INTERNATIONAL ATOMIC ENERGY AGENCY
UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION

INTERNATIONAL CENTRE FOR THEORETICAL PHYSICS
34100 TRIESTE (ITALY) - P.O.B. 586 - MIRAMARE - STRADA COSTIERA 11 - TELEPHONES: 224281/2/3/4/5/6
CABLE: CENTRATOM - TELEX 460392-I

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COLLEGE ON SOIL PHYSICS

15 April - 3 May 1985

COLLOQUIUM ON ENERGY FLUX AT THE SOIL ATMOSPHERE INTERFACE

6 - 10 May 1985

THE SOIL RESOURCE: SOIL GENESIS AND CLASSIFICATION OF THE SOILS OF THE WORLD

H. VAN BAREN
International Soil Reference
and Information Centre (ISRIC)
9 Duivendaal
P.O. Box 353
6700 AJ Wageningen
The Netherlands

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

Missing or extra copies are available from Room 231.

International Centre for Theoretical Physics - Trieste - Italy

College on Soil Physics, 15 April to 3 May 1985

Lecture on: The Soil Resource: Soil Genesis and Classification of the Soils of the World
at: 15 April 1985
by: Hans van Baren,
Curator
International Soil Reference and Information Centre (ISRIC)
P.O. Box 353, 6700 AJ Wageningen, the Netherlands

Contents of lecture:

The lecture starts with an introduction on soil forming factors and soil formation processes, to arrive at a basic understanding of the great variety of soils of the world.

After some approaches to soil classification, two systems will be treated in more detail: the FAO-Unesco Soil Map of the World legend and the USDA Soil Conservation Service Soil Taxonomy.

In the afternoon a film will be shown, entitled 'The fate of the forest'.

The following lecture notes are provided:

Added is a listing of some recent books on general aspects of soil science, mostly in the English language. (43)

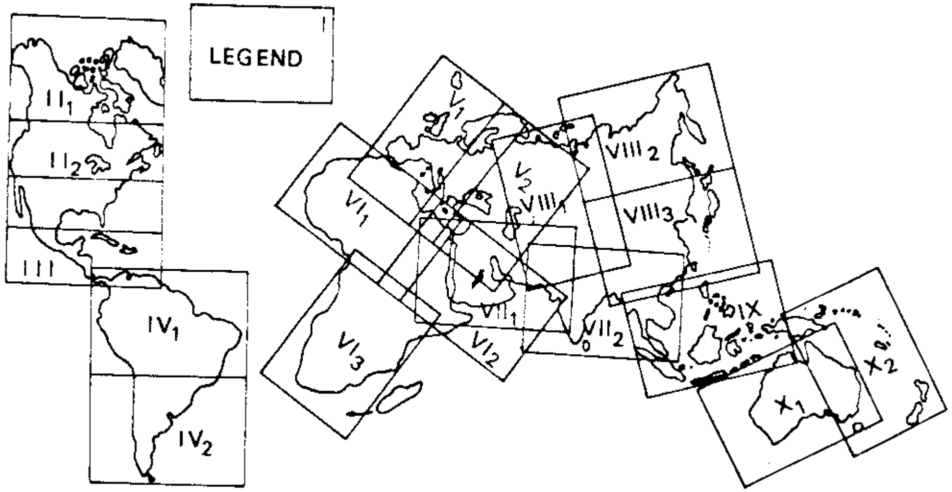
FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION

FAO - Unesco

Soil map of the world

1 : 5 000 000



The soil maps of all regions are accompanied by explanatory texts.

Maps and texts can be purchased at:

Unesco Press	Unesco national	ISRIC
B.P. 3.07	sales agents	P.O.Box 353
75700 Paris	around	6700 AJ Wageningen
France	the world	Netherlands

Prices available on request.

List of Soil Units of the FAO-Unesco Soil Map of the World

The FAO-Unesco Soil Map of the World at a scale of 1:5.000.000 shows about 5000 map units. These consist of soil units or associations of soil units occurring within the limits of a mappable physiographic entity.
The legend sheet copied here presents the 106 soil units in an order which reflects the general processes of soil formation.
The abbreviations mentioned are used on the map.

J FLUVISOLS

- Je Eutric Fluvisols
- Jc Calcaric Fluvisols
- Jd Dystric Fluvisols
- Jt Thionic Fluvisols

G GLEYSOLS

- Ge Eutric Gleysols
- Gc Calcaric Gleysols
- Gd Dystric Gleysols
- Gm Mollic Gleysols
- Gh Humic Gleysols
- Gp Plinthic Gleysols
- Gx Gelic Gleysols

R REGOSOLS

- Re Eutric Regosols
- Rc Calcaric Regosols
- Rd Dystric Regosols
- Rx Gelic Regosols

I LITHOSOLS

Q ARENOSOLS

- Qc Cambic Arenosols
- Ql Luvic Arenosols
- Qf Ferralic Arenosols
- Qa Albic Arenosols

E RENDZINAS

U RANKERS

T ANDOSOLS

- To Ochric Andosols
- Tm Mollic Andosols
- Th Humic Andosols
- Tv Vitric Andosols

V VERTISOLS

- Vp Pellic Vertisols
- Vc Chromic Vertisols

Z SOLONCHAKS

- Zo Orthic Solonchaks
- Zm Mollic Solonchaks
- Zt Takyric Solonchaks
- Zg Gleyic Solonchaks

S SOLONETZ

- So Orthic Solonetz
- Sm Mollic Solonetz
- Sg Gleyic Solonetz

Y YERMOSOLS

- Yh Haplic Yermosols
- Yk Calcic Yermosols
- Yy Gypsic Yermosols
- Yl Luvic Yermosols
- Yt Takyric Yermosols

X XEROSOLS

- Xh Haplic Xerosols
- Xk Calcic Xerosols
- Xy Gypsic Xerosols
- Xl Luvic Xerosols

K KASTANOZEMS

- Kh Haplic Kastanozems
- Kk Calcic Kastanozems
- Kl Luvic Kastanozems

C CHERNOZEMS

- Ch Haplic Chernozems
- Ck Calcic Chernozems
- Cl Luvic Chernozems
- Cg Glossic Chernozems

H PHAEOZEMS

- Hh Haplic Phaeozems
- Hc Calcaric Phaeozems
- Hl Luvic Phaeozems
- Hg Gleyic Phaeozems

M GREYZEMS

- Mo Orthic Greyzems
- Mg Gleyic Greyzems

B CAMBISOLS

- **Be** Eutric Cambisols
- **Bd** Dystric Cambisols
- **Bh** Humic Cambisols
- **Bg** Gleyic Cambisols
- **Bx** Gelic Cambisols

- **Bk** Calcic Cambisols
- **Bc** Chromic Cambisols
- **Bv** Vertic Cambisols

- **Bf** Ferralic Cambisols

L LUVISOLS

- **Lo** Orthic Luvisols
- **Lc** Chromic Luvisols
- **Lk** Calcic Luvisols
- **Lv** Vertic Luvisols
- **Lf** Ferric Luvisols
- **La** Albic Luvisols
- **Lp** Plinthic Luvisols
- **Lg** Gleyic Luvisols

D PODZOLUVISOLS

- **De** Eutric Podzoluvisols
- **Dd** Dystric Podzoluvisols
- **Dg** Gleyic Podzoluvisols

P PODZOLS

- **Po** Orthic Podzols
- **Pl** Leptic Podzols
- **Pf** Ferric Podzols
- **Ph** Humic Podzols
- **Pp** Placic Podzols
- **Pg** Gleyic Podzols

W PLANOSOLS

- **We** Eutric Planosols
- **Wd** Dystric Planosols
- **Wm** Mollic Planosols
- **Wh** Humic Planosols
- **Ws** Solodic Planosols
- **Wx** Gelic Planosols

A ACRISOLS

- **Ao** Orthic Acrisols
- **Af** Ferric Acrisols
- **Ah** Humic Acrisols
- **Ap** Plinthic Acrisols
- **Ag** Gleyic Acrisols

N NITOSOLS

- **Ne** Eutric Nitosols
- **Nd** Dystric Nitosols
- **Nh** Humic Nitosols

F FERRALSOLS

- **Fo** Orthic Ferralsols
- **Fx** Xanthic Ferralsols
- **Fr** Rhodic Ferralsols
- **Fh** Humic Ferralsols
- **Fa** Acric Ferralsols
- **Fp** Plinthic Ferralsols

O HISTOSOLS

- **Oe** Eutric Histosols
- **Od** Dystric Histosols
- **Ox** Gelic Histosols

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 soil maps are accompanied by explanatory texts.
Maps and texts can be purchased at:

Unesco Press
B.P. 3.07
75700 Paris
France

Unesco national
sales agents
around the
world

ISRIC
P.O. Box 353
6700 AJ Wageningen
Netherlands

Major Characteristics of Diagnostic Soil Horizons of the FAO-Unesco Soil Map of the World

Histic H:

- H horizon, usually 20-40 cm thick, but 40-60 cm if 75 vol. perc. or more is Sphagnum, less than 25 cm if high in OM

Mollic A:

- strong structure, not both massive and (very) hard when dry
- chroma less than 3.5 moist, darker than 3.5 moist and 5.5 dry
- BSP 50 or more (NH_4OAc method)
- OM at least 1% throughout control layer
- thickness 10 cm or more if on hard rock/horizon; at least 18 cm or more than one-third of the solum if less than 75 cm, and more than 25 cm when solum is more than 75 cm thick
- P_2O_5 content less than 250 ppm

Umbric A:

- as mollic A, but BSP less than 50

Ochric A:

- too light in colour, too high a chroma, too little OM, or too thin to be mollic/umbric, or both massive and (very) hard dry

Argillic B:

- clay increase within a vertical distance of 30 cm;
  * if eluvial hor. less than 15% clay, arg. B at least 3% more clay.
  + if eluvial hor. 15-40% clay, ratio in arg. B to E hor. is 1.2 or more.
  + if eluvial hor. more than 40% clay, arg. B at least 8% more clay.
- thickness at least one-tenth of the thickness of the sum of the overlying horizons, or more than 15 cm thick if E + B over 150 cm thick. Lamellae together at least 1 cm thick
- oriented clay bridging sand grains, clay skins on peds, or oriented clay in 1% or more of the cross section

Natric B:

- argillic B + columnar/prismatic structure + ESP more than 15 within upper 40 cm

Cambic B:

An altered horizon lacking properties of argillic, natric, spodic, mollic, umbric, histic H.
- texture v.f. sand, l.v.f. sand or finer
- soil structure, absence rock structure in at least half the horizon
- significant amounts of weatherable minerals, CEC over 16 me/100 g clay
- evidence of alteration (higher clay content than underlying hor., colour, removal of carbonates)
- evidences of reduction or reduction and segregation of iron
- enough thickness that its base is at least at 25 cm depth

Spodic B:

Below a depth of 12.5 cm or Ap, one or more of:
- subhor. of more than 2.5 cm continuously cemented by a combination of organic matter with iron or aluminium or with both
- sandy or coarse loamy texture with distinct dark pellets of coarse silt size or with sand grains covered with cracked coatings
- one or more subhor. with iron and aluminium requirements

Oxic B:

A hor. that is not argillic/natric and that
- is at least 30 cm thick
- CEC 16 meq or less/100 g clay (NH_4OAc)
- only traces of primary weatherable minerals
- texture sandy loam or finer and more than 15% clay
- mostly gradual or diffuse boundaries
- less than 5% rock structure

Calcic:

- accumulation of secondary calcium carbonate in C, B or A hor.
- 15 cm or more thick, 15% or more calcium carbonate equivalent and at least 5% more than in the C horizon

Gypsic:

- accumulation of secondary calcium sulphate
- 15 cm or more thick, at least 5% more gypsum than in the C horizon
- product of thickness (cm) and percent gypsum is 150 or more

Sulfuric:

- pH less than 3.5 and jarosite mottles with a hue of 2.5Y or more and a chroma of 6 or more

Albic E:

- clay and free iron oxides have been removed or oxides have been segregated and colour is determined by primary sand and silt particles
- colour value 4 or more moist, or 5 or more dry, or both. If value dry 7 or more, or moist 6 or more, chroma is 3 or less
- may overlie spodic B, argillic/natric B, fragipan, impervious layer

FAO-Unesco Soil Map of the World

Soil horizon designations

Soil horizon designations

A soil horizon may be defined as a layer of soil, approximately parallel to the soil surface, with characteristics produced by soil-forming processes (U.S. Soil Conservation Service, 1951). A soil horizon is commonly differentiated from the one adjacent by characteristics that can be seen or measured in the field — such as colour, texture, structure, consistence — and sometimes also in laboratory tests. In addition to genetic soil horizons many soils show stratification due to variations in parent material or lithological discontinuities. Strictly speaking, a succession of different materials should not be differentiated as " horizons " but as " layers. " The distinction is not always very clear, however, since soil-forming processes are often active throughout stratified materials.

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

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

Though the ABC horizon nomenclature is used by the great majority of soil scientists, the definition of these designations and their qualification with suffixes or figures vary widely. Within the framework of the Soil Map of the World project, the International Society of Soil Science (ISSS) convened a panel of experts[1] to work out a system of soil horizon designations which could be recommended for international use. A first draft was published in Bulletin No. 31 of ISSS in 1967 and discussed at the Ninth Congress of the Society held at Adelaide, Australia, in 1968.

The following definitions incorporate the numerous suggestions received both during discussion at the Congress and by correspondence.

The symbols used to designate soil horizons are as follows:

Capital letters **H, O, A, E, B, C and R indicate master horizons, or dominant kinds of departure** from the assumed parent material. Strictly, C and R should not be labelled as " soil horizons " but as " layers," since their characteristics are not produced by soil-forming factors. They are listed here with the master horizons as important elements of a soil

[1] This working group met at FAO Headquarters in Rome in September 1967. It was composed of J. Bennema (Netherlands), J. Boulaine (France), D. Luis Bramão (FAO), R. Dudal (FAO), S. Evteev (Unesco), I.P. Gerasimov (U.S.S.R.), E. Mückenhausen (Federal Republic of Germany), R.W. Simonson (United States), A.J. Smyth (FAO), F.A. Van Baren (Netherlands).

Copied from: FAO-Unesco Soil Map of the World, Volume I, Legend, pp. 20-23.
Unesco, Paris, 1974

profile. A combination of capital letters is used for transitional horizons.

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

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

Arabic figures are used as prefixes to mark lithological discontinuities.

Master horizons

H: An organic horizon formed or forming from accumulations of organic material deposited on the surface, that is saturated with water for prolonged periods (unless artificially drained) and contains 30 percent or more organic matter if the mineral fraction contains more than 60 percent of clay, 20 percent or more organic matter if the mineral fraction contains no clay, or intermediate proportions or organic matter for intermediate contents of clay.

H horizons form at the surface of wet soils, either as thick cumulative layers in organic soils or as thin layers of peat or muck over mineral soils. Even when ploughed the surface soil keeps a high content of organic matter following the mixing of peat with mineral material. The formation of the H horizon is related to prolonged waterlogging, unless soils are artificially drained. H horizons may be buried below the surface.

O: An organic horizon formed or forming from accumulations of organic material deposited on the surface, that is not saturated with water for more than a few days a year and contains 35 percent or more organic matter.

O horizons are the organic horizons that develop on top of some mineral soils — for example, the "raw humus" mat which covers certain acid soils. The organic material in O horizons is generally poorly decomposed and occurs under naturally well-drained conditions. This designation does not include horizons formed by a decomposing root mat below the surface of the mineral soil which is characteristic of A horizons. O horizons may be buried below the surface.

A: A mineral horizon[4] formed or forming at or adjacent to the surface that either:

(*a*) shows an accumulation of humified organic matter intimately associated with the mineral fraction, or

(*b*) has a morphology acquired by soil formation but lacks the properties of E and B horizons.

The organic matter in A horizons is well decomposed and is either distributed as fine particles or is present as coatings on the mineral particles. As a result A horizons are normally darker than the adjacent underlying horizons. The organic material is derived from plant and animal remains and incorporated in the soil through biological activity rather than by translocation. In warm arid climates where there is only slight or virtually no accumulation of organic matter, surface horizons may be less dark than adjacent underlying horizons. If the surface horizon has a morphology distinct from that of the assumed parent material and lacks features characteristic of E and B horizons, it is designated as an A horizon on account of its surface location.

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

E horizons are eluvial horizons which generally underlie an H, O or A horizon from which they are normally differentiated by a lower content of organic matter and a lighter colour. From an underlying B horizon an E horizon is commonly differentiated by colours of higher value or lower chroma, or by coarser texture, or both.

B: A mineral horizon in which rock structure is obliterated or is but faintly evident, characterized by one or more of the following features:

(*a*) an illuvial concentration of silicate clay, iron, aluminium, or humus, alone or in combinations;

(*b*) a residual concentration of sesquioxides relative to source materials;

(*c*) an alteration of material from its original condition to the extent that silicate clays are formed, oxides are liberated, or both, or granular, blocky, or prismatic structure is formed.

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[4] The term "mineral horizon" is used here to indicate that organic matter contents are lower than those present in organic horizons defined above as H and O. When necessary an additional symbol L can be used to designate limnic layers which include both organic and inorganic material. In order to secure compatibility between horizon designations and diagnostic horizons the criteria used to separate mineral and organic horizons are drawn from *Soil taxonomy* (U.S. Soil Conservation Service, 1974).

B horizons may differ greatly. It is generally necessary to establish the relationship between overlying and underlying horizons and to estimate how a B horizon has been formed before it can be identified. Consequently, B horizons generally need to be qualified by a suffix to have sufficient connotation in a profile description. A "humus B" horizon is designated as Bh, an "iron B" as Bs, a "textural B" as Bt, a "colour B" as Bw. It should be stressed here that the horizon designations are qualitative descriptions only. They are not defined in the quantitative terms required for diagnostic purposes. B horizons may show accumulations of carbonates, of gypsum or of other more soluble salts. Such accumulations, however, do not by themselves distinguish a B horizon.

C: A mineral horizon (or layer) of unconsolidated material from which the solum is presumed to have formed and which does not show properties diagnostic of any other master horizons.

Traditionally, C has been used to designate "parent material." It is seldom possible to ascertain that the material underlying the A, E and B horizons and from which they are assumed to have developed is unchanged. The designation C is therefore used for the unconsolidated material underlying the solum that does not meet the requirements of the A, E or B designations. This material may, however, have been altered by chemical weathering below the soil and may even be highly weathered ("preweathered").

Accumulations of carbonates, gypsum or other more soluble salts may be included in C horizons if the material is otherwise little affected by the processes which contributed to the formation of these interbedded layers. When a C horizon consists mainly of sedimentary rocks such as shales, marls, siltstones or sandstones, which are sufficiently dense and coherent to permit little penetration of plant roots but can still be dug with a spade, the C horizon is qualified by the suffix m for compaction.

R: A layer of continuous indurated rock. The rock of R layers is sufficiently coherent when moist to make hand digging with a spade impracticable. The rock may contain cracks but these are too few and too small for significant root development. Gravelly and stony material which allows root development is considered as C horizon.

Transitional horizons

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

Mixed horizons that consist of intermingled parts, each of which are identifiable with different master horizons, are designated by two capital letters separated by a diagonal stroke (for instance E/B, B/C). The first letter marks the master horizon that dominates. It should be noted that transitional horizons are no longer marked by suffix figures.

Letter suffixes

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

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

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

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

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

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

k. Accumulation of calcium carbonate.

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

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

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

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

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

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

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

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.

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

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

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

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

When needed, i, e and a suffixes can be used to qualify H horizons composed of fibric, hemic or sapric organic material respectively (U.S. Soil Conservation Service, 1974).

Letter suffixes can be used to describe diagnostic horizons and features in a profile (for example, argillic B horizon: Bt; natric B horizon: Btn; cambic B horizon: Bw; spodic B horizon: Bhs, Bh or Bs; oxic B horizon: Bws; calcic horizon: k; petrocalcic horizon: mk; gypsic horizon: y; petrogypsic horizon: my; petroferric horizon: ms; plinthite: sq; fragipan: x; strongly reduced gleyic horizon: r; mottled layers: g). But it should be emphasized that the use of a certain horizon designation in a profile description does not necessarily point to the presence of a diagnostic horizon or feature — see also under B horizon above — since the letter symbols merely reflect a qualitative estimate.

Figure suffixes

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

Numbered subdivisions can also be applied to transitional horizons (for example, AB1 - AB2), in which case it is understood that the suffix applies to the entire horizon and not only to the last capital letter.

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

Figure prefixes

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

Summary of diagnostic properties of FAO-Unesco Soil Map of the World

Abrupt Textural Change

A considerable increase in clay content within a very short distance.
- Between an A or E horizon and underlying horizon.
- When A or E horizon has less than 20% clay, clay content should at least be double within 8 cm.
- If 20% clay or more, clay content should at least be 20% higher (e.g. from 30 to 50% clay) within 8 cm, and clay content in some part of the underlying horizon should at least be double than that of the A or E horizon above.

Albic Material

Soil material with a high colour value.
- Albic materials are exclusive of E horizons, colour value moist 4 or more, or value dry 5 or more, or both.
- If value dry 7 or more, chroma is 3 or less.
- If parent material have hue of 5YR or redder, chroma of 3 is permitted if chroma is due to colour of uncoated, silt or sand grains.

Aridic moisture regime

Arid regions with no available water in more than half of the time.
- Yermosols and Xerosols have an aridic moisture regime.
- In most years no available water in the moisture control section (m.c.s.) more than half the time that the soil temperature at 50 cm is above 5°C.
- No period as long as 90 consecutive days when there is moisture in the m.c.s. with temperature at 50 cm continuously above 8°C.

Exchange complex dominated by amorphous material

Material with all or most of the properties of allophane.
- Exchange capacity of the clay at pH 8.2 more than 150 meq/100 g clay and commonly more than 500 meq/100 g.
- If there is enough clay to have a 15-bar water content of 20% or more, pH of 1 g soil in 50 ml 1N NaF is more than 9.4 after 2 minutes.
- Ratio of 15-bar water content to measured clay is more than 1.0.
- Organic carbon more than 0.6 percent.
- DTA shows a low temperature endotherm.
- Bulk density of the fine-earth fraction is less than 0.85 g/cm^3 at 1/3-bar tension.
- Material generally amorphous under X-ray analyses, but crystalline materials may cause small and disordered peaks.

Ferralic properties

Cambisols and Arenosols with low CEC.
- CEC (NH_4Cl) less than 24 meq/100 g clay in: at least some subhorizon of the cambic B of Cambisols, or immediately underlying the A horizon of Arenosols.

Ferric properties

Luvisols and Acrisols with coarse reddish mottles, indurated nodules and/or low CEC.
- Luvisols and Acrisols with one or more of:
  - 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 enriched and weakly cemented or indurated with iron;
  - CEC (NH_4Cl) less than 24 meq/100 g clay in at least some subhorizon of the argillic B.

Gilgai

Microrelief typical of clayey soils.
- Consists of either a succession of enclosed microbasins and microknolls in level areas, or of microvalleys and microridges that run up and down the slope.

High organic matter content in the B horizon

Ferralsols, Nitosols of low base saturation, and Acrisol with high organic matter content in the B horizon.
- In Ferralsols and Nitosols of low base saturation organic matter content is 1.35 % or more to 100 cm.
- In Acrisols 1.5% or more organic matter in upper part of the B horizon, and/or 1.35% or more to 100 cm.

High salinity

Soils with high electric conductivity.
- Electric conductivity (EC) more than 15 mmhos/cm at 25°C at some time of the year, within 125 cm of the surface when texture is coarse, within 90 cm when texture is medium and within 75 cm when fine, or
- EC 4 mmhos or more within 25 cm if pH (H_2O, 1:1) exceeds 8.5.

Hydromorphic properties

Properties indicating saturation with water at some period of the year.
- Hydromorphic properties occur in Gleysols, which are strongly influenced by groundwater and as 'gleyic' groups in other soils, of which only the lower horizons are influenced by groundwater or have a seasonally perched watertable.
- Characterized by one or more of:
  - saturation by groundwater of whole profile;
  - occurrence of histic H horizon;
  - dominant hues neutral N, or bluer than 10Y;
  - saturation with water, with evidence of reduction processes or of reduction processes or of reduction and segregation of iron; forms of which depending on the horizon.
    Usually: moist chroma 2 or less; mottles due to segregation of iron; Fe-Mn concretions.

Interfingering

Penetration of albic E into argillic or natric B horizon.
- Penetration of albic E horizon into underlying argillic or natric B horizon into underlying argillic or natric B horizon along ped faces, primarily vertical faces.
- Penetrations not wide enough to constitute tonguing, but then form continuous skeletons (ped coatings of clean silt or sand, more than 1 mm thick on the vertical ped faces).
- Total thickness of more than 2 mm is required if each ped has a coating of more than 1 mm.
- Skeletons form more than 15% of the volume of any subhorizon in which interfingering is recognized.

Permafrost

A layer with temperature perennially at or below 0°C.

Plinthite

Non-indurated mixture of Fe and Al-oxides, quarts and other diluents.
- Occurs commonly as dark red mottles in platy, polygonal or reticulate patterns.
- Changes irreversibly to ironstone hardpans or irregular aggregates on exposure to repeated wetting and drying.
- After hardening it is called ironstone.

Slickensides

Polished and grooved surfaces.
- Produced by one mass sliding past another.
- Common in swelling clays in which there are marked changes in moisture content.

Smeary consistence

A reversible gel-sol transformation.
- Is the result of a kind of structure that, if broken down, can rebuild itself.
- Breakdown may be by agitation, by shearing or ultrasonic waves.
- Occurs in certain Andosols.
- Also known as thixotropy.

Soft powdery lime

Translocated authigenic lime.
- Soft enough to be cut readily with a finger nail.
- Precipitated in place from the soil solution rather than inherited from parent material.
- Occurs as spheroidal aggregates, white eyes that are soft and powdery, soft coatings in pores or on structural faces.
- Pseudomycelia which come and go with changing moisture conditions are not considered as soft powdery lime.

Sulfidic materials

Waterlogged soil material with 0.75% or more sulfur (dry weight) and less than 3 times as much carbonate.
- Mineral or organic soil materials.
- Mostly occurring in the form of sulfides, originating from biologically reduced sulfates.
- Most common in coastal marshes.
- If drained, sulfides oxidize and form sulfuric acid, pH drops below 3.5. Differs from sulfuric horizon in that it does not show jarosite mottles with a hue of 2.5Y or more or a chroma of 6 or more.

Takyric features

Heavy textured soils with polygonal elements.
- Soils with takyric features have a heavy texture, crack into polygonal elements when dry and form a platy or massive surface crust.
- Occur in some Solonchaks and Yermosols.

Thin iron pan

Thin pan, cemented with iron and manganese.
- A black to dark reddish, brittle pan.
- Cemented by iron, iron and manganese or by iron-organic matter complex.
- Thickness generally 2-10 mm, rarely 1 or 20-40 mm.
- In the solum, roughly parallel to the surface, commonly within the upper 50 cm of the mineral soil.
- Pronounced wavy or convolute form.
- Normally a single pan.
- Occurs in some Podzols.

Tonguing

Penetration of material into underlying horizons.
- In Podzoluvisols:
  - penetration of albic E horizon into argillic B horizon along ped surfaces, if peds are present;
  - penetrations must have greater depth than width;
  - horizontal dimensions: 5 mm or more in fine textured, 10 mm or more in moderately fine textured, and 15 mm or more in medium or coarser textured argillic horizons;
  - penetrations must occupy more than 15% of the mass of the upper part of the argillic horizon;
- In Chernozems:
  - penetration of A horizon into cambic B horizon or into C horizon;
  - penetrations must have greater depth than width;
  - penetrations must occupy more than 15% of the mass of the upper part of the horizon in which they occur.

Vertic properties

Wide, deep, cracks at some period in most years.
- Width 1 cm or more wide within 50 cm of the surface.
- Extend to the surface or at least to the upper part of the B horizon.

Weatherable minerals

Minerals unstable in a humid climate.
- Unstable relative to other minerals, such as quartz and 1:1 lattice clays.
- Plant nutrients and iron and aluminium are liberated when weathering occurs.
- They include: all 2: 1 lattice clays except Al-interlayered chlorite; sepiolite, talc, glauconite; silt- and sand-size minerals, e.g. feldspars, ferromagnesian minerals, micas, zeolites.

N.B.: It should be noted that only the original text (FAO-Unesco Soil Map of the World, Volume I, Legend. Unesco, 1974) is authoritative.

Definitions of Major Soil Units of the FAO-Unesco Soil Map of the World

FLUVISOLS[6] (J)

Soils developed from recent alluvial deposits having no diagnostic horizons other than (unless buried by 50 cm or more new material) an ochric or an umbric A horizon, a histic H horizon, or a sulfuric horizon. As used in this definition, recent alluvial deposits are fluviatile, marine, lacustrine, or colluvial sediments characterized by one or more of the following properties:

(*a*) having an organic matter content that decreases irregularly with depth or that remains above 0.35 percent to a depth of 125 cm (thin strata of sand may have less organic matter if the finer sediment below meets the requirements);

(*b*) receiving fresh material at regular intervals and/or showing fine stratification;

(*c*) having sulfidic material within 125 cm of the surface.

GLEYSOLS (G)

Soils formed from unconsolidated materials exclusive of recent alluvial deposits,[7] showing hydromorphic properties within 50 cm of the surface; having no diagnostic horizons other than (unless buried by 50 cm or more new material) an A horizon, a histic H horizon, a cambic B horizon, a calcic or a gypsic horizon; lacking the characteristics which are diagnostic for Vertisols; lacking high salinity; lacking bleached coatings on structural ped surfaces when a mollic A horizon is present which has a chroma of 2 or less to a depth of at least 15 cm.[8]

REGOSOLS (R)

Soils from unconsolidated materials, exclusive of recent alluvial deposits, having no diagnostic horizons (unless buried by 50 cm or more new material) other than an ochric A horizon; lacking hydromorphic properties within 50 cm of the surface;[8] lacking the characteristics which are diagnostic for Vertisols and Andosols; lacking high salinity; when coarse textured, lacking lamellae of clay accumulation, features of cambic or oxic B horizons or albic material which are characteristic of Arenosols.

LITHOSOLS (I)

Soils which are limited in depth by continuous coherent hard rock within 10 cm of the surface.

ARENOSOLS (Q)

Soils from coarse-textured unconsolidated materials, exclusive of recent alluvial deposits, consisting of albic material occurring over a depth of at least 50 cm from the surface or showing characteristics of argillic, cambic or oxic B horizons which, however, do not qualify as diagnostic horizons because of textural requirements; having no diagnostic horizons (unless buried by 50 cm or more new material) other than an ochric A horizon; lacking hydromorphic properties within 50 cm of the surface; lacking high salinity.

RENDZINAS (E)

Soils having a mollic A horizon[10] which contains or immediately overlies calcareous material with a calcium carbonate equivalent of more than 40 percent; lacking hydromorphic properties within 50 cm of the surface; lacking the characteristics which are diagnostic for Vertisols; lacking high salinity.

RANKERS (U)

Soils, exclusive of those formed from recent alluvial deposits, having an umbric A horizon which is not more than 25 cm thick;[11] having no other diagnostic horizons (unless buried by 50 cm or more new material); lacking hydromorphic properties within 50 cm of the surface; lacking the characteristics which are diagnostic for Andosols.

ANDOSOLS (T)

Soils 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 (unless buried by 50 cm or more new material); having to a depth of 35 cm or more one or both of:

(*a*) a bulk density (at 1/3-bar water retention) of the fine earth (less than 2 mm) fraction of the soil of less than 0.85 g/cm^3 and an exchange complex dominated by amorphous material;

(*b*) 60 percent or more vitric[12] volcanic ash, cinders, or other vitric pyroclastic material in the silt, sand and gravel fractions;

lacking hydromorphic properties within 50 cm of the surface; lacking the characteristics which are diagnostic for Vertisols; lacking high salinity.

VERTISOLS (V)

Soils having, after the upper 20 cm have been mixed, 30 percent or more clay in all horizons to a depth of at least 50 cm; developing cracks from the soil surface downward which at some period in most years (unless the soil is irrigated) are at least 1 cm wide to a depth of 50 cm; having one or more of the following: gilgai microrelief, intersecting slickensides, or wedge-shaped or parallelepiped structural aggregates at some depth between 25 and 100 cm from the surface.

SOLONCHAKS (Z)

Soils, exclusive of those formed from recent alluvial deposits, having a high salinity and having no diagnostic horizons other than (unless buried by 50 cm or more new material) an A horizon, a histic H horizon, a cambic B horizon, a calcic or a gypsic horizon.

SOLONETZ (S)

Soils having a natric B horizon; lacking an albic E horizon which shows hydromorphic properties in at least a part of the horizon and an abrupt textural change.

YERMOSOLS (Y)

Soils occurring under an aridic moisture regime; having a very weak ochric A horizon and one or more of the following: a cambic B horizon, an argillic B horizon, a calcic horizon, a gypsic horizon; lacking other diagnostic horizons; lacking the characteristics which are diagnostic for Vertisols; lacking high salinity; lacking permafrost within 200 cm of the surface.

XEROSOLS (X)

Soils occurring under an aridic moisture regime; having a weak ochric A horizon and one or more of the following: a cambic B horizon, an argillic B horizon, a calcic horizon, a gypsic horizon; lacking other diagnostic horizons; lacking the characteristics which are diagnostic for Vertisols; lacking high salinity; lacking permafrost within 200 cm of the surface.

KASTANOZEMS (K)

Soils having a mollic A horizon with a moist chroma of more than 2 to a depth of at least 15 cm; having one or more of the following: a calcic or gypsic horizon or concentrations of soft powdery lime within 125 cm of the surface;[14] lacking a natric B horizon; lacking the characteristics which are diagnostic for Rendzinas, Vertisols, Planosols or Andosols; lacking high salinity; lacking hydromorphic properties

CHERNOZEMS (C)

Soils having a mollic A horizon with a moist chroma of 2 or less to a depth of at least 15 cm; having one or more of the following: a calcic or gypsic horizon or concentrations of soft powdery lime within 125 cm of the surface;[14] lacking a natric B horizon; lacking the characteristics which are diagnostic for Rendzinas, Vertisols, Planosols or Andosols; lacking high salinity; lacking hydromorphic properties within 50 cm of the surface when no argillic B horizon is present;[16] lacking bleached coatings on structural ped surfaces.

PHAEOZEMS (H)

Soils having a mollic A horizon; lacking a calcic horizon, a gypsic horizon and concentrations of soft powdery lime within 125 cm of the surface;[14] lacking a natric and an oxic B horizon; lacking the characteristics which are diagnostic for Rendzinas, Vertisols, Planosols or Andosols; lacking high salinity; lacking hydromorphic properties within 50 cm of the surface when no argillic B horizon is present;[16] lacking bleached coatings 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.

GREYZEMS (M)

Soils having a mollic A horizon with a moist chroma of 2 or less to a depth of at least 15 cm and showing bleached coatings on structural ped surfaces;[17] lacking a natric and oxic B horizon; lacking the characteristics which are diagnostic for Rendzinas, Vertisols, Planosols or Andosols; lacking high salinity.

CAMBISOLS (B)

Soils having a cambic B horizon and (unless buried by more than 50 cm or more new material) no diagnostic horizons other than an ochric or an umbric A horizon, a calcic or a gypsic horizon; the cambic B horizon may be lacking when an umbric A horizon is present which is thicker than 25 cm; lacking high salinity; lacking the characteristics diagnostic for Vertisols or Andosols; lacking an aridic moisture regime; lacking hydromorphic properties within 50 cm of the surface.

LUVISOLS (L)

Soils having an argillic horizon which has a base saturation of 50 percent or more (by NH_4OAc) at least in the lower part of the B horizon within 125 cm of the surface; lacking a mollic A horizon; lacking the albic E horizon overlying a slowly permeable horizon, the distribution pattern of the clay and the tonguing which are diagnostic for Planosols, Nitosols and Podzoluvisols respectively; lacking an aridic moisture regime.

PODZOLUVISOLS (D)

Soils having an argillic 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 (ranging from 2 to 5 cm up to 30 cm in diameter) 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.

PODZOLS (P)

Soils having a spodic B horizon.

PLANOSOLS (W)

Soils having an albic E horizon overlying a slowly permeable horizon within 125 cm of the surface (for example, an argillic or natric B horizon showing an abrupt textural change, a heavy clay, a fragipan), exclusive of a spodic B horizon; showing hydromorphic properties at least in a part of the E horizon.

ACRISOLS (A)

Soils having an argillic B horizon with a base saturation of less than 50 percent (by NH_4OAc) at least in the lower part of the B horizon within 125 cm of the surface; lacking a mollic A horizon; lacking an albic E horizon overlying a slowly permeable horizon, the distribution pattern of the clay and the tonguing which are diagnostic for Planosols, Nitosols and Podzoluvisols respectively; lacking an aridic moisture regime.

NITOSOLS (N)

Soils having an argillic B horizon with a clay distribution where the percentage of clay does not decrease from its maximum amount by as much as 20 percent within 150 cm of the surface;* lacking a mollic A horizon; lacking an albic E horizon; lacking the tonguing which is diagnostic for the Podzoluvisols; lacking ferric and vertic properties; lacking plinthite within 125 cm of the surface;* lacking an aridic moisture regime.

FERRALSOLS (F)

Soils having an oxic B horizon.

HISTOSOLS (O)

Soils having an H 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) 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 rocks or on fragmental material of which the interstices are filled with organic matter.

Simplified key major soil units FAO-Unesco Soil Map of the World.

Organic soils	Histosols
Mineral soils	
coherent and hard rock within 10 cm	Lithosols
30% or more clay, cracks, slickensides/gilgai	Vertisols
recent alluvial deposits	Fluvisols
high salinity	Solonchaks
hydromorphic properties within 50 cm	Gleysols
in volcanic materials	Andosols
coarse texture; albic materials or characteristics of argillic, cambic or oxic B	Arenosols
ochric A	Regosols
umbric A less than 25 cm thick	Rankers
mollic A on calcareous material	Rendzina
spodic B	Podzols
oxic B	Ferralsols
albic E on slowly permeable horizon, hydromorphic properties in E	Planosols
natric B	Solonetz
mollic A, moist chroma 2 or less to 15 cm depth, bleached coatings on peds	Greyzems
mollic A, moist chroma 2 or less to 15 cm depth, calcic hor./gypsic hor./soft powdery lime	Chernozems
mollic A, moist chroma more than 2, calcic hor./ gypsic hor./soft powdery lime	Kastanozems
mollic A	Phaeozems
argillic B with irregular or broken upper boundary (tonguing)	Podzoluvisols
weak ochric A, aridic moisture regime	Xerosols
very weak ochric A, aridic moisture regime	Yermosol
deep argillic B	Nitosols
argillic B, base saturation less than 50% in some part of B within 125 cm	Acrisols
argillic B	Luvisols
cambic B or umbric A more than 25 cm thick	Cambisols

FAO-Unesco Soil Map of the World

Direct benefits and uses of the Soil Map of the World

The most immediate and most direct beneficiary of the Soil Map of the World is soil science in general. It is for the first time in history that all soils of the world have been mapped with one legend. At a scale of 1 to 5 million it is, of course, not possible to plan development at a local level. For this purpose one needs maps of a much larger scale. However, it makes possible a first appraisal of the world's soil resources and it provides a common framework for further research.

As the most important result should be regarded the establishment of a soil classification and nomenclature, accepted by many scientists around the world. This common language is gradually being used in the international soils literature (e.g. Soils and Fertilizers) as well, so that the transfer of information and experience is facilitated. Also, some great centres of documentation, such as Commonwealth Bureaux of Soils have adopted the terminology as key words in their reference systems. It will be clear that this map is also an excellent tool for education at universities, agricultural high schools, etc..

The SMW legend has also provoked soil correlation and new mapping activities at country and regional level. In fact, some countries made, for the first time, a national soil map based on the legend (Mexico) and others to convert their pre-existing classifications to conform to the new terminology (Japan).

It can rightly be stated that there are many uses to which the SMW can be put. No doubt it will greatly facilitate the work of many specialists in agriculture, hydrology, etc. Also, already now, many other maps and studies are based on the SMW.

a) The Map of the World Distribution of Arid Regions, produced by FAO, Unesco, UNEP and WMO at a scale of 1 to 25 million. The information of the map units of the SMW such as texture, slope, stoniness and lithology is combined with climatic data and the analysis of the vegetation has enabled scientists to assess the degree of desertification and risk of desertification.

b) The World Map of Soil Degradation. The soil units of the SMW are defined in terms of measurable soil properties. From these data, combined with other factors of degradation (climate, topography, human action) one is able to assess soil degradation risks, danger zones, zones with identical problems, etc.. FAO, UNEP and Unesco have started work on the preparation of a 1 to 5 million map. The maps of North Africa and the Near and Middle East have already been published.

c) A systems of Global Land Evaluation. FAO has made a study of the potential crop productivity by major agro-ecological zones. It is regarded as a first step in the process to get to know what ultimately can be produced, under what conditions with what interventions, and at what risk, in any part of the world. The yields attainable of specific crops under two levels of farm management are calculated by agro-ecological zones. These zones are based on the information derived from the SMW, and climatic information such as temperature regime and the length of the growing season. The reports on Africa, South Asia and South America have been completed. A comparable study was made on the Near East.

For the expert consultation on land resources for populations of the future, Sijs and Riquier prepared a working paper on the ratings of the SMW soil units for specific crop production.

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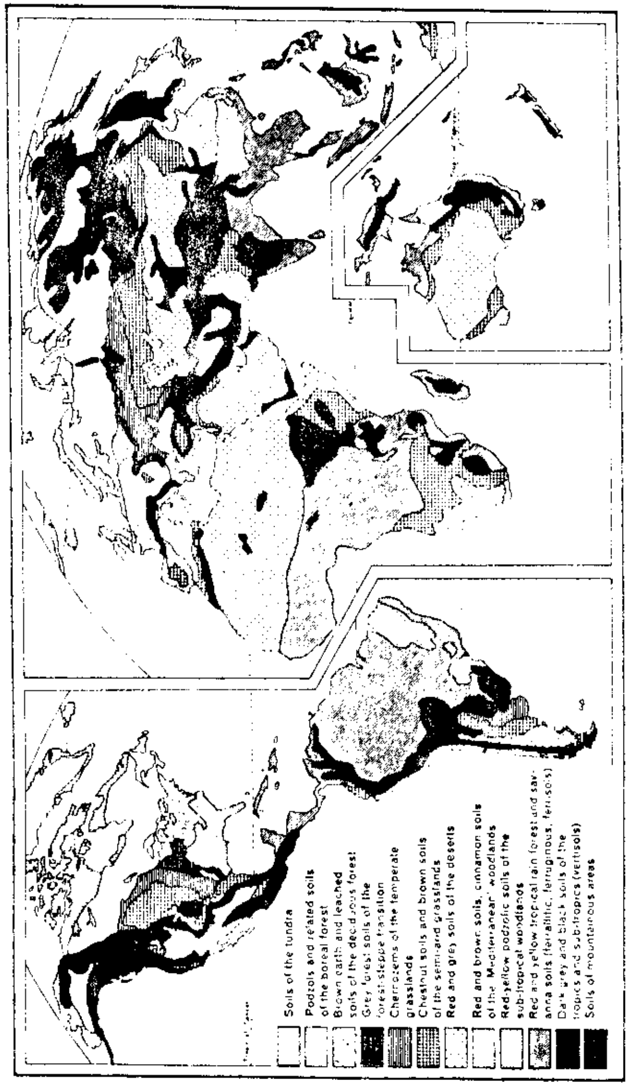
SIMPLIFIED WORLD SOIL MAP



E.M. Bridges, World Soils, Second Edition, Cambridge University Press, 1978

Short Descriptions of the Epipedons and Horizons of the USDA Soil Taxonomy

EPIPEDONS

Anthropic epipedon — A surface layer of mineral soil that has the same requirements as the mollic epipedon with respect to color, thickness, organic carbon content, consistence and base saturation, but that has more than 250 ppm of P_2O_5 soluble in 1% citric acid, or is dry more than 10 months (cumulative) during the period when not irrigated. The anthropic epipedon forms under long continued cultivation and fertilization.

Cambic horizon — A mineral soil horizon that has a texture of loamy very fine sand or finer, has soil structure rather than rock structure, contains some weatherable minerals, and is characterized by the alteration or removal of mineral material as indicated by mottling or gray colors, stronger or redder hues than in underlying horizons, or the removal of carbonates. The cambic horizon lacks cementation or induration and has too few evidences of illuviation to meet the requirements of the argillic or spodic horizon.

Histic epipedon — A thin organic soil horizon that is saturated with water at some period of the year unless artificially drained and that is at or near the surface of a mineral soil. The histic epipedon has a maximum thickness depending on the kind of materials in the horizon and the lower limit of organic carbon is the upper limit for the mollic epipedon.

Mollic epipedon — A surface horizon of mineral soil that is dark colored and relatively thick, contains at least 0.58% organic carbon, is not massive and hard or very hard when dry, has a base saturation of more than 50% when measured at pH 7, has less than 250 ppm of P_2O_5 soluble in 1% citric acid, and dominately saturated with bivalent cations.

Ochric epipedon — A surface horizon of mineral soil that is too light in color, too high in chroma, too low in organic carbon, or too thin to be a plaggen, mollic, umbric, anthropic or histic epipedon, or that is both hard and massive when dry.

Plaggen epipedon — A man-made surface horizon more than 50 cm thick that is formed by long-continued manuring and mixing.

Umbric epipedon — A surface layer of mineral soil that has the same requirements as the mollic epipedon with respect to color, thickness, organic carbon content, consistence, structure, and P_2O_5 content, but that has a base saturation of less than 50% when measured at pH 7.

HORIZONS

agric horizon — A mineral soil horizon in which clay, silt and humus derived from an overlying cultivated and fertilized layer have accumulated. The wormholes and illuvial clay, silt and humus, occupy at least 5% of the horizon by volume. The illuvial clay and humus occur as horizontal lamellae or fibers, or as coatings on ped surfaces or in wormholes.

albic horizon — A mineral soil horizon from which clay and free iron oxides have been removed or in which the oxides have been segregated to the extent that the color of the horizon is determined primarily by the color of the primary sand and silt particles rather than by coatings on these particles.

argillic horizon — A mineral soil horizon that is characterized by the illuvial accumulation of layer-lattice silicate clays. The argillic horizon has a certain minimum thickness depending on the thickness of the solum, a minimum quantity of clay in comparison with an overlying eluvial horizon depending on the clay content of the eluvial horizon, and usually has coatings of oriented clay on the surface of pores or peds or bridging sand grains.

duripan — A mineral soil horizon that is cemented by silica, usually opal or microcrystalline forms of silica, to the point that air-dry fragments will not slake in water or HCl. A duripan may also have accessory cement such as iron oxide or calcium carbonate.

fragipan — A natural subsurface horizon with high bulk density relative to the solum above, seemingly cemented when dry, but when moist showing a moderate to weak brittleness. The layer is low in organic matter, mottled, slowly or very slowly permeable to water, and usually shows occasional or frequent bleached cracks forming polygons. It may be found in profiles of either cultivated or virgin soils but not in calcareous material.

gypsic horizon — A mineral soil horizon of secondary calcium sulfate enrichment that is more than 15 cm thick, has at least 5% more gypsum than the C horizon, and in which the product of the thickness in centimeters and the percent calcium sulfate is equal to or greater than 150% cm.

natric horizon — A mineral soil horizon that satisfies the requirements of an argillic horizon, but that also has prismatic, columnar, or blocky structure and a subhorizon having more than 15% saturation with exchangeable sodium.

oxic horizon — A mineral soil horizon that is at least 30 cm thick and characterized by the virtual absence of weatherable primary minerals or 2:1 lattice clays, the presence of 1:1 lattice clays and highly insoluble minerals such as quartz sand, the presence of hydrated oxides of iron and aluminum, the absence of water-dispersible clay, and the presence of low cation exchange capacity and small amounts of exchangeable bases.

petrocalcic horizon — A continuous, indurated calcic horizon that is cemented by calcium carbonate and, in some places, with magnesium carbonate. It cannot be penetrated with a spade or auger when dry, dry fragments do not slake in water, and it is impenetrable to roots.

petrogypsic horizon — A continuous, strongly cemented, massive, gypsic horizon that is cemented by calcium sulfate. It can be chipped with a spade when dry. Dry fragments do not slake in water and it is impenetrable to roots.

placic horizon — A black to dark reddish mineral soil horizon that is usually thin but that may range from 1 mm to 25 mm in thickness. The placic horizon is commonly cemented with iron and is slowly permeable or impenetrable to water and roots.

sombric horizon — A subsurface mineral horizon that is darker in color than the overlying horizon but that lacks the properties of a spodic horizon. Common in cool, moist soils of high altitude in tropical regions.

spodic horizon — A mineral soil horizon that is characterized by the illuvial accumulation of amorphous materials composed of aluminum and organic carbon with or without iron. The spodic horizon has a certain minimum thickness, and a minimum quantity of extractable carbon plus iron plus aluminum in relation to its content of clay.

(From: Glossary of Soil Science Terms, SSSA, Madison, January 1978)

Soil Moisture and Soil Temperature Regimes of the USDA Soil Taxonomy

SOIL MOISTURE REGIMES

aquic — A mostly reducing soil moisture regime nearly free of dissolved oxygen due to saturation by ground water or its capillary fringe and occurring at periods when the soil temperature at 50 cm is above 5C.

aridic — A soil moisture regime that has no moisture available for plants for more than half the cumulative time that the soil temperature at 50 cm is above 5C, and has no period as longs as 90 consecutive days when there is moisture for plants while the soil temperature at 50 cm is continuously above 8C.

torric — A soil moisture regime defined like aridic moisture regime but used in a different category of the soil taxonomy.

udic — A soil moisture regime that is neither dry for as long as 90 cumulative days nor for as long as 60 consecutive days in the 90 days following the summer solstice at periods when the soil temperature at 50 cm is above 5C.

ustic — A soil moisture regime that is intermediate between the aridic and udic regimes and common in temperate subhumid or semiarid regions, or in tropical and subtropical regions with a monsoon climate. A limited amount of moisture is available for plants but occurs at times when the soil temperature is optimum for plant growth.

xeric — A soil moisture regime common to Mediterranean climates that have moist cool winters and warm dry summers. A limited amount of moisture is present but does not occur at optimum periods for plant growth. Irrigation or summerfallow is commonly necessary for crop production.

SOIL TEMPERATURE REGIMES

pergelic — A soil temperature regime that has mean annual soil temperatures of less than 0C. Permafrost is present.

cryic — A soil temperature regime that has mean annual soil temperatures of more than 0C but less than 8C, more than 5C difference between mean summer and mean winter soil temperatures at 50 cm, and cold summer temperatures.

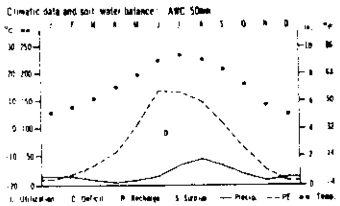
frigid — A soil temperature regime that has mean annual soil temperatures of more than 0C but less than 8C, more than 5C difference between mean summer and mean winter soil temperatures at 50 cm, and warm summer temperatures.
isofrigid is the same except the summer and winter temperatures differ by less than 5C.

mesic — A soil temperature regime that has mean annual soil temperatures of 8C or more but less than 15C, and more than 5C difference between mean summer and mean winter soil temperatures at 50 cm.
isomesic is the same except the summer and winter temperatures differ by less than 5C.

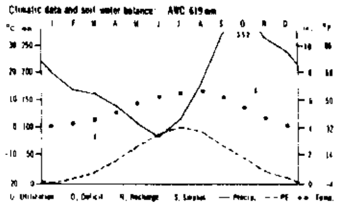
thermic — A soil temperature regime that has mean annual soil temperatures of 15C or more but less than 22C, and more than 5C difference between mean summer and mean winter soil temperatures at 50 cm.
isothermic is the same except the summer and winter temperatures differ by less than 5C.

hyperthermic — A soil temperature regime that has mean annual soil temperatures of 22C or more and more than 5C difference between mean summer and mean winter soil temperatures at 50 cm.
isohyperthermic is the same except the summer and winter temperatures differ by less than 5C.

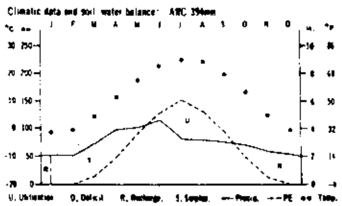
(From: Glossary of Soil Science Terms, SSSA, Madison, January 1978)



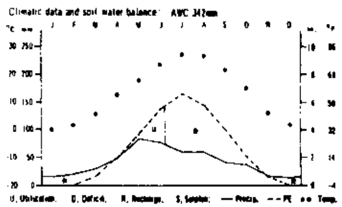
—Climatic data and soil water balance for a soil that has an aridic (torric) soil moisture regime.



—Climatic data and soil water balance for a soil that has a perudic soil moisture regime.



—Climatic data and soil water balance for a soil that has a udic soil moisture regime.



—Climatic data and soil water balance for a soil that has an ustic soil moisture regime.

AWC = Available Water Capacity

U = Utilization R = Recharge

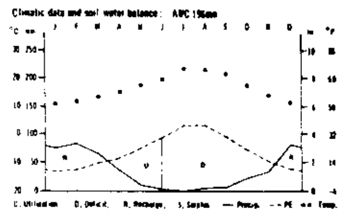
D = Deficit S = Surplus

— = Precipitation

-- = Pot. Evapotranspiration

... = Mean Temperature

Perudic = Udic with P greater than PE in all months of the year



—Climatic data and soil water balance for a soil that has a xeric soil moisture regime.

Short Descriptions of the Orders and Suborders of the USDA Soil Taxonomy

Outline of the system

Order (10)
- Suborder (47)
  - Great group (225)
    - Subgroup (1000 in US)
      - Family (4500 in US)
        - Series (10500 in US)
          - Type

Orders:	Alfisols	(5 suborders)
	Aridisols	(2 ")
	Entisols	(5 ")
	Histosols	(4 ")
	Inceptisols	(6 ")
	Mollisols	(7 ")
	Oxisols	(5 ")
	Spodosols	(4 ")
	Ultisols	(5 ")
	Vertisols	(4 ")

ALFISOLS — Mineral soils that have umbric or ochric epipedons, argillic horizons, and that hold water at less than 15-bars tension during at least 3 months when the soil is warm enough for plants to grow outdoors. Alfisols have a mean annual soil temperature of less than 8C or a base saturation in the lower part of the argillic horizon of 35% or more when measured at pH 8.2.

Aqualfs — are saturated with water for periods long enough to limit their use for most crops other than pasture or woodland unless they are artificially drained. Aqualfs have mottles, iron-manganese concretions or gray colors immediately below the A1 or Ap horizons and gray colors in the argillic horizon.

Boralfs — have formed in cool places. Boralfs have frigid or cryic but not pergelic temperature regimes and have udic moisture regimes. Boralfs are not saturated with water for periods long enough to limit their use for most crops.

Udalfs — have a udic soil moisture regime and mesic or warmer soil temperature regimes. Udalfs generally have brownish colors throughout, and are not saturated with water for periods long enough to limit their use for most crops.

Ustalfs — have an ustic soil moisture regime and mesic or warmer soil temperature regimes. Ustalfs are brownish or reddish throughout and are not saturated with water for periods long enough to limit their use for most crops.

Xeralfs — have a xeric soil moisture regime. Xeralfs are brownish or reddish throughout.

ARIDISOLS — Mineral soils that have an aridic moisture regime, an ochric epipedon, and other pedogenic horizons but no oxic horizon.

Argids — have an argillic or a natric horizon.

Orthids — have a cambic, calcic, petrocalcic, gypsic, or salic horizon or a duripan but that lack an argillic or natric horizon.

ENTISOLS — Mineral soils that have no distinct pedogenic horizons within 1 m of the soil surface.

Aquents — are saturated with water for periods long enough to limit their use for most crops other than pasture unless they are artificially drained. Aquents have low chromas or distinct mottles within 50 cm of the surface, or are saturated with water at all times.

Arents — contain recognizable fragments of pedogenic horizons that have been mixed by mechanical disturbance. Arents are not saturated with water for periods long enough to limit their use for most crops.

Fluvents — form in recent loamy or clayey alluvial deposits, are usually stratified, and have an organic carbon content that decreases irregularly with depth. Fluvents are not saturated with water for periods long enough to limit their use for most crops.

Orthents — have either textures of very fine sand or finer in the fine earth fraction, or textures of loamy fine sand or coarser and a coarse fragment content of 35% or more and that have an organic carbon content that decreases regularly with depth. Orthents are not saturated with water for periods long enough to limit their use for most crops.

Psamments — have textures of loamy fine sand or coarser in all parts, have less than 35% coarse fragments and that are not saturated with water for periods long enough to limit their use for most crops.

HISTOSOLS — Organic soils that have organic soil materials in more than half of the upper 80 cm, or that are of any thickness if overlying rock or fragmental materials that have interstices filled with organic soil materials.

Fibrists — have a high content of undecomposed plant fibers and a bulk density less than about 0.1. Fibrists are saturated with water for periods long enough to limit their use for most crops unless they are artificially drained.

Folists — have an accumulation of organic soil materials mainly as forest litter that is less than 1 m deep to rock or to fragmental materials with interstices filled with organic materials. Folists are not saturated with water for periods long enough to limit their use if cropped.

Hemists — have an intermediate degree of plant fiber decomposition and a bulk density between about 0.1 and 0.2. Hemists are saturated with water for periods long enough to limit their use for most crops unless they are artificially drained.

Saprists — have a high content of plant materials so decomposed that original plant structures cannot be determined and a bulk density of about 0.2 or more. Saprists are saturated with water for periods long enough to limit their use for most crops unless they are artificially drained.

INCEPTISOLS — Mineral soils that have one or more pedogenic horizons in which mineral materials other than carbonates or amorphous silica have been altered or removed but not accumulated to a significant degree. Under certain conditions, Inceptisols may have an ochric, umbric, histic, plaggen or mollic epipedon. Water is available to plants more than half of the year or more than 3 consecutive months during a warm season.

Andepts — have formed either in vitric pyroclastic materials, or have low bulk density and large amounts of amorphous materials, or both. Andepts are not saturated with water long enough to limit their use for most crops.

Aquepts — are saturated with water for periods long enough to limit their use for most crops other than pasture or woodland unless they are artificially drained. Aquepts have either a histic or umbric epipedon and gray colors within 50 cm, or an ochric epipedon underlain by a cambic horizon with gray colors, or have sodium saturation of 15% or more.

Ochrepts — are formed in cold or temperate climates and that commonly have an ochric epipedon and a cambic horizon. They may have an umbric or mollic epipedon less than 25 cm thick or a fragipan or duripan under certain conditions. These soils are not dominated by amorphous materials and are not saturated with water for periods long enough to limit their use for most crops.

Plaggepts — have a plaggen epipedon.

Tropepts — have a mean annual soil temperature of 8°C or more, and less than 5°C difference between mean summer and mean winter temperatures at a depth of 50 cm below the surface. Tropepts may have an ochric epipedon and a cambic horizon, or an umbric epipedon, or a mollic epipedon under certain conditions but no plaggen epipedon, and are not saturated with water for periods long enough to limit their use for most crops.

Umbrepts — are formed in cold or temperate climates that commonly have an umbric epipedon, but they may have a mollic or an anthropic epipedon 25 cm or more thick under certain conditions. These soils are not dominated by amorphous materials and are not saturated with water for periods long enough to limit their use for most crops.

MOLLISOLS — Mineral soils that have a mollic epipedon overlying mineral material with a base saturation of 50% or more when measured at pH 7. Mollisols may have an argillic, natric, albic, cambic, gypsic, calcic, or petrocalcic horizon, a histic epipedon, or a duripan, but not an oxic or spodic horizon.

Albolls — have an albic horizon immediately below the mollic epipedon. These soils have an argillic or natric horizon and mottles, iron-manganese concretions, or both, within the albic, argillic or natric horizon.

Aquolls — are saturated with water for periods long enough to limit their use for most crops other than pasture unless they are artificially drained. Aquolls may have a histic epipedon, a sodium saturation in the upper part of the mollic epipedon of more than 15% than decreases with depth or mottles or gray colors within or immediately below the mollic epipedon.

Borolls — have a mean annual soil temperature of less than 8°C and are never dry for 60 consecutive days or more within the 3 months following the summer solstice. Borolls do not contain material that has more than 40% $CaCO_2$ equivalent unless they have a calcic horizon, and they are not saturated with water for periods long enough to limit their use for most crops.

Rendolls — have no argillic or calcic horizon but that contain material with more than 40% $CaCO_3$ equivalent within or immediately below the mollic epipedon. Rendolls are not saturated with water for periods long enough to limit their use for most crops.

Udolls — have an ustic soil moisture regime and mesic or warmer soil temperature regimes. Ustolls may have a calcic, petrocalcic, or gypsic horizon, and are not saturated with water for periods long enough to limit their use for most crops.

Ustolls — have an ustic soil moisture regime and mesic or warmer soil temperature regimes. Ustolls may have a calcic, petrocalcic, or gypsic horizon, and are not saturated with water for periods long enough to limit their use for most crops.

Xerolls — have a xeric soil moisture regime. Xerolls may have a calcic, petrocalcic, or gypsic horizon, or a duripan.

OXISOLS — Mineral soils that have an oxic horizon within 2 m of the surface or plinthite as a continuous phase within 30 cm of the surface, and that do not have a spodic or argillic horizon above the oxic horizon.

Aquox — have continuous plinthite near the surface, or that are saturated with water sometime during the year if not artificially drained. Aquox have either a histic epipedon, or mottles or colors indicative or poor drainage within the oxic horizon or both.

Humox — are moist all or most of the time and that have a high organic carbon content within the upper meter. Humox have a mean annual soil temperature of less than 22°C and a base saturation within the oxic horizon of less than 35%, measured at pH 7.

Orthox — are moist all or most of the time, and that have a low to moderate content of organic carbon within the upper 1 m or a mean annual soil temperature of 22°C or more.

Torrox — have a torric soil moisture regime.

Ustox — have an ustic moisture regime and either hyperthermic or isohyperthermic soil temperature regimes or have less than 20 kg organic carbon in the surface cubic meter.

SPODOSOLS — Mineral soils that have a spodic horizon or a placic horizon that overlies a fragipan.

Aquods — are saturated with water for periods long enough to limit their use for most crops other than pasture or woodland unless they are artificially drained. Aquods may have a histic epipedon, an albic horizon that is mottled or contains a duripan, or mottling or gray colors within or immediately below the spodic horizon.

Ferrods — have more than six times as much free iron (elemental) than organic carbon in the spodic horizon. Ferrods are rarely saturated with water or do not have characteristics associated with wetness.

Humods — have accumulated organic carbon and aluminum, but not iron, in the upper part of the spodic horizon. Humods are rarely saturated with water or do not have characteristics associated with wetness.

Orthods — have less than six times as much free iron (elemental) than organic carbon in the spodic horizon but the ratio of iron to carbon is 0.2 or more. Orthods are not saturated with water for periods long enough to limit their use for most crops.

ULTISOLS — Mineral soils that have an argillic horizon with a base saturation of less than 35% when measured at pH 8.2. Ultisols have a mean annual soil temperature of 8°C or higher.

Aquults — are saturated with water for periods long enough to limit their use for most crops other than pasture or woodland, unless they are artificially drained. Aquults have mottles, iron-manganese concretions or gray colors immediately below the A1 or Ap horizons and gray colors in the argillic horizon.

Humults — have a high content of organic carbon. Humults are not saturated with water for periods long enough to limit their use for most crops.

Udults — have low or moderate amounts of organic carbon, reddish or yellowish argillic horizons, and a udic soil moisture regime. Udults are not saturated with water for periods long enough to limit their use for most crops.

Ustults — have low or moderate amounts of organic carbon, are brownish or reddish throughout, and have an ustic soil moisture regime.

Xerults — have low or moderate amounts of organic carbon, are brownish or reddish throughout, and have a xeric soil moisture regime.

VERTISOLS — Mineral soils that have 30% or more clay, deep wide cracks when dry, and either gilgai microrelief, intersecting slickensides, or wedgeshaped structural aggregates titled at an angle from the horizontal.

Torrerts — are in arid regions and have wide, deep cracks that remain open throughout the year in most years.

Uderts — are in relatively humid regions and have wide, deep cracks that usually remain open continuously for less than 2 months or intermittently for periods that total less than 3 months.

Usterts — are in temperate or tropical regions and have wide, deep cracks that usually remain open for periods that total more than 3 months but do not remain open continuously throughout 3 years, and have either a mean annual soil temperature of 22°C or more or a mean summer and mean winter soil temperature at 50 cm that differ by less than 5°C or have cracks that open and close more than once during the year.

Xererts — are in Mediterranean climates and have wide, deep cracks that open and close once each year and usually remain open continuously for more than 2 months. Xererts have a mean annual soil temperature of less than 22°C.

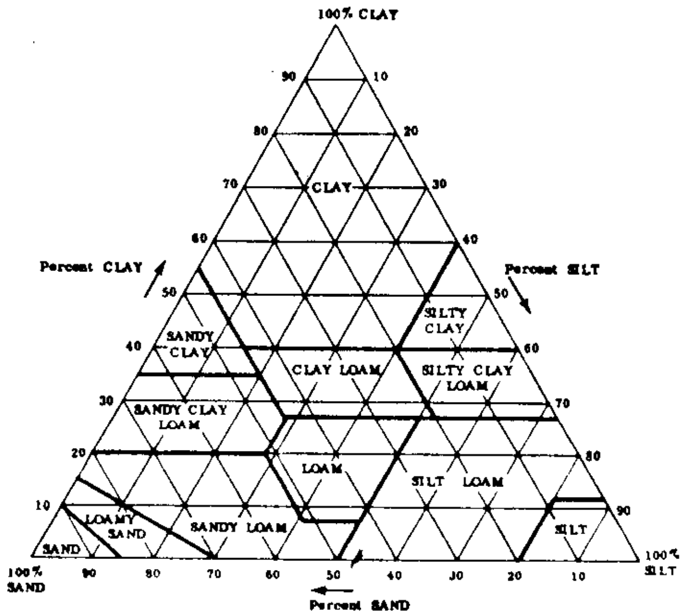
(mainly from: Glossary of Soil Science Terms, SSSA, Madison, January 1978)

Order	Suborder	Great group
Alfisols	Aqualfs	Albaqualfs
		Duraqualfs
		Fragiaqualfs
		Glossaqualfs
		Natraqualfs
		Ochraqualfs
		Plinthaqualfs
		Tropaqualfs
		Umbraqualfs
	Boralfs	Cryoboralfs
		Eutroboralfs
		Fragiboralfs
		Glossoboralfs
		Natriboralfs
		Paleboralfs
	Udalfs	Agrudalfs
		Ferrudalfs
		Fraglossudalfs
		Fragiudalfs
		Glossudalfs
		Hapludalfs
		Natrudalfs
		Paleudalfs
		Rhodudalfs
		Tropudalfs
	Ustalfs	Durustalfs
		Haplustalfs
		Natrustalfs
		Paleustalfs
		Plinthustalfs
		Rhodustalfs
	Xeralfs	Durixeralfs
		Haploxeralfs
		Natrixeralfs
		Palexeralfs
		Plinthoxeralfs
		Rhodoxeralfs
Aridisols	Argids	Durargids
		Haplargids
		Nadurargids
		Natrargids
		Paleargids
	Orthids	Calciorthids
		Camborthids
		Durorthids
		Gypsiorthids
		Paleorthids
		Salorthids
Entisols	Aquents	Cryaquents
		Haplaquents
		Hydraquents
		Psammaquents
		Tropaquents
	Arents	Arents
	Fluvents	Cryofluvents
		Torrifluvents
		Tropofluvents
		Udifluvents
		Ustifluvents
		Xerofluvents
	Orthents	Cryorthents
		Torriorthents
		Troporthents
		Udorthents
		Ustorthents
		Xerorthents
	Psamments	Cryopsamments
		Quartzipsamments
		Torripsamments
		Tropopsamments
		Udipsamments
		Ustipsamments
		Xeropsamments

Order	Suborder	Great group
Histosols	Fibrists	Borofibrists
		Cryofibrists
		Luvifibrists
		Medifibrists
		Sphagnofibrists
		Tropofibrists
	Folists	Borofolists
		Cryofolists
		Tropofolists
	Hemists	Borohemists
		Cryohemists
		Luvihemists
		Medihemists
		Tropohemists
	Saprists	Borosaprists
		Cryosaprists
		Medisaprists
		Troposaprists
Inceptisols	Andepts	Cryandepts
		Durandepts
		Dystrandepts
		Eutrandepts
		Hydrandepts
		Placandepts
		Vitrandepts
	Aquepts	Andaquepts
		Cryaquepts
		Fragiaquepts
		Halaquepts
		Haplaquepts
		Humaquepts
		Plinthaquepts
		Tropaquepts
	Ochrepts	Cryochrepts
		Durochrepts
		Dystrochrepts
		Eutrochrepts
		Fragiochrepts
		Ustochrepts
		Xerochrepts
	Plaggepts	Plaggepts
	Tropepts	Dystropepts
		Eutropepts
		Humitropepts
		Sombritropepts
		Ustropepts
	Umbrepts	Anthrumbrepts
		Cryumbrepts
		Fragiumbrepts
		Haplumbrepts
		Xerumbrepts
Mollisols	Albolls	Argialbolls
		Natralbolls
	Aquolls	Argiaquolls
		Calciaquolls
		Cryaquolls
		Duraquolls
		Haplaquolls
		Natraquolls
	Borolls	Argiborolls
		Calciborolls
		Cryoborolls
		Haploborolls
		Natriborolls
		Paleborolls
		Vermiborolls
	Rendolls	Rendolls
	Udolls	Argiudolls
		Hapludolls
		Paleudolls
		Vermudolls
	Ustolls	Argiustolls
		Calciustolls
		Durustolls
		Haplustolls
		Natrustolls
		Paleustolls
		Vermustolls

Order	Suborder	Great group
Mollisols	Xerolls	Argixerolls
		Calcixerolls
		Durixerolls
		Haploxerolls
		Natrixerolls
		Palexerolls
Oxisols	Aquox	Gibbsiaquox
		Ochraquox
		Plinthaquox
		Umbraquox
	Humox	Acrohumox
		Gibbsihumox
		Haplohumox
		Sombrihumox
	Orthox	Acrorthox
		Eutrorthox
		Gibbsiorthox
		Haplorthox
		Sombriorthox
		Umbriorthox
	Torrox	Torrox
	Ustox	Acrustox
		Eutrustox
		Gibbsiustox
		Haplustox
		Sombriustox
Spodosols	Aquods	Cryaquods
		Duraquods
		Fragiaquods
		Haplaquods
		Placaquods
		Sideraquods
		Tropaquods
	Ferrods	Ferrods
	Humods	Cryohumods
		Fragihumods
		Haplohumods
		Placohumods
		Tropohumods
	Orthods	Cryorthods
		Fragiorthods
		Haplorthods
		Placorthods
		Troporthods
Ultisols	Aquults	Albaquults
		Fragiaquults
		Ochraquults
		Paleaquults
		Plinthaquults
		Tropaquults
		Umbraquults
	Humults	Haplohumults
		Palehumults
		Sombrihumults
		Tropohumults
	Udults	Fragiudults
		Hapludults
		Paleudults
		Plinthudults
		Rhodudults
		Tropudults
	Ustults	Haplustults
		Paleustults
		Plinthustults
		Rhodustults
		Tropustults
	Xerults	Haploxerults
		Palexerults
Vertisols	Torrerts	Torrerts
	Uderts	Chromuderts
		Pelluderts
	Usterts	Chromusterts
		Pellusterts
	Xererts	Chromoxererts
		Pelloxererts

Classes and Subclasses of Soil Texture



Graph showing the percentages of sand, silt, and clay in the soil classes.

sand — Soil material that contains 85% or more of sand; percentage of silt, plus 1.5 times the percentage of clay, shall not exceed 15.

coarse sand - 25% or more very coarse and coarse sand, and < 50% any other one grade of sand.

sand - 25% or more very coarse, coarse, and medium sand, and < 50% fine or very fine sand.

fine sand - 50% or more fine sand (or) < 25% very coarse, coarse, and medium sand and < 50% very fine sand.

very fine sand - 50% or more very fine sand.

loamy sand — Soil material that contains at the upper limit 85 to 90% sand, and the percentage of silt plus 1.5 times the percentage of clay is not less than 15; at the lower limit it contains not less than 70 to 85% sand, and the percentage of silt plus twice the percentage of clay does not exceed 30.

loamy coarse sand - 25% or more very coarse and coarse sand, and < 50% any other one grade of sand.

loamy sand - 25% or more very coarse, coarse, and medium sand, and < 50% fine or very fine sand.

loamy fine sand - 50% or more fine sand (or) < 25% very coarse, coarse, and medium sand and < 50% very fine sand.

loamy very fine sand - 50% or more very fine sand.

sandy loam — Soil material that contains either 20% clay or less, and the percentage of silt plus twice the percentage of clay exceeds 30, and 52% or more sand; or < 7% clay, < 50% silt, and between 43% and 52% sand.

coarse sandy loam - 25% or more very coarse and coarse sand and < 50% any other one grade of sand.

sandy loam - 30% or more very coarse, coarse, and medium sand, but < 25% very coarse sand, and < 30% very fine or fine sand.

fine sandy loam - 30% or more fine sand and < 30% very fine sand (or) between 15 and 30% very coarse, coarse, and medium sand.

very fine sandy loam - 30% or more very fine (or) > 40% fine and very fine sand, at least half of which is very fine sand and < 15% very coarse, coarse, and medium sand.

loam — Soil material that contains 7 to 27% clay, 28 to 50% silt, and < 52% sand.

silt loam — Soil material that contains 50% or more silt and 12 to 27% clay (or) 50 to 80% silt and < 12% clay.

silt — Soil material that contains 80% or more silt and < 12% clay.

sandy clay loam — Soil material that contains 20 to 35% clay, < 28% silt, and 45% or more sand.

clay loam — Soil material that contains 27 to 40% clay and 20 to 45% sand.

silty clay loam — Soil material that contains 27 to 40% clay and < 20% sand.

sandy clay — Soil material that contains 35% or more clay and 45% or more sand.

silty clay — Soil material that contains 40% or more clay and 40% or more silt.

clay — Soil material that contains 40% or more clay, < 45% sand, and < 40% silt.

Size limits in micron

sand	2000 - 50
very coarse sand	2000 - 1000
coarse sand	1000 - 500
medium sand	500 - 250
fine sand	250 - 100
very fine sand	100 - 50
silt	
coarse silt	50 - 20
fine silt	20 - 2
clay	< 2
fine clay	< 0.2

ypes and classes of soil structure

Class	Type (shape and arrangement of peds)						
	Platelike with one dimension (the vertical) limited and greatly less than the other two; arranged around a horizontal plane; faces mostly horizontal	Prismlike with two dimensions (the horizontal) limited and considerably less than the vertical; arranged around a vertical line; vertical faces well defined; vertices angular		Blocklike; polyhedronlike, or spheroidal, with three dimensions of the same order of magnitude, arranged around a point			
				Blocklike; blocks or polyhedrons having plane or curved surfaces that are casts of the molds formed by the faces of the surrounding peds		Spheroids of polyhedrons having plane or curved surfaces which have slight or no accommodation to the faces of surrounding peds	
		Without rounded caps	With rounded caps	Faces flattened; most vertices sharply angular	Mixed rounded and flattened faces with many rounded vertices	Relatively nonporous peds	Porous peds
	Platy	Prismatic	Columnar	(Angular) Blocky	Subangular blocky	Granular	Crumb
Very fine or very thin	Very thin platy; < 1 mm	Very fine prismatic; < 10 mm	Very fine columnar; < 10 mm	Very fine angular blocky; < 5 mm	Very fine subangular blocky; < 5 mm	Very fine granular; < 1 mm	Very fine crumb; < 1 mm
Fine or thin	Thin platy; 1-2 mm	Fine prismatic; 10-20 mm	Fine columnar; 10-20 mm	Fine angular blocky; 5-10 mm	Fine subangular blocky; 5-10 mm	Fine granular; 1-2 mm	Fine crumb; 1-2 mm
Medium	Medium platy; 2-5 mm	Medium prismatic; 20-50 mm	Medium columnar; 20-50 mm	Medium angular blocky; 10-20 mm	Medium subangular blocky; 10-20 mm	Medium granular; 2-5 mm	Medium crumb; 2-5 mm
Coarse or thick	Thick platy; 5-10 mm	Coarse prismatic; 50-100 mm	Coarse columnar 50-100 mm	Coarse angular blocky; 20-50 mm	Coarse subangular blocky; 20-50 mm	Coarse granular 5-10 mm	
Very coarse or very thick	Very thick platy; > 10 mm	Very coarse prismatic; > 100 mm	Very coarse columnar; > 100 mm	Very coarse angular blocky; > 50 mm	Very coarse subangular blocky > 50 mm	Very coarse granular > 10 mm	

Grades of soil structure — A grouping or classification of soil structure on the basis of inter- and intra-aggregate adhesion, cohesion, or stability within the profile. Four grades of structure designated from 0 to 3 are recognized as follows:

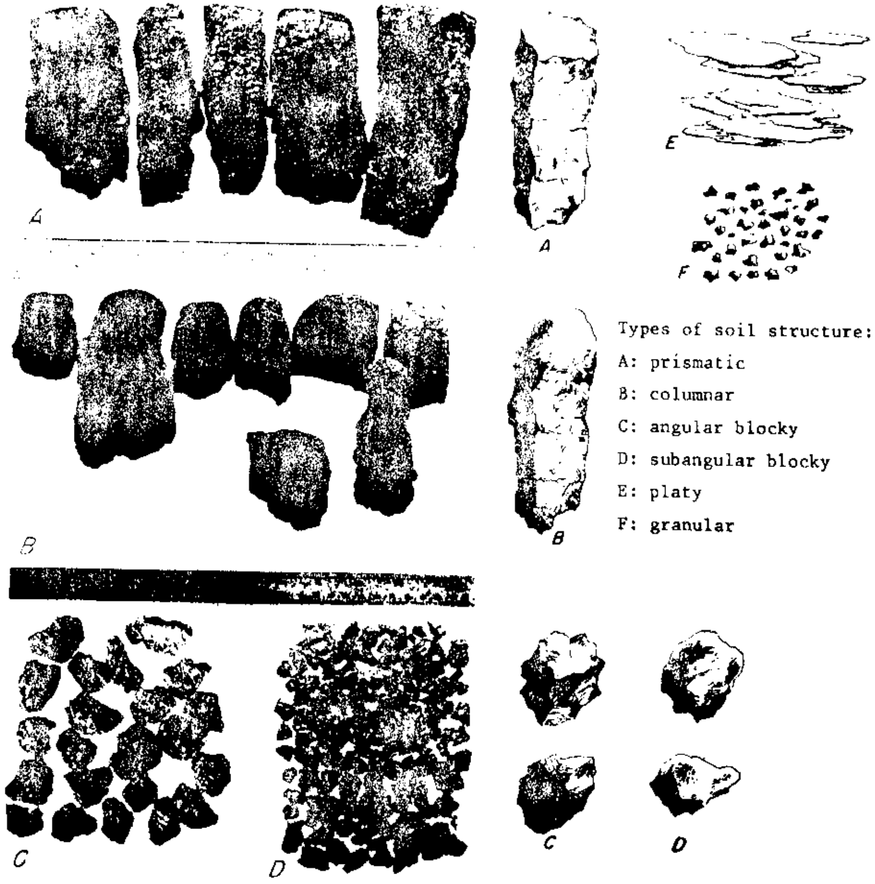
0) *Structureless* — no observable aggregation or no definite and orderly arrangement of natural lines of weakness. *Massive,* if coherent; *single-grain,* if noncoherent.

1) *Weak* — poorly formed indistinct peds, barely observable in place.

2) *Moderate* — well-formed distinct peds, moderately durable and evident, but not distinct in undisturbed soil.

3) *Strong* — durable peds that are quite evident in undisturbed soil, adhere weakly to one another, withstand displacement, and become separated when the soil is disturbed.

(From: Soil survey manual, U.S. Dept. Agr. Handbook 18, Soil Survey Staff, SCS, USDA. U.S. Government Printing Office, Washington, 1951)



Types of soil structure:

A: prismatic

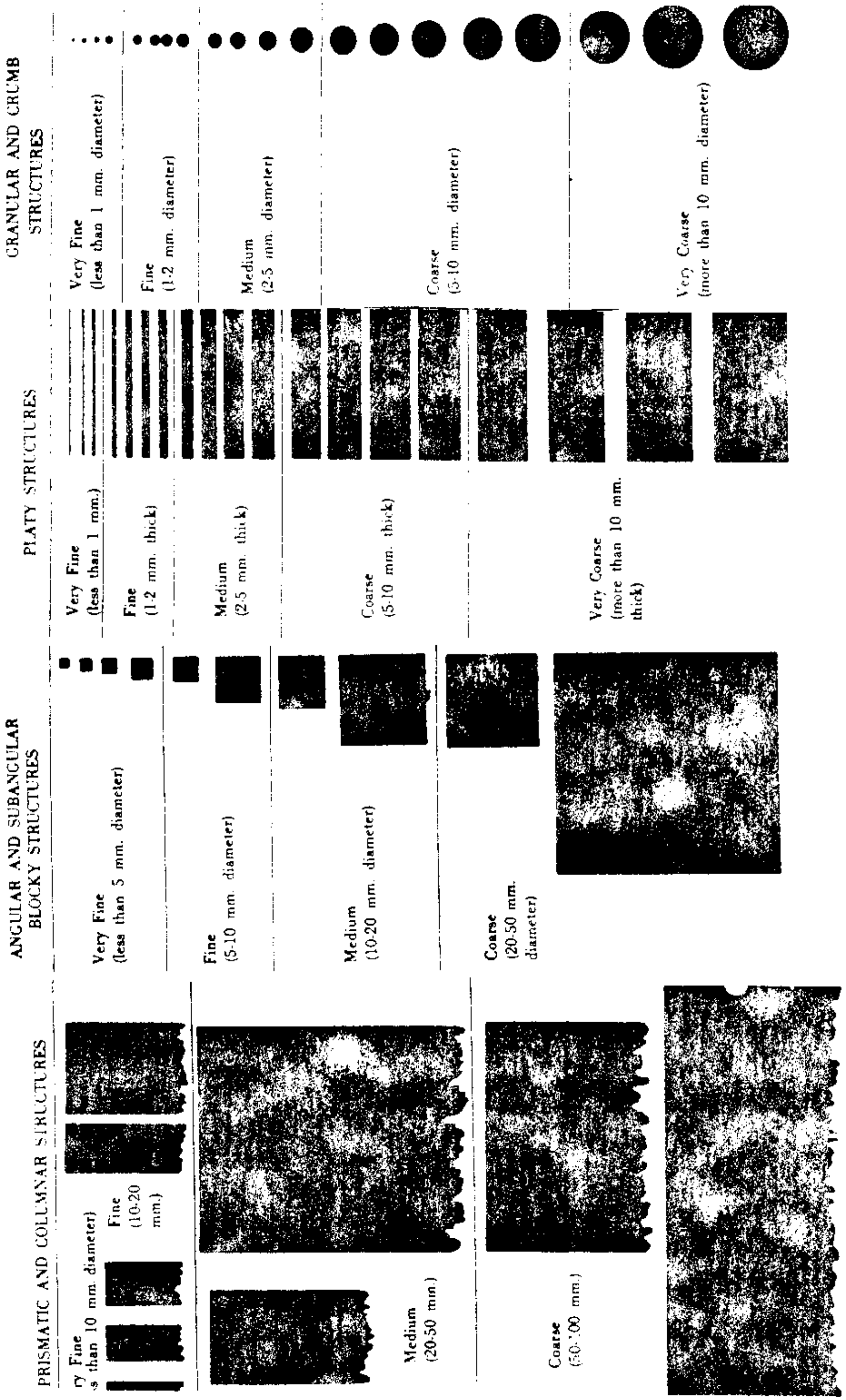
B: columnar

C: angular blocky

D: subangular blocky

E: platy

F: granular



PRINCIPLES OF SOIL CLASSIFICATION

General Concepts of Classification

Classification (also called taxonomy) involves the grouping of objects, in the mind, on the basis of one or more properties. The objects to be classified are commonly called <u>individuals</u>. The individual is the smallest natural body that can be defined as a thing in itself. All the individuals of a natural phenomenon, collectively, are a <u>population</u> or a <u>universe</u>. Plants, animals, rocks, atoms and soils for example, are populations, each consisting of many individuals.

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

When classifying the individuals of a large and widely varying population, such as plants and soils, classification is necessary not only of individuals into classes, but also of classes into wider or higher classes, and of those into still higher classes. This is called a <u>multiple category</u> or <u>hierarchical</u> system of classification.

The individuals are grouped into classes of the lowest category, which are subsequently grouped into classes of higher categories. The highest categories have small numbers of classes, defined in broad general terms, by means of a few differentiating characteristics. In the lower categories there are large numbers of classes of narrow range, defined in quite specific terms by a large number of differentiating characteristics.

Within every class is a central core or nucleus to which the individual members are related in varying degrees. It is called the <u>central concept</u> or <u>modal individual</u>. It is not a real class member, but an idealized individual which typifies the class. Some individuals of the class are very similar to the central concept so that no doubt can exist as to their membership of the class. Other individuals are less strongly resembling the central concept and show similarities with one or more other classes.

The Purpose of Classification

The purposes of classification are manifolc. It is an essential aspect of scientific activity. The study of natural phenomena begins with observation and classification in order to bring out and understand their relationships. New relationships and principles become evident.

From a practical point of view classification enables the human mind to remember the properties of the objects and make predictions about the behaviour of these objects and identify their best use. Classification also provides the basis for a "language" by means of which scientists can exchange ideas and provide information for practical purposes (e.g. soil maps).

Soil Classification

The soil individual

Soil may be defined as "the collection of natural bodies occupying portions of the earth's surface that support plants and that have properties due to the integrated effect of climate and living matter, acting upon parent material, as conditioned by relief, over periods of time" (Soil Survey Staff, 1952, p.8).

Recent developments in soil classification have increased the interest in defining the soil individual, i.e. the smallest soil body, which can be used as the fundamental unit for classification.
It has been debated whether the soil individual is a natural individual that is discrete (i.e. separate and distinct) with boundaries independent of the observer or whether it should be considered as an artificial individual, which is a human construct, with boundaries created arbitrarily, for convenience.

Present trends indicate that the soil scientists tend to accept the idea of soil individuals being artificial. Since the introduction of the USDA Comprehensive System of Soil Classification(Soil Survey Staff 1960), the concept of the pedon and polypedon has been acknowledged by many.

The pedon is the smallest volume that can be called "a soil". It has three dimensions. Its lower limit is the vague and somewhat arbitrary limit between soil and "not-soil". The lateral dimensions are large enough to permit study of the nature of any horizon present. Its area ranges from one to ten square meters. The shape of the pedon is roughly hexagonal.

A polypedon is a soil body consisting of one or more contiguous (i.e. adjoining and being in close contact) pedons having the same characteristics diagnostic for a soil sereis, the series being the lowest category in the US system of classification. A polypedon is bounded on all sides by "not-soil" or by pedons having characteristics of a different soil series.
By means of these concepts it is possible to divide the continuum of soil into soil individuals (polypedons) that can be arranged in a classification system.

Soil classification and soil mapping

Probably the most important purpose of soil classification is to provide the basis for soil survey. Soil mapping involves the identification of different soils in the field, the determination of their boundaries and the delineation of these boundaries on a suitable base map. Ideally the mapping units should correspond to the units of the classification. However, this can only be achieved by using a very large scale. Usually the scale of the base map is smaller and, as a consequence, it is only possible to delineate soil bodies which tend to approximate landscape units. These often include more than one polypedon (soil individual), which may fall in different classes, even at the highest level.

The reader may be warned, that often the terminology of the classification system is used for map legends, seemingly without trouble. This is the source of much confusion.

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New developments in world soil classification

Soil constitutes a continuum and most of its characteristics change with time. Soil classification is a conceptual system to arrange the knowledge on soils. Newly acquired knowledge will result in new concepts of classification and, ultimately, in new classification schemes and systems. In other words: soil classification systems have a temporary validity and need to change with time to fit the expansion of knowledge. Also the aims and requirements of the classification may change.

The FAO-Unesco Soil Map of the World legend was developed in the 1960's and published in 1974. The development of the USDA Soil Taxonomy ended somewhat later and was published in 1975. Both systems have their values, but also shortcomings, a number of these being:

- the two systems distinguish soils at different levels of generalization and by different criteria, so that many units overlap and differ in their range of variability;
- differences in terminology and nomenclature add to the difficulties of establishing correlations and international understanding;
- a part of the soils, especially those occurring in the (sub)tropics and in (very) dry regions are not adequately characterized.

In short, it can be stated that there is a strong need for an international agreement on soil classification; both with regard to the principal classes to be recognized, as well as to the criteria and methodology for defining and separating them.

The following international activities can be mentioned to illustrate the continuing search for an improved soil classification system:

- an International Reference Base for soil classification (IRB), initiated by UNEP, FAO, Unesco and ISSS. An IRB is needed as a means of communication for a classification of the soils of the world and for a global exchange of experiences and information. The system will have 15-20 units at the first, highest, level, which will be subdivided at a second to fourth level, and beyond the fourth level according to the requirements of the countries concerned. A first draft of the ideas are given in the annex to this lecture note, showing that IRB should be seen as an improvement and expansion of the Soil Map of the World legend.
- a number of International Committees have been set up to advise on the further development of Soil Taxonomy. The presence of non-American soil scientists will ensure that the proposals of the Committees are also based on knowledge of soils outside the U.S.a. A few of the Committees are: ICOMLAC (Int. Comm. on Low-Activity Clays), ICOMVERT (Int. Comm. on Vertisols), ICOMOX (Int. Comm. on Oxisols), and ICOMMORT (Int. Comm. on Moisture Regimes in the Tropics).

International Reference Base for soil classification (IRB)
Proposals for soil classification on different levels*

1st level	2nd level	(tentative name, FAO-equivalent)		3rd	4th
1. shallow weakly developed	on hard parent m.	Lithosols	=		
	" coarse p.m.	Arenosols	=		
	" medium p.m.	Regosols	= (medium)		
	" alluvial p.m.	Fluvisols	=, most		
2. swelling/ shrinking	clayey, low kf	Vertisols	=		
	" " "	Pelosols			
3. surface water		Pseudogleys			
	+albic	Stagnogleys,			
	"	Planosols	=		
4. ground water		Gleysols	=		
	+thionic	Thiosols	thionic Fluvi		
5. saline and/or alkaline		Solonchaks	=		
		Solonetz	=		
6. aridic	calcic	Calcisols	Xero		
	gypsic	Gypsisols	Yermo		
7. mollic (humus saturated)	+Ca-redistribution	Kastanozems	=		
	"	Chernozems	=		
	-Ca-redistribution	Greyzems	=		
	"	Phaeozems	=		
	"	Rendzina	=		
8. umbric (humus unsaturated)		Rankers	=		
	+cambic	Umbrisols	humic Cambi		
9. sialic (CEC >24, Fe_d <4)		Cambisols	=, most		
	+argillic	Luvisols	=, most		
			Podzoluvi, Acri		
10. fersialic (CEC >24, Fe_d >10)		Chromosols	chromic Cambi		
	+argillic		" Luvi		
11. ferralic (CEC <24)		Ferralsols	=		
	+argillic	Nitosols	=		
	"	Ferluvisols	ferric Luvi		
	"	Feracrisols	" Acri		
12. andic		Andosols	=		
13. FeAl/humus-B		Podzols	=		
14. organic		Histosols	=		
15. permafrost		Gelisols	gelic groups		
16. anthropogenic		Anthroposols			

*as presented at 12 International Congress of Soil Science, New Delhi, Feb. 1982

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