay content measured when the sample is shaken overnight in water without dispersing agent and without applying any pretreatment.

Bulk density

Bulk density is determined by the dry weight of a 100 ml undisturbed core sample taken at field-moist conditions (approximately 33 kPa water).

Ref.: Blake, G.R. and Hartge, K.H. (1986). Bulk density. In: Klute, A. (ed.) *Methods of soil analysis. Part 1. Physical and mineralogical methods*. Second ed. Agronomy Series no. 9, ASA, SSSA, Madison, Wis., USA, p. 363-375.

Chemical analysis

pH

The pH is determined with a pH-meter (combination electrode) in the supernatant suspension of a 1:2.5 soil:liquid mixture. The liquid is water or 1 M KCl solution. For identification of a sulphuric horizon and salic properties pH-H₂O is measured in a 1:1 suspension. The water extracts are monitored for the presence of soluble salts by measuring the electrical conductivity.

Ref.: McLean, E.O. (1982). Soil pH and lime requirement. In: Page, A.L. (ed.) *Methods of soil analysis. Part 2. Chemical and microbiological properties*. Second ed. Agronomy Series no. 9, ASA, SSSA, Madison, Wis., USA, p.199-234.

Electrical conductivity

Electrical conductivity is measured with a conductivity meter in the saturation extract of saline soils.

Ref.: Rhoades, J.D. (1982). Soluble salts. In: Page, A.L. (ed.) Methods of soil analysis. Part 2. Chemical and microbiological properties. Second ed. Agronomy Series no. 9, ASA, SSSA, Madison, Wis., USA, p. 172.

Organic carbon

The Walkley-Black procedure is followed. It applies wet combustion of the organic matter with a potassium dichromate/sulphuric acid mixture and titration of residual dichromate with ferrous sulphate.

Ref.: Nelson, D.W. and Sommers, L.E. (1982). Total carbon, organic carbon, and organic matter. In: Page, A.L. (ed.) Methods of soil analysis. Part 2. Chemical and microbiological properties. Second ed. Agronomy Series no. 9, ASA, SSSA, Madison, Wis., USA, p. 570.

Carbonate equivalent

The rapid titration method by Piper is followed (acid neutralization method). The sample is treated with dilute hydrochloric acid and the residual acid is titrated with sodium hydroxide.

Ref.: Allison, L.E. and Moodie, C.D. (1965). In: C.A. Black (ed.) Methods of soil analysis. Part 1. Physical and mineralogical properties. Agronomy Series no. 9, ASA, SSSA, Madison, Wis., USA, p. 1387.

Gypsum

Gypsum is dissolved by shaking the sample with water. It is then selectively precipitated from the extract by adding acetone. This precipitate is redissolved in water and the gypsum is determined by measuring the Ca concentration in the solution.

Ref.: Hesse, P.R. (1971). A textbook of soil chemical analysis. John Murray, London, p. 85.

Cation exchange properties

Exchangeable bases: are measured by percolation of the sample with ammonium acetate at pH 7. The Ca, Mg, K and Na are determined in percolate.

Cation exchange capacity (CEC): after percolation with ammonium acetate at pH 7, the sample is washed free of excess salt and percolated with potassium chloride. Ammonium is determined in the percolate. Alternatively, after percolation with ammonium acetate at pH 7, the sample is percolated with sodium acetate at pH 7, washed free of excess salt and percolated with ammonium acetate. Sodium is measured in the percolate.

Exchangeable acidity (H + Al): the sample is percolated with 1M KCl. Acidity is measured by titration of the percolate. Exchangeable aluminium is determined separately in this percolate.

Effective cation exchange capacity (ECEC): is determined by summation of exchangeable bases and exchangeable aluminium.

Extractable acidity: the sample is equilibrated with a BaCl₂-TEA buffer at pH 8.2. Titration of residual base with acid.

Note: As an alternative for the ammonium acetate method the silver thiourea method may be used, this being a rapid and convenient single-step non-alcoholic procedure for both CEC and exchangeable bases unbuffered or buffered at pH 7.

Ref.: Dewis, J. and Freitas, F. (1970). Physical and chemical methods of soil and water analysis. Soils Bulletin no. 10. FAO, Rome.

Chhabbra, R., Pleysier, J.L. and Cremers, A. (1975). The measurement of the cation exchange capacity and exchangeable cations in soils: a new method. Proc. Int. Clay Conf., Mexico, 1975.

Extractable iron, aluminium and silicon

Dithionite extraction: two procedures can be used.

1. Mehra and Jackson procedure in which the sample is heated in a complexing buffer of sodium citrate/bicarbonate to which solid sodium dithionite is added as a reducing agent. Fe and Al are measured in the extract.

2. Holmgren procedure in which the sample is shaken with a complexing and reducing buffer of sodium citrate and sodium dithionite. Al and Fe are measured in the extract.

Acid oxalate extraction: the sample is shaken with a solution of ammonium oxalate at pH 3. Fe, Al and Si are measured in the extract.

Pyrophosphate extraction: the sample is shaken with a sodium pyrophosphate solution. Fe and Al are measured in the extract.

Ref.: McKeague, J.A. and J.H. Day (1966). Dithionite and oxalate-extractable Fe and Al as aids in differentiating various classes of soils. *Can. J. Soil Sci.* 46:13-22.

Blakemore, L.C., P.L. Searle and B.K. Daly (1981). Methods for chemical analysis of soils. N.Z. Soil Bur. Sci. Rep. 10A. Soil Bureau, Lower Hutt, New Zealand.

Holmgren, G.G.C. (1967). A rapid citrate-dithionite extractable iron procedure. *Soil Sci. Soc. Amer. Proc.* 31:210-211.

Mehra, O.P. and M.L. Jackson (1960). Iron oxide removal from soils and clays by a dithionite-citrate system buffered with sodium bicarbonate. *Clays and Clay Min.* 7th Conf.: 317-327.

Phosphate retention

The Blakemore procedure is followed. The sample is equilibrated with a phosphate solution and the proportion of phosphate withdrawn is determined.

Ref.: Blakemore, L.C., Searle, P.L. and Daly, B.K. (1981). Methods for chemical analysis of soils. N.Z. Soil Bur. Sci. Rep. 10A. Soil Bureau, Lower Hutt, New Zealand.

Phosphorus soluble in citric acid (for the fimic A horizon)

The sample is shaken with a 1 percent citric acid solution and P is measured in the extract.

Ref.: Hofstee, J. (1983). Methods of analysis. Part I: Soil. Ministry of Transport and Public Works, Rijksdienst voor de IJsselmeerpolders, Lelystad, Netherlands, p. 74.

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LIST OF SOIL UNITS

FL	FLUVISOLS	AR	ARENOSOLS
FLe	Eutric Fluvisols	ARh	Haplic Arenosols
FLc	Calcaric Fluvisols	ARb	Cambic Arenosols
FLd	Dystric Fluvisols	ARl	Luvic Arenosols
FLm	Mollic Fluvisols	ARo	Ferralic Arenosols
FLu	Umbric Fluvisols	ARa	Albic Arenosols
FLt	Thionic Fluvisols	ARc	Calcaric Arenosols
FLs	Salic Fluvisols	ARg	Gleyic Arenosols
GL	GLEYSOLS	AN	ANDOSOLS
GLe	Eutric Gleysols	ANh	Haplic Andosols
GLk	Calcic Gleysols	ANm	Mollic Andosols
GLd	Dystric Gleysols	ANu	Umbric Andosols
GLa	Andic Gleysols	ANz	Vitric Andosols
GLm	Mollic Gleysols	ANG	Gleyic Andosols
GLu	Umbric Gleysols	ANi	Gelic Andosols
GLt	Thionic Gleysols		
GLi	Gelic Gleysols		
		VR	VERTISOLS
RG	REGOSOLS	VRe	Eutric Vertisols
RGe	Eutric Regosols	VRd	Dystric Vertisols
RGc	Calcaric Regosols	VRk	Calcic Vertisols
RGy	Gypsic Regosols	VRy	Gypsic Vertisols
RGd	Dystric Regosols		
RGu	Umbric Regosols		
RGi	Gelic Regosols		
LP	LEPTOSOLS		
LPe	Eutric Leptosols		
LPd	Dystric Leptosols		
LPk	Rendzic Leptosols		
LPm	Mollic Leptosols		
LPu	Umbric Leptosols		
LPq	Lithic Leptosols		
LPi	Gelic Leptosols		

CM	CAMBISOLS	CL	CALCISOLS
CMe	Eutric Cambisols	CLh	Haplic Calcisols
CMd	Dystric Cambisols	CLl	Luvic Calcisols
CMu	Humic Cambisols	CLp	Petric Calcisols
CMc	Calcaric Cambisols		
CMx	Chromic Cambisols		
CMv	Vertic Cambisols	GY	GYPSISOLS
CMo	Ferralic Cambisols		
CMg	Gleyic Cambisols	GYh	Haplic Gypsisols
CMi	Gelic Cambisols	GYk	Calcic Gypsisols
		GYl	Luvic Gypsisols
		GYp	Petric Gypsisols
		SN	OLONETZ
		SNh	Haplic Solonetz
		SNm	Mollic Solonetz
		SNk	Calcic Solonetz
		SNy	Gypsic Solonetz
		SNj	Stagnic Solonetz
		SNg	Gleyic Solonetz
		SC	OLONCHAKS
		SCh	Haplic Solonchaks
		SCm	Mollic Solonchaks
		SCh	Calcic Solonchaks
		SCy	Gypsic Solonchaks
		SCn	Sodic Solonchaks
		SCg	Gleyic Solonchaks
		SCi	Gelic Solonchaks

KS	KASTANOZEMS	LV	LUVISOLS
KSh	Haplic Kastanozems	LVh	Haplic Luvisols
KSl	Luvic Kastanozems	LVf	Ferric Luvisols
KSk	Calcic Kastanozems	LVx	Chromic Luvisols
KSy	Gypsic Kastanozems	LVk	Calcic Luvisols
		LVv	Vertic Luvisols
CH	CHERNOZEMS	LVa	Albic Luvisols
		LVj	Stagnic Luvisols
CHh	Haplic Chernozems	LVg	Gleyic Luvisols
CHk	Calcic Chernozems		
CHl	Luvic Chernozems		
CHw	Glossic Chernozems	PL	PLANOSOLS
CHg	Gleyic Chernozems		
		PLe	Eutric Planosols
		PLd	Dystric Planosols
PH	PHAEZEMS	PLm	Mollic Planosols
		PLu	Umbric Planosols
PHh	Haplic Phaeozems	PLi	Gelic Planosols
PHc	Calcaric Phaeozems		
PHl	Luvic Phaeozems		
PHj	Stagnic Phaeozems	PD	PODZOLUVISOLS
PHg	Gleyic Phaeozems		
		PDe	Eutric Podzoluvisols
		PDd	Dystric Podzoluvisols
GR	GREYZEMS	PDj	Stagnic Podzoluvisols
		PDg	Gleyic Podzoluvisols
GRh	Haplic Greyzems	PDi	Gelic Podzoluvisols
GRg	Gleyic Greyzems		
		PZ	PODZOLS
		PZh	Haplic Podzols
		PZb	Cambic Podzols
		PZf	Ferric Podzols
		PZc	Carbic Podzols
		PZg	Gleyic Podzols
		PZi	Gelic Podzols

LX LIXISOLS

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

HS HISTOSOLS

HSi Follic Histosols
HSs Terric Histosols
HSf Fibric Histosols
HSt Thionic Histosols
HSi Gelic Histosols

AC ACRISOLS

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

AT ANTHROSOLS

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

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

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

