INTRODUCTION TO SOIL CLASSIFICATION

Compendium of undergraduate lecture notes

Balthazar M. MSANYA
BSc(Agric)(Hons)(Dar)
MSc (Soil Sci)(Ghent)
PhD(Pedology)(Ghent)

Department of Soil Science
Faculty of Agriculture
Sokoine University of Agriculture
Morogoro, Tanzania

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Dr. Balthazar M. MSANYA
Asssociate Professor

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These course notes are meant for BSc students majoring in agriculture, forestry and related fields. They have to be supplemented with extra reading to enable students and other readers understand the important concepts in soil classification so that they can classify soils correctly using both the USDA Soil Taxonomy and the FAO-UNESCO soil classification systems. Important reference books and manuals are listed below.

IMPORTANT READING MATERIALS

1. *Buol, S.W., F.D. Hole and R.J. McCracken, 1989. Soil genesis and classification, 3rd edition, Iowa State University Press, 462 pp.*
2. *Duchaufour, D., 1982. Pedology, pedogenesis and classification. Vol. 1 & 2, George Allen and Unwin.*
3. *Euroconsult, 1989.* Agricultural compendium for rural development in the tropics and subtropics. Elsevier Science Publishers, B.V. Amsterdam.
4. *Fanning, D.S. and M.C.B. Fanning, 1989. Soil morphology, genesis and classification. John Wiley & Sons.*
5. *FAO, 1990. Guidelines for soil description. 3rd edition (revised). Soil Resources, Management and Conservation Service Land and Water Development Division, Rome.*
6. *FAO, 1998. World reference base for soil resources. World Soil Resources Reports No. 84. FAO, Rome. 88 pp.*
7. *FAO-UNESCO, 1989. Soil map of the world, revised edition. International Soil Reference and Information Centre, Wageningen.*
8. *FitzPatrick, E.A., 1983. Soils - Their formation, classification and distribution. Longman, 553 pp.*
9. *Landon, J.R., 1984. Booker tropical soil manual. A handbook for soil survey and land evaluation in the tropics. Longman Group Ltd., 450 pp.*
10. *Munsell Color Company, 1992. Munsell oil color charts. Revised edition, Munsell Color Co. Inc., Baltimore.*
11. *Sanchez, P., 1976. Properties and management of soils in the tropics. John Wiley & Sons, 618 pp.*
12. *Soil Survey Staff, 1951. Soil survey manual. Agriculture handbook no. 18. Soil Conservation Service, United States Department of Agriculture, Washington, D.C.*
13. *Soil Survey Staff, 1990. Keys to Soil Taxonomy. Agency for International Development, United States of Agriculture, Soil Management Support Services technical monograph no. 19. Virginia Polytechnic Institute and State University, 422 pp.*
14. *USDA Soil Conservation Service, 1988. Soil Taxonomy. A basic system of soil classification for making and interpreting soils surveys. Reprint edition. Robert E. Krieger Publishing Co., 754 pp.*
15. *Wilding, L.P., N.E. Smeck and G.F. Hall, 1983. Pedogenesis and Soil Taxonomy. Concepts and Interactions. Developments in Soil Science 11A. Elsevier. The Soil Orders. Developments in Soil Science 11B. Elsevier.*

Definition

Soil classification is the systematic arrangement of soils into groups or categories on the basis of their characteristics. Classification of soils is necessary for the following reasons:

i. to organise knowledge and thereby contribute to economy of thought
ii. to bring out and understand relationships among soils and classes of soils being classified
iii. to remember properties of the soils being classified
iv. to learn new relationships and principles in the soils being classified
v. to establish groups or subdivisions (classes) of the soils under study in a manner useful for practical and applied purposes in:
    a. Predicting their behaviour
    b. Identifying their best uses
    c. Estimating their productivity
    d. Providing objects or units for research and for extending and extrapolating research results or observations

The role of soil classification

According to De Bakker (1970) soil classification serves two main purposes:

i. Theoretical or scientific purposes, which emphasize the origin of soils and their relationships, and
ii. Purposes of practical importance, which are aimed at the application in agriculture or other technological uses of soils. For these kinds of purposes soil survey is an essential link to the practical application.

Basically, a soil classification system organises knowledge about sets of soil properties and concepts, and groups them into taxonomic classes. Literature review (Manil, 1956; Stobbe, 1962; Cline, 1963; Smith, 1963; Northcote, 1965; Kovda *et al.*, 1967; Avery, 1973; Beinroth, 1978; Mapping Systems Working Group, 1981) indicates that one of the prime objectives of soil classification is to serve as a base for soil survey. Soil classification provides the vocabulary to describe the mapping units of the legend to a soil map.

Mulcahy and Humphries (1967) distinguished two major types of soil classification. A *special* classification is one devised for a particular purpose, or for a limited number of purposes. Special classifications are based on a small number of characters, although this is not their essential feature. Such classifications are also referred to as *extrinsic*, meaning that they are made with reference to some external criteria. On the other hand, *general* or *intrinsic* classifications attempt to collect all possible information about a population without reference to external criteria.

Soil surveys based on general soil classifications are the most useful in the case of under-developed areas, where there is little agronomic experience, but information about the soils and environmental factors will determine the range of possible users. Special classifications are by definition limited in use to cases where objectives can be adequately defined. In many occasions, a choice between general and special classifications is not open; each has a distinct area of application, the recognition of which will lead to more efficient use of both.

SOIL CLASSIFICATION SYSTEMS

There are many soil classification systems in the world, most of which being national and

others international in terms of their usage. The following is a list of the most prevalent systems of classification:

i. United States Soil Classification System (also referred to as Soil Taxonomy)
ii. FAO-UNESCO Soil Classification System
iii. USSR Soil Classification System
iv. Natural System of Soil Classification of Kubiena (1953)
v. ORSTOM Soil Classification System. ORSTOM is French and stands for Office de la Recherche Scientifique et Technique Outre-Mer (Bureau of Scientific and Technical Research Abroad)
vi. British System of Soil Classification
vii. Australian System of Soil Classification
viii. Canadian Soil Classification System

The first two systems enjoy a very wide international recognition. The ORSTOM system serves mostly the French-speaking tropical countries.

There is no general agreement on the classification of tropical soils. The classification system used in the United States is more comprehensive than the other systems. However, this system now known as the SOIL TAXONOMY, is not completely satisfactory especially for tropical soils. Modifications aimed at improving the system for classification of these soils are still being made. The wide range of climate, past and present in the present day tropical countries makes it very difficult to classify them satisfactorily.

THE USDA SOIL TAXONOMY

An introduction to the US Soil Classification will be given here. The SOIL TAXONOMY is a multi-categorical and hierarchical system of classification. *Multi-categorical* means many levels or categories; *hierarchical* means arrangement with grades from top to bottom. The levels of the system are ORDER, SUBORDER, GREATGROUP, SUBGROUP, FAMILY and SERIES arranged from top to bottom in that sequence (see Figure 1).

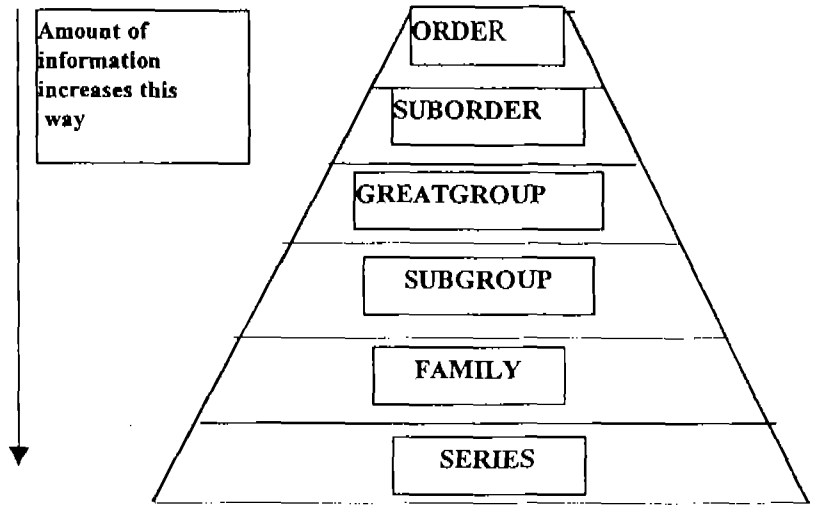


Figure 1. The categories of the USDA Soil Taxonomy

The amount of information required to classify soils at the various levels differ from level to level; it increases from order to series.

The nature of differentiating characteristics of the categories of Soil Taxonomy

ORDER:	Soil forming processes as indicated by presence or absence of major diagnostic horizons (key horizons used to identify soils)
SUBORDER:	Subdivision of orders according to the presence or absence of properties associated with wetness, soil moisture regimes, major parent materials, and vegetation effects as indicated by key properties, organic fibre decomposition stage e.g. in Histosols.
GREATGROUP:	Subdivision of suborders according to similar kind, arrangement, and degree of expression of horizons, base status, soil temperature and moisture regimes, presence or absence of diagnostic layers e.g. *plinthite, fragipan, duripan.*
SUBGROUP:	Central concept taxa* for greatgroups and properties indicating intergradations to other greatgroups, suborders and orders. The concept of "*Typic*" and "*Non-typic*" subgroups is introduced here. At this level one intends to separate the Typic subgroups (those in which the key properties defining the greatgroups i.e. the central concept) are there, and the non-typic ones (those with properties inter-grading to other greatgroups, suborders, orders, or those extragrading to non-existent soils -nonsoils) *Taxon: a class at any categorical level in the US Soil Classification System.
FAMILY:	Properties important for plant root growth; broad soil textural classes; mineralogical classes; soil temperature classes etc.
SERIES:	Kind and arrangement of horizons, colour, texture, structure, consistence, and reaction of horizons, chemical and mineralogical properties of the horizons.

Principles of nomenclature (see Table 6 p.84, Soil Taxonomy)

ORDER

The name of each order ends in *sol* (L. *solum*. soil) with the connecting vowel o for Greek roots and connecting vowel i for other roots. For example Alfisol, Aridisol, Entisol, Histosol, Inceptisol, Mollisol, Oxisol, Ultisol, Vertisol, Andisol. Prior to 1990 only the first 10 orders were recognised. The order Andisol was introduced afterwards, and the number of soil orders became 11. More recently another order Gelisol representing soils with permafrost has been introduced (Soil Survey Staff, 1999). So the current number of soil orders is 12.

Formative elements (used as endings for names at the other levels of the classification)

Each name of order contains a formative element that begins with the vowel next preceding the connecting vowel, and ends with the last consonant preceding the connecting vowel. Consider as an example the order **ENTISOL**: -the connecting vowel is i; the vowel next preceding the connecting vowel is e; the last consonant preceding the connecting vowel i is t. Hence the formative element is *-ent*. Table 1 presents the formative elements for the different soil ORDERS.

Table 1. Formative elements in the names of orders (derived from table 8 p. 87, Soil Taxonomy)

Name of order	Formative element	Derivation of formative element
Alfisol	Alf	Meaningless syllable
Aridisol	Id	L. aridus, dry
Entisol	Ent	Meaningless syllable
Histosol	Ist	Gr. histos, tissue
Inceptisol	Ept	L. inceptum, beginning
Mollisol	Oll	L. mollis, soft
Oxisol	Ox	F. oxide, oxide
Spodosol	Od	Gr. spodos, wood ash
Ultisol	Ult	L. ultimus, last
Vertisol	Ert	L. verto, turn
Andisol	And	J. an, dark; do, soil
Gelisol	El	L. gelare, to freeze

SUBORDER

Names have exactly two syllables, the first syllable connotes something of the diagnostic properties of the soil, and the second syllable is the formative element derived from the order name. Example: *Aqu*ent, Aquod, *Fluv*ent, *Per*ox. These formative elements are used with the other formative elements derived from order names to make names of suborders. Table 2 presents the formative elements used in the names of suborders.

Table 2. Formative elements in names of suborders (derived from table 9, p. 88 Soil Taxonomy)

Formative element	Derivation	Connotation
Alb	L. albus, white	Presence of albic horizon
Aqu	L. aqua, water	Aquic moisture regime
Ar	L. arare to plow	Mixed horizons
Arg	L. argilla, white clay	Presence of argillic horizon
Bor	Gr. boreas, northern	Cool
Cry	Gr. kryos, icy cold	Cold
Ferr	L. ferrum, iron	Presence of iron
Fibr	L. fibra, fibres	Least decomposed stage

Table 2 continued

Fluv	L. fluvius, river	Floodplain
Fol	L. folia, leaves	Mass of leaves
Hem	Gr. hemi, half	Intermediate stage of decomposition
Hum	L. humus, earth	Presence of organic matter
Ochr	Gr. Ochros, pale	Presence of ochric epipedon
Orth	Gr. orthos, true	The common ones
*Plagg	Ger. plaggen, sod	Presence of plaggen epipedon
Psamm	Gr. psammos, sand	Sand texture
Rend	Modified from rendzina	High carbonate content
Sapr	Gr. sapros, rotten	Most decomposed stage
Torr	L. torridus, hot and dry	Torric moisture regime
Ud	L. udus, humid	Udic moisture regime
Umbr	L. umbra, shade	Presence of umbric epipoedon
Ust	L. ustus, burnt	Ustic moisture regime
Vitr	L. vitrum, glass	Presence of glassy or vitric material
Xer	Gr. xeros, dry	Xeric moisture regime

*plaggen = sod = upper layer of grassland including grass with its roots and earth

GREATGROUP

The name of a greatgroup consists of a name of a suborder and a *prefix* that consists of one or two formative elements suggesting something of the diagnostic properties of the soil. Thus its name is of three or four syllables and ends with the name of the suborder. For example *Cryo*fluv*ent*, *Sombri*per*ox*. Table 3 gives the formative elements used for names of greatgroups.

Table 3. Formative elements used in the names of greatgroups (derived from Table 10, p.89, Soil Taxonomy)

Formative element	Derivation	Connotation
Acr	Gr. Akros, at the end	Extreme weathering
Agr	L. ager, field	Presence of an agric horizon
Alb	L. albus, white	Presence of an albic horizon
And	J. an, dark; do, soil	Soils rich in volcanic material with dark surface soil
Arg	L. argilla, white clay	Presence of argillic horizon
Bor	Gr. boreas, northern	Cool
Calc	L. calcis, lime	Presence of calcic horizon
Camb	L. cambiare, to change	Presence of cambic horizon
Chrom	Gr. chromos, colour	High chroma (bright colours)
Cry	Gr. kryos, icy cold	Cold
Dur	L. durus, hard	Presence of a duripan
Dystr	Gr. dys, ill, dystrophic, infertile	Low base saturation
Eutr	Gr.eu, good, eutrophic, fertile	High base saturation
Ferr	L. ferrum, iron	Presence of iron

Table 3. continued

Fluv	L. fluvius, river	Floodplain
Frag	L. fragilis, britle	Presence of a fragipan
Fragloss	Compound of fra(g) and gloss	See formative elements frag and gloss
Fulv	----------	Used to separate some Ãndisols
Gel	L. gelu, frost	Permafrost
Gibbs	Modified from gibbsite	Presence of gibbsite
Gyps	L. gypsum, gypsum	Presence of gypsic horizon
Gloss	L. glossa, tongue	Tongued
Hal	Gr. hals, salt	Salty
Hapl	Gr. haplous, simple	Minimum horizon
Hum	L. humus, earth	Presence of humus
Hydr	Gr. hydor, water	Presence of water
Luv	Gr. louo, to wash	Illuvial
Med	L. media, middle	Of temperate climate (mid-latitudes)
Melan	Gr. melas-anos, black	Presence of melanic epipedon
Nadur	Compound of na(tr) and dur	See formative elements natr and dur
Natr	L. natrium, sodium	Presence of a natric horizon
Ochr	Gr. ochros, pale	Presence of ochric epipedon
Pale	Gr. paleos, old	Excessive development
Pell	Gr. pellos, dusky	Low chroma (dark colours)
Plac	Gr. plax, flat stone	Presence of a thin pan
Plagg	Ger. plaggen, sod*	Presence of plaggen epipedon
Plinth	Gr. plinthos, brick	Presence of plinthite
Psamm	Gr. psammos, sand	Sandy texture
Quartz	Germ. quarz, quartz	High quartz content
Rhod	Gr. rhodon, rose	Dark red colour
Sal	L. sal, salt	Presence of salic horizon
Sider	Gr. sideros, iron	Presence of free iron oxides
Sombr	Fr. sombre, dark	Presence of dark horizon
Sphagn	Gr. sphagnos, bog	Presence of sphagnum
Sulf	L. sulfur, sulphur	Presence of sulphides or their oxidation products
Torr	L. torridus, hot and dry	Torric soil moisture regime
Trop	Gr. tropikos, tropical	Humid and continually warm
Ud	Ludus, humid	Udic soil moisture regime
Umbr	L. umbra, shade	Presence of umbric epipedon
Ust	L. ustus, burnt	Ustic soil moisture regime
Verm	Gr. vermos, worm	Wormy, or mixed by animals
Vitr	L. vitrum, glass	Presence of glassy or vitric material
Xer	Gr. xeros, dry	Xeric soil moisture regime

*sod = upper layer of grassland including the grass with its roots and earth

SUBGROUP

Subgroup consists of a name of greatgroup modified by one or more adjectives. Differernt types of subgroups are recognised:

1. Typic subgroups: The adjective *Typic* is used for subgroup that has typical properties (central concept) defining the greatgroup. For example *Typic Cryofluvent, Typic Torrifluvent.*

2. Intergrade subgroups: These belong to one greatgroup but have some properties of another order, suborder or greatgroup. They are named by using appropriate modifier in the form of adjectival names. Example: *Vertic Torrifluvents* have some of the properties of Vertisols superimposed on the complete set of diagnostic properties of Torrifluvents

3. Extragrade subgroups: These have important properties not representative of the greatgroup, but that do not indicate transition to any other known kind of soil. They are named by modifying the greatgroup name with an adjective that connotes something of the aberrant properties. For example *Lithic Hapluxerults* are Haploxerults that have a shallow lithic contact.

It is possible to have a subgroup with several modifiers arranged alphabetically e.g.

Cumulic Glossic Natraqualfs are Natraqualfs with thickened epipedon and tongued boundaries. Table 4 gives the adjectives used in the names of extragrades and their meaning.

Table 4. Adjectives in names of extragrades and their meaning (derived from Table 11, p.90, Soil Taxonomy)

Adjective	Derivation	Connotation
Abruptic	L. abruptum, torn off	Abrupt textural change
Anthropic	Gr. anthropos, man	Presence of an anthropic epipedon
Arenic	L.arena, sand	Sandy epipedon between 50 and 100 cm
Cumulic	L. cumulus. Heap	Thickened epipedon
Glossic	Gr. glossa, tongue	Tongued horizon boundaries
Grossarenic	L grossus, thick and L. arena, sand	Thick sandy epipedon >1 m thick
Hydric	Gr. hydor, water	Presence of water
Leptic	Gr. leptos, thin	A thin soil
Limnic	Gr. limn, lake	Presence of limnic layer
Lithic	Gr. lithos, stone	Presence of a shallow lithic contact
Pachic	Gr. pachys, thick	A thick epipedon
Paralithic	Gr. para, besides,and lithic	Presence of shallow paralithic (lithic-like) contact
Pergelic	L.per, throughout & L gelare to freeze	Permanently frozen, having permafrost
Petrocalcic	Gr. petra, rock & L. calcis, lime	Presence of petrocalcic horizon
Petroferric	Gr. petra, rock & L. ferrum, iron	Presence of petroferric horizon (ironstone)
Plinthic	Gr. plinthos, brick	Presence of plinthite
Ruptic	L. ruptum, broken	Broken horizons
Terric	L. terra, earth	A mineral substratum
Thapto	Gr. thapto, buried	Buried soil

FAMILY

The names at family level are polynomial consisting of the name of a subgroup and adjectives, generally three or more to indicate:

1. particle size class
2. mineralogy
3. calcareousness
4. reaction
5. depth
6. consistence
7. slope
8. temperature regime

For example, *coarse-loamy, mixed, acid, Typic Cryorthent, clayey over loamy, mixed, calcareous, hyperthermic, Vertic Torrifluvent.*

SERIES

Names of the series, as a rule are abstract place names. The name usually is taken from a place near the one where the series was first recognised. For example *Mgeta series, Morogoro series.*

Meaning of soil names

The name of a soil up to family level indicates its properties, as formative elements are indicative of properties. Hence it is possible to tell the properties of a soil by systematically breaking the soil name into its component formative elements.

DIAGNOSTIC HORIZONS AND FEATURES USED IN THE SOIL TAXONOMY

The US system of classification relies on the identification of diagnostic horizons and features in the surface and subsurface. Diagnostic horizons are soil horizons that represent a set of features used for soil identification. Since the characteristics of soil horizons are produced by soil forming processes, the use of diagnostic horizons for separating soils relates soil classification to general principles of soil genesis. Epipedons are simply the uppermost soil horizons. Epipedon is not synonymous with A horizon and may be thinner than the A horizon or may include some of the B horizons.

DIAGNOSTIC EPIPEDONS

Originally only 6 diagnostic epipedons were recognised in the Soil Taxonomy. In 1990, a new epipedon i.e. *melanic* was introduced to bring the number of diagnostic epipedons to 7. Their definitions are summarised below. The reader is referred to their full definitions in The Soil Taxonomy Handbook and the Keys to Soil Taxonomy (Soil Survey Staff, 1990).

1. MOLLIC EPIPEDON

This is a thick dark coloured surface horizon which meets the following requirements:
i. structure is sufficiently strong that the horizon is not both massive and hard or very hard when dry.
ii. has colours with a chroma of less than 3.5 when moist, and a value darker than 3.5 when moist and 5.5 when dry.
iii. base saturation (by IM NH_4 OAc at pH 7.0) is 50 percent or more.
iv. organic carbon content is at least 0.6 percent
v. thickness = or > 10 cm if resting directly on hard rock, or petrocalcic horizon, petrogypsic horizon, or duripan; where the solum < 75 cm thick, thickness of horizon = or > 18 cm and > 1/3 of the thickness of the solum; and where the solum = or > 75 cm thick must be more than 25 cm
vi. content of P_2O_5 soluble in 1 percent citric acid is less than 250 mg/kg soil.
vii. n value is < 0.7.
viii. horizon not naturally dry for > 3 months per year.

2. UMBRIC EPIPEDON

This horizon meets all the requirements of mollic epipedon in terms of colour, organic carbon and phosphorus content, consistence, structure and thickness except that it has a base saturation (by 1M NH_4OAc at pH 7.0) of less than 50 percent.

3. ANTHROPIC EPIPEDON

i. this is a man-made surface layer = or > 50 cm thick which has been produced by long continued fertilization particularly with phosphatic fertilizers.
ii. it commonly contains artifacts such as bits of bricks and pottery throughout its depth.
iii. meets all requirements of mollic epipedon except that the content of P_2O_5 soluble in 1 percent citric acid is 250 mg/kg soil or more.

4. HISTIC EPIPEDON

i. this is an organic horizon having its upper boundary within 40 cm of the surface and is > 20 cm but < 40 cm thick.
ii. it can be > 40 cm but < 60 cm thick if it consists of 75% or > by volume of sphagnum fibers or has a BD when moist of < 0.1 Mg/m^3.

iii. it has 18% or > OC if mineral fraction contains > 60% clay, or 8% or > OC if mineral fraction contains no clay, or intermediate contents of OC for intermediate contents of clay.
iv. it is water-saturated for 30 or > consecutive days per year.

5. PLAGGEN EPIPEDON
i. this is a man-made surface horizon that is 50 cm or > thick, created by many years of manure addition
ii. it commonly contains artifacts such as bits of bricks and pottery, spade marks etc. throughout its depth.

6. MELANIC EPIPEDON
i. this is a thick black horizon containing high concentration of OC.
ii. it has its upper boundary at or within 30 cm of the soil.
iii. has andic* properties.
iv. has moist colour value and chroma of 2 or <
v. has OC of 6% or >.

Andic properties:
a. Acid-oxalate extractable Al + ½ acid-oxalate extractable Fe = or >2.0 in fine earth fraction
b. BD of the fine earth = or < 0.9 g/cc
c. phosphate retention capacity of the fine earth = or > 85%

7. OCHRIC EPIPEDON
This is a surface horizon that is too light in colour, has too high a chroma, too little OC or is too thin to be mollic, anthropic, umbric, histic, plaggen or melanic, or that is both hard and massive when dry.

SUBSURFACE DIAGNOSTIC HORIZONS

1. ARGILLIC HORIZON
i. this is a B horizon that is clay-enriched i.e. contains more clay than the overlying eluvial horizon.The textural differentiation may be due to illuvial accumulation of clay or to destruction of clay in the surface horizon, or to selective surface erosion of clay, or to biological activity, or to a combination of two or more of these different processes.
ii. has texture that is sandy loam or finer and has at least 8 percent clay in the fine earth fraction.
iii. lacks the set of properties which characterize the oxic horizon.
iv. contains more total clay than an overlying coarser-textured horizon:
   a. if the overlying horizon has <15 % total clay in the fine earth fraction, the argillic horizon must contain at least 3% more clay.
   b. if the overlying horizon has 15 % or > but < 40 % total clay in the fine earth fraction, the ratio of clay in the horizon to that in the overlying horizon must be 1.2 or more.
   c. if the overlying horizon has 40 % or > total clay in the fine earth fraction, the argillic B-horizon must contain at least 8% more clay.
v. the argillic horizon must be at least one tenth of the thickness of the sum of all overlying horizons.
vi. presence of clay skins (cutans)

2. NATRIC HORIZON
i. this horizon meets all the requirements of the argillic horizon.
ii. moreover it has a prismatic or columnar structure and ESP = or > 15 % .

1. SPODIC HORIZON

i. this is subsurface horizon with illuvial accumulation of OM with Fe and /or Al.
ii. it has a subhorizon > 2.5 cm thick that is continuously cemented by some combinations of OM, Al, Fe
iii. there are many specific limitations dealing with Al, Fe, OM and clay ratios.
iv. its particle size class is sandy or coarse loamy

2. AGRIC HORIZON

i. this horizon is formed directly under the plow layer.
ii. it has illuvial clay, silt and humus accumulated in worm channels, root channels or ped surfaces as in-fillings or as thick, dark lamellae to the extent that they occupy at least 15% of the soil volume.
iii. the in-fillings or lamellae are always with colour values and chromas lower than those of the soil matrix.

5. CAMBIC HORIZON

i. this is an altered horizon lacking properties that meet the requirements of an argillic, natric or spodic horizon, having the following properties:
ii. has a texture of sandy loam or finer and has at least 8 % clay in the fine earth fraction.
iii. it is at least 15 thick.
iv. soil structure is only moderately developed
v. shows evidence of alteration in one of the following forms:
-stronger (=higher) chroma, redder hue, or higher clay content than the underlying horizon,
-evidence of removal of carbonates.

3. KANDIC HORIZON

i. this is a subsurface horizon enriched with clay just like the argillic horizon.
ii. it is rich in kandite group of clay minerals e.g. kaolinite.
iii. it has a CEC = 16 or < cmol(+)/kg clay or an effective cation exchange capacity ECEC) = 12 or < cmol(+)/kg clay (ECEC= sum of bases extracted with 1N NH_4OAc pH 7 + 1N KCl extractable Al).
iv. it is at least 30 cm thick.
v. it has a texture of loamy very fine sand or finer.
vi. it underlies a coarser textured surface horizon.
vii. clay skins may or may not be present.

7. OXIC HORIZON

This is a subsurface horizon that has the following properties:
i. has a texture that is sandy loam or finer and has at least 8 % clay in the fine earth fraction.
ii. it is at least 30 cm thick.
iii. it is highly weathered and dominated by 1:1 silicate clay minerals and sesquioxides.
iv. has a CEC of the fine earth fraction = or < 16 cmol(+)/kg clay, or has an effective cation exchange capacity (ECEC) of the fine earth fraction = or < 12 cmol(+)/kg clay.
v. has < 10 % weatherable minerals in the 50-200 μm fraction.
vi. has < 10 % water-dispersible clay
vii. has a silt-clay ratio which is = or < 0.2.
viii. has < 5 % by volume showing rock structure.

8. ALBIC HORIZON
i. this is typically an eluvial horizon, with certain colour limitations; colour values = 5 or > dry, or = 4 or > moist.
ii. it is generally white due to loss of clay, OM and free Fe oxides.
iii. it is normally underlain by a spodic, argillic or natric horizon.

9. FRAGIPAN
i. this is a subsoil layer of high bulk density, brittle when moist, and very hard when dry.
ii. it is very low in organic matter content.
iii. the texture is commonly loamy.

1. CALCIC HORIZON
i. this is a layer of secondary accumulations of carbonates, usually of Ca and Mg, having 15% or > $CaCO_3$ equivalent.
ii. it contains at least 5% more carbonate than an underlying layer.
iii. it is 15 cm or > thick.

2. GYPSIC HORIZON
i. this is a horizon of calcium sulphate (gypsum) enrichment.
ii. it contains at least 5% more calcium sulphate than underlying material.
iii. it is 15 cm or > thick.
iv. the product of thickness in cm and % gypsum = 150 or >.

12. PETROCALCIC HORIZON
i. this is an indurated calcic horizon.
ii. it has a hardness of 3 or > (Mohs' scale of hardness).
iii. at least half of it breaks in acid, but does not break in water.

13. PETROGYPSIC HORIZON
i. this is an indurated gypsic horizon.
ii. it is hard to the extent that dry fragments do not slake in water and roots cannot enter.

14. PLINTHITE
i. this is a sesquioxide-rich, humus-poor horizon which hardens irreversibly to ironstone hardpan or aggregates with repeated wetting and drying.
ii. it commonly occurs as dark red mottles.
iii. it generally forms in areas which are saturated with water at some season.

15. DURIPAN
i. this is a silica-cemented subsurface horizon.
ii. cementation is strong enough that dry fragments do not slake in water.
iii. has coatings of silica which are insoluble in 1N HCl even after prolonged soaking, but soluble in hot concentrated KOH.

16. SALIC HORIZON
i. this is a horizon of secondary accumulation of soluble salts (salts more soluble in cold water than gypsum).
ii. it is 15 cm or > thick.
iii. it contains at least 2% salt.
iv. the product of its thickness in cm and salt % by weight = 60 or >.

17. SOMBRIC HORIZON

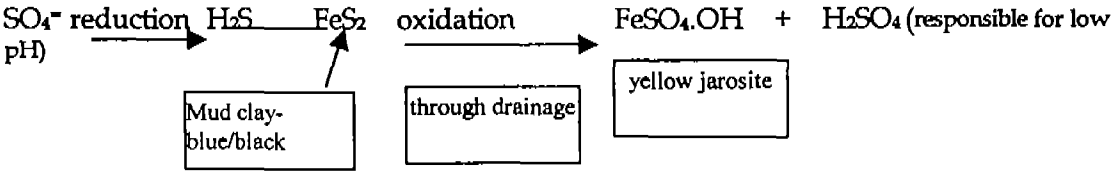
i. this is a subsurface horizon of mineral soils formed under free drainage.
ii. it contains illuvial humus that is neither associated with Al as the humus in the spodic horizon, nor dispersed by sodium as is common in the natric horizon.
iii. does not have the high CEC of a spodic horizon relative to clay, and does not have the high BS of a natric horizon.
iv. it does not underlie an albic horizon.

18. PLACIC HORIZON

i. this is a thin cemented pan.
ii. it is cemented by iron, or by iron and manganese, or by an iron-OM complex.
iii. it has black to dark reddish colour.
iv. its thickness generally ranges from 2 to 10 mm.
v. it is a barrier to water and roots.

19. SULFURIC HORIZON

i. this is a horizon composed either of mineral or organic material that has both a pH < 3.5 (ratio 1:1 in water) and jarosite mottles the colour of which has a hue of 2.5Y or yellower and chroma = 6 or >.
ii. it forms as a result of artificial drainage and oxidation of sulfide-rich mineral or organic material as shown below:



iii. the sulfuric acid so produced brings down the pH to values of less than 3.5, which makes the horizon highly toxic to plants and free of living roots. If $CaCO_3$ is present in the soil (or is added), this neutralises to some degree the H_2SO_4 so that the pH is not too acidic.

$H_2SO_4 + CaCO_3 \longrightarrow CaSO_4 + H_2CO_3$

OTHER DIAGNOSTIC SOIL CHARACTERISTICS

1. ABRUPT TEXTURAL CHANGE

i. this is a change from an ochric epipedon or an albic horizon to an argillic horizon.
ii. there is in the zone of contact, a very appreciable increase in clay content within a very short distance in depth as follows:
-if % clay in the ochric/albic horizon is < 20, then it should double in the argillic.
-if % clay in the ochric/albic horizon = 20 or >, the increase in clay content should be at least 20%, for example from 22 to 42%.

2. DURINODES

i. these are weakly cemented to indurated nodules whose main cement is SiO_2 presumably opal and microcrystalline forms of silica.
ii. it breaks down in hot concentrated KOH after treatment with HCl to remove carbonates, but it does not break down in hot concentrated HCl alone.

3. GILGAI

i. this is the microrelief that is typical of clayey soils that have a high coefficient of expansion with changes in moisture content and also have distinct seasonal changes in moisture content.

ii. the microrelief consists of a succession of enclosed microbasins and microknolls in nearly level areas, or of microvalleys and microridges that run up and down the slope.

iii. the height of the microridges commonly ranges from a few centimeters to 1 metre.

4. COEFFICIENT OF LINEAR EXTENSIBILITY (COLE)

i. this is ratio of the difference between the moist length and dry length of a clod* to its dry length.

ii. it can be presented as: COLE = (Lm – Ld)/Ld where Lm is the length at 1/3 bar tension, and Ld the length when dry.

iii. when COLE >0.09, significant swell-shrink activity can be expected; when COLE > 0.03, significant amount of montimorillonitic clay is expected.

*clod: is a compact, coherent mass of soil produced artificially by man through plowing or digging, especially when these operations are done on soils that are too wet or too dry for normal tillage operations.

5. POTENTIAL LINEAR EXTENSIBILITY

This characteristic is the sum of the products, for each horizon, of the thickness of the horizon in centimeters and the COLE of the horizon over a specified soil profile depth.

6. SLICKENSIDES

i. these are polished and grooved surfaces that are produced by one soil mass moving past another.

ii. slickesides are very common in soils rich in swelling clays.

7. n-VALUE

i. this refers to the relationship between the percentage of water under field conditions and the percentage of clay and humus.

ii. it can be presented as: n-value = (A -0.2R) / (L + 3H) where A is the % water in the soil under field conditions calculated on a dry soil basis; R is the % silt plus sand; L is the % clay and H is the % OM.

iii. the value is helpful in predicting whether the soil may be grazed by livestock or will support other loads, and the degree of subsidence that would occur after drainage.

iv.the critical value is n-value = 0.7; greater values imply problems (low/poor carrying capacity).

8. SOFT POWDERY LIME

i. soft powdery lime is used in the definition of a number of taxa.

ii. it refers to translocated lime, which is soft enough to be cut readily with fingernail, that was precipitated in place from soil solution rather than inherited from soil parent material.

9. LITHIC CONTACT

This is a boundary between soil and continuous coherent material, with a hardness = 3 or > (Mohs' scale).

10. PARALITHIC (lithic-like) CONTACT

This is a boundary between soil and continuous coherent material, with a hardness < 3 (Mohs' scale).

11. PERMAFROST
This is a continuously frozen layer.

12. LIMNIC MATERIALS
i. these are organic or inorganic materials deposited in water by the action of aquatic organisms or derived from underwater and floating organisms.
ii. marl (soft loose $CaCO_3$ usually mixed with clay and other impurities) and sedimentary peat are limnic materials.

13. PETROFERRIC CONTACT
This is a boundary between soil and a continuous layer of indurated material in which iron in an important cement and organic matter is absent or is present only in traces.

14. SOIL MOISTURE REGIMES
The soil moisture regime as the term is used here, refers to the presence or absence either of ground water or of water held at a tension < 1500 kPa in the soil or in specific horizons. Using climatic data on rainfall, it is possible to estimate the soil moisture regime (SMR). However, careful field and laboratory experimentation during different seasons may be necessary. The following classes of soil moisture regimes are recognised in the Soil Taxonomy:

(a) *Aquic SMR*: The soil must be partly or wholly saturated with water for at least some days during a year. This implies a reducing regime that is virtually free of dissolved oxygen.

(b) *Aridic* and *torric SMRs*: In most years the soil is dry in all parts more than half the time (cumulative) when the soil temperature at a depth of 50 cm is > 5°C; the soil is never moist in some or all parts for as long as 90 consecutive days when the soil temperature at a depth of 50 cm is above 8°C. Soils with aridic or torric SMR are normally found in arid climates. A few are in semi-arid climates. There is little or no leaching in these moisture regimes.

(c) *Udic SMR*: The soil is not dry in any part for as long as 90 cumulative days. Extreme wet regime is called *perudic*.

(d) *Ustic SMR*: This moisture regime is intermediate between the aridic and udic regime. It describes a condition of limited water, but soil water is present at a time when conditions are suitable for plant growth.

(e) *Xeric SMR*: This is typical of Mediterranean climates, where winters are moist and cool and summers are dry and warm. The soil is dry in all parts for 45 or more consecutive days within the 4 months that follow the *summer solstice (i.e. July, August, September, October). It is moist in all parts for 45 or more consecutive days within the 4 months that follow the *winter solstice (i.e. January, February, March, April).

Summer solstice: the time when the sun is farthest N of the Equator. This is on 21st June.
Winter solstice: the time when the sun is farthest S of the Equator. This is on 22nd December.

15. SOIL TEMPERATURE REGIMES
Soil temperature regimes are also used to classify soils. Mean atmospheric temperatures are obtained to estimate the soil temperature regime (STR). Mean annual air temperature, mean summer and mean winter temperatures have to be determined; and these are ultimately used to estimate the mean annual soil temperature (MAST). The following classes of soil temperature regimes are recognised in the Soil Taxonomy:

(a) *Pergelic STR*: (Meaning permanent frost). MAST < 0°C.

(b) *Cryic STR*: (Meaning very cold soils). MAST ≥ 0°C < 8°C.

(c) *Frigid STR*: The soil is warmer in summer than one in the cryic regime, but its MAST < 8°C.

(d) *Mesic STR*: The MAST =or> 8°C but < 15°C.

(e) *Thermic STR*: MAST =or> 15°C but < 22°C

(f) *Hyperthermic STR*: MAST =or> 22°C

If the name of a soil temperature regime has a prefix *"iso"* e.g. isomesic, isothermic etc. the mean summer and winter temperatures differ by < 5°C at a depth of 50 cm or at a lithic or paralithic contact, whichever is shallower.

16. WEATHERABLE MINERALS

Minerals that are included in the meaning of weatherable minerals are the following:
i. clay minerals: all 2:1 lattice clays except Al-interlayered chlorite. Sepiolite, talc and glauconite are also included in the meaning of this group of weatherable minerals, although they are not everywhere of clay size.

ii. Silt- and sand-size minerals (0.02 – 0.2 mm in diameter): feldspars, ferromagnesian minerals, micas and apatite are examples.

17. TONGUING OF ALBIC MATERIALS

Tongues of albic materials consist of penetrations of bleached material that has the colour of an albic horizon into an argillic horizon or a natric horizon, along ped surfaces if peds are present. The orientation of the tongues is vertical only.

18. INTERFINGERING OF ALBIC MATERIALS

Consist of penetrations of albic materials into underlying argillic horizon or a natric horizon, along ped faces, primarily in vertical sense but to a lesser degree along horizontal faces

DIAGNOSTIC FEATURES OF ORGANIC SOILS

The definitions of these features are based on the degree of decomposition of the organic material as measured by organic fibre content and colour of Na-pyrophosphate extracts. The fibre content decreases with increased degree of decomposition. The organic matter – Na-pyrophosphate extracts become darker with increased degree of decomposition.

On the basis of fibre content and colour of Na-pyrophosphate extracts, three types of organic materials are recognised:

i. FIBRIC MATERIALS

In rubbed condition, fibres compose ¾ or more of the soil volume, or the fibre content in a rubbed condition is 2/5 or more of soil volume and the material yields almost clear solution when extracted in Na-pyrophosphate. This situation represents least degree of decomposition. Fibric materials were formerly called peat.

ii. SAPRIC MATERIALS

In a rubbed condition, the fibre content is less than 1/6 of the soil volume and the material yields Na-pyrophosphate extracts with colours lower in value and higher in chroma than 10YR 7/3. They have the smallest amount of plant fibre, the highest BD and the lowest water content (on dry weight basis). Sapric materials were formerly called muck.

iii. HEMIC MATERIALS

These materials represent intermediate degree of decomposition between the less decomposed fibric stage and the more decomposed sapric stage. They have morphological features that give intermediate values between the fibric and sapric materials. Hemic materials were formerly called peaty muck or mucky peat.

SIMPLIFIED KEY TO SOIL ORDERS (USDA SOIL TAXONOMY)

1. Soils containing high OC content (at least 12% OC or 18% OC depending on clay content) and do not have andic properties in layers 35 cm or more thick within 60 cm from the surface

HISTOSOLS

2. Other soils developed in volcanic ejecta having a melanic epipedon; or having andic properties throughout subhorizons which have a cumulative thickness of 35 cm or more within 60 cm from the surface

ANDISOLS

3. Other soils that have either a spodic horizon whose upper boundary is within 200 cm from the surface or a placic horizon that meets all requirements of spodic horizon except thickness and index of accumulation of amorphous material

SPODOSOLS

4. Other soils that have an oxic horizon with its upper boundary within 150 cm from the soil surface and do not have properties characteristic of kandic horizon within a depth of 150 cm

OXISOLS

5. Other soils that do not have lithic or paralithic contact, petrocalcic horizon or duripan within 50 cm from the surface; having 30% clay or more in all subhorizons to a depth of 50 cm or more and having at some time in most years open cracks (at least 1 cm wide) at 50 cm that extend upward to the surface and having one or more of the following: gilgai microrelief, slickensides, or wedge-shaped aggregates

VERTISOLS

6. Other soils that are dry more than 50% of the year (aridic SMR) and have an ochric or an anthropic epipedon and either have salic horizon whose upper boundary is within 75 cm from the surface; or have one or more of the following horizons whose upper boundary is within 100 cm from the surface: calcic, petrocalcic, gypsic, petrogypsic, cambic or duripan

ARIDISOLS

7. Other soils that have a mesic, isomesic or warmer STR and have one of the following combinations of characteristics:

- have an argillic or kandic horizon but not a fragipan and have a BS by sum of cations (pH 8.2) of < 35%
- have a fragipan that meets all requirements of an argillic or kandic horizon and a BS by sum of cations (pH 8.2) of < 35%

ULTISOLS

8. Other soils that have a mollic epipedon or a surface horizon that meets all requirements of mollic except thickness, and have a BS (NH_4OAc pH 7.0) of 50% or more

MOLLISOLS

9. Other soils that have either an argillic, kandic or natric horizon but no fragipan or have fragipan that meets all requirements of argillic or kandic or has clay skins more than 1 mm thick in some part

ALFISOLS

10. Other soils that have no sulfidic materials within 50 cm from the surface, and have one or more of the following: an umbric, mollic or plaggen epipedon or a cambic horizon or SAR of 13 or more

INCEPTISOLS

11. Other soils that have either a permafrost within 100 cm of the soil surface ; or gelic materials within 100 cm of the soil surface and a permafrost within 200 cm of the soil surface

GELISOLS

Other soils

ENTISOLS

SUBORDERS OF THE USDA SOIL TAXONOMY

There are 56 suborders according to the USDA Soil Taxonomy. A brief description of the taxa is given below.

ORDER	SUBORDERS
Entisols	Aquents: with aquic soil moisture regime (SMR); permanently or seasonally wet and even if artificially drained, they display bluish gray (gleyed) or very motled horizons. Arents: exhibit fragments of diagnostic horizons below the Ap horizon due to deep plowing. Fluvents: alluvial soils with very simple profiles having irregular change of OM content with depth, and stratification is common. Psamments: have textures of loamy fine sand or coarser. Orthents: loamy and clayey Entisols with regular decrease in OM with depth.
Vertisols	Torrerts: with torric SMR; usually dry in all parts of the solum and the cracks are open the whole year to the surface in most years unless irrigated; or they are closed for less than 60 consecutive days. Usterts: with ustic SMR, the cracks open and close more than once a year but remain open for a total of 90 or more days a year. Xererts: with xeric SMR; the cracks open and close once a year and remain open for 60 or more consecutive days a year. Uderts: with udic SMR; usually moist, but cracks open at some time during the year but do not remain open for as long as 90 cumulative days.
Inceptisols	Aquepts: with aquic SMR; saturated with water at some period in the year unless artificially drained. Plaggepts: have plaggen epipedon. Tropepts: Inceptisols of the tropical regions. They have isomesic or warmer iso- temperature regime. Ochrepts: with ochric epipedon; or with umbric or mollic epipedon that is less than 25 cm thick and have mesic or warmer STR. Umbrepts: other Inceptisols.

MOLLISOLS

9. Other soils that have either an argillic, kandic or natric horizon but no fragipan or have fragipan that meets all requirements of argillic or kandic or has clay skins more than 1 mm thick in some part

ALFISOLS

10. Other soils that have no sulfidic materials within 50 cm from the surface, and have one or more of the following: an umbric, mollic or plaggen epipedon or a cambic horizon or SAR of 13 or more

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Aridisols

Argids: with argillic horizon.
Orthids: without argillic horizon.

Mollisols

Albolls: have albic horizon under the mollic; may have argillic or natric horizon.
Aquolls: with aquic SMR; show characteristics of wetness.
Borolls: have mean annual soil temperature (MAST) of less than 8°C.
Rendolls: have epipedons that are less than 50 cm thick and overly coarse fragments of calcareous rocks and stones.
Udolls: with udic SMR; not dry for as long as 90 cumulative day per year or 60 consecutive days per year.
Ustolls: with ustic SMR; are dry for more than 90 cumulative days per year, but not as long as 60 consecutive days per year.
Xerolls: with xeric SMR; are dry for more than 60 consecutive days per year in most years.

Spodosols

Aquods: with aquic SMR; commonly saturated with water, or if artificially drained, display evidences of former wetness.
Ferrods: have more than six times as much Fe as C in the spodic horizon.
Humods: have spodic horizon containing dispersed OM and Al but little Fe (less than 0.5% of the fine earth).
Orthods: have in the spodic horizon a content of Fe not more than six times that of C.

Alfisols

Aqualfs: with aquic SMR; are seasonally water saturated, or if artificially drained, display evidence of former wetness such as mottles, low chromas and Fe-Mn concretions.
Boralfs: are cool with MAST of less than 8°C (and commonly exhibit an albic horizon that tongues into the argillic or natric horizon).
Udalfs: have a udic SMR and mesic or warmer soil temperature regime (STR).
Ustalfs: have ustic SMR; are dry for less than 60 consecutive days per year, and commonly have a carbonate accumulation at the base of the solum.
Xeralfs: have xeric SMR; are dry for more than 60 consecutive days per year.

Ultisols

Aquults: with aquic SMR; are either saturated with water at some period of the year or are artificially drained and display evidence of former wetness as shown by presence of mottles, Fe-Mn concretions or low chromas.
Ustults: with ustic SMR; are dry for 90 or more cumulative days per year in most years.
Xerults: with xeric SMR; are in areas of prolonged dry season, MAST is less than 22°C. OM content is low and the soils are dry for 60 or more consecutive days per year.
Humults: have high OM content. By definition they contain more than 0.9% OC in the upper 15 cm of the argillic horizon or have over 12 kg of OM in a cubic metre of the upper 1 metre of the soil excluding an O horizon.
Udults: have udic SMR; are of humid regions where dry periods are of short duration; OM content is low.

Oxisols	Aquox: with aquic SMR; are either saturated with water during some period of the year, or are artificially drained and have an oxic horizon with characteristics associated with wetness. Torrox: with torric/aridic SMR. Ustox: have ustic SMR. Perox: have perudic SMR. Udox: other Oxisols (with udic SMR).
Histosols	Folists: with accumulation of organic soil materials mainly as forest liter. Fibrists: have fibric material dominant. Hemists: have hemic material dominant. Saprists: have sapric material dominant.
Andisols	Aquands: with aquic SMR Cryands: with cryic or pergelic STR. Torrands: with torric/aridic SMR. Xerands: with xeric SMR. Vitrands: dominated by vitric (glassy/amorphous) materials. Ustands: with ustic SMR. Udands: with udic SMR.
Gelisols	Histels: with large amounts of OC that accumulates under anaerobic conditions Turbels: with one or more horizons showing cryoturbation in the form of irregular, broken or distorted horizon boundaries Orthels: other Gelisols

THE FAO-UNESCO SOIL CLASSIFICATION SYSTEM

This system of classification was established to assist in the preparation of the Soil Map of the World at a scale of 1:5 000 000. The first version of the classification was published in 1974 and the revised edition was produced in 1988 (FAO, 1988). The two versions are slightly different in that some names of the old system have been dropped and some new ones have been introduced in the new version. The objectives of preparing the Soil Map of the World were to:

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

The FAO-Unesco classification system is basically a bi-categorical system i.e. with two levels of classification. The two levels are level-1 soil names, and level-2 soil names. Like in the USDA Soil Taxonomy, this system of classification makes use of diagnostic horizons and properties to give names to soils. Apparently most of the diagnostic features used in this system are derived from those of the USDA and have been modified and simplified to suit the purposes of the classification scheme. The salic, the sombric, and the agric horizons of the USDA Soil Taxonomy have not been used as diagnostic horizons. The duripan, fragipan and the placic horizon are used as phases. Most soil names end with *-sol(s)* and this is connected with formative elements which indicate some properties of the soils.

According to the revised edition of the legend of the Soil Map of the World (FAO, 1988) there are now 28 level-1 soil units and 153 level-2 soil units. Phases are also used in this classification to include features of the land which are significant to its use and management. Phases usually cut across soil boundaries and hence have not been used to define individual soil units. 16 phases are recognized in the FAO (1988) version.

SUMMARY OF DIAGNOSTIC HORIZONS (see FAO-UNESCO Classification Handbook and USDA Soil Taxonomy for full definitions)

DIAGNOSTIC HORIZONS	MOST PROMINENT FEATURES
histic H - horizon	peaty surface soil of 20 to 40 cm depth; in some cases till 60 cm.
mollic A - horizon	surface horizon with dark colour due to organic matter; base saturation = or >50%.
umbric A - horizon	similar to a mollic A - horizon but base saturation < 50%.
fimic A - horizon	man-made surface layer, 50 cm or more thick, produced by long-continued manuring.
ochric A - horizon	surface horizon without stratification and lacking the characteristics of a histic H - horizon, or a mollic, umbric or fimic A – horizon.
albic E - horizon	bleached eluviation horizon with the colour of

	uncoated primary soil material, usually overlying an illuviation horizon.
argic B - horizon	clay accumulation horizon lacking properties of a natric B - horizon and/or a ferralic B - horizon.
natric B - horizon	clay accumulation horizon with more than 15 percent exchangeable sodium, usually with a columnar or prismatic structure.
spodic B - horizon	horizon with illuviation of organic matter with iron or aluminium or with both.
ferralic B - horizon	highly weathered horizon, at least 30 cm thick, with a cation exchange capacity = or < 16 cmol(+)/kg clay.
cambic B - horizon	genetically young B - horizon (therefore not meeting the criteria for argic, natric, spodic or ferralic B - horizons) showing evidence of alteration: modified colour, removal of carbonates or presence of soil structure.
calcic horizon	horizon with distinct calcium carbonate enrichment.
gypsic horizon	horizon with distinct calcium sulphate enrichment.
petrocalcic horizon	a continuous cemented or indurated calcic horizon.
petrogypsic horizon	a gypsic horizon hardened to the extent that dry fragments do not slake in water and roots cannot enter.
sulfuric horizon	horizon of at least 15 cm thick, having jarosite mottles and pH(H_2O, 1: 1) < 3.5.

OTHER DIAGNOSTIC PROPERTIES AND FEATUTES (see FAO-UNESCO Classification Handbook and USDA Soil Taxonomy for full definitions)

DIAGNOSTIC PROPERTIES	MOST PROMINENT FEATURES
andic properties	refer to largely volcanic material; normally high in extractable aluminium.
ferralic properties	mark a cation exchange capacity (by 1M NH_40Ac at pH 7.0) of < 24 cmol(+)/kg clay in Cambisols and Arenosols.
ferric properties	mark the presence of Fe - enriched mottles or nodules in Alisols, Lixisols and Acrisols.
fluvic properties	mark ongoing sedimentation or stratification or an irregular organic carbon profile in recent alluvial deposits.
geric properties	mark soil materials having 1.5 cmol(+)/kg soil or < of extractable bases plus aluminium and a pH(1M KCl) = or > 5.0; or having a delta-pH (pH KC1 minus pH H_20) of +0.1 or more.
gleyic and stagnic properties	present visible evidence of prolonged waterlogging either by shallow groundwater (gleyic properties) or by a perched water table (stagnic properties).
nitic properties	mark a moderate to strong angular blocky elements, showing shiny ped faces.
salic properties	mark an electrical conductivity of the saturation extract of more than 15 dS/m, or of more than 4 dS/m if the pH (H_2O, 1:1) exceeds 8.5.

sodic properies	mark high saturation of the exchange complex by sodium (15 percent or more).
vertic properties	mark cracks, slickensides, wedge - shaped structural aggregates that are not in a combination, or are not sufficiently expressed for the soil to qualify as a Vertisol.
abrupt textural	mark a doubling of the clay content or an increase of the clay content by 20 percent, over a short distance in a soil profile.
calcareous	refers to soil material which shows strong effervescence in contact with HC1 and/or having more than 2 percent of $CaCO_3$ - equivalent.
continuous hard rock	material which is sufficiently coherent and hard when moist to make digging with a spade impracticable.
interfingering	narrow penetrations of an albic E - horizon into an underlying argic or natric B- horizon along mainly vertical ped faces and to some extent in horizontal direction.
gypsiferous	Refers to soil material which contains 5% or more gypsum.
organic soil materials	water-saturated soil materials (unless drained) having 18% or > organic carbon if having 60% or > clay, or having 12% or > organic carbon if without clay; or having a proportional carbon content if the clay content is between 0 and 60%percent; or soil materials that are never saturated for more than a few days having 20% or > organic carbon.
permafrost	the condition of soil temperatures being perennially at or below °C.
plinthite	an iron - rich, humus - poor mixture of clay and quartz that hardens irreversibly on drying.
slickensides	polished and grooved surfaces that are produced by one soil mass sliding past another.
smeary consistence	a consistence which changes under pressure and returns to the original state after the pressure is released ('thixotropic' materials in Andosols).
soft powdery lime	calcium carbonate which changes under precipitated in situ and soft enough to be cut with a finger nail.
strongly humic	refers to soil materials having more than 1.4 % organic carbon as a weighted average over a depth of 100 cm from the surface.
sulfidic materials	waterlogged mineral or organic soil material containing 0.75% or > sulfur and less than three times as much carbonates as sulfur.
tonguing	relatively wide penetrations of an albic E - horizon into an underlying argic or natric B - horizon along vertical ped faces.
Weatherable minerals	minerals that release plant nutrients and iron or aluminium by weathering

FORMATIVE ELEMENTS USED FOR NAMING MAJOR SOIL GROUPINGS (LEVEL-1)

There are 28 level-1 soil names:

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

ALISOLS: from L. *alumen*; connotative of soils with high aluminum content.

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

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

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

CALCISOLS: from L. *calcis,* lime; connotative of soils with accumulation of calcium carbonate.

CAMBISOLS: from L. *cambiare,* to change; connotative of soils showing some pedogenic development as evidenced from changes in colour, structure and consistence.

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

FERRALSOLS: from L. *ferrum,* iron, *alumen,* aluminium; connotative of soils rich in sesquioxides.

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

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

GREYZEMS: from English *grey,* and Russian *zemlja,* earth; connotative of soils with with uncoated silt and quartz grains which are present in layers rich in organic matter.

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

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

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

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

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

LUVISOLS: from L. *luere,* to wash; connotative of soils with accumulation of clay.

NITISOLS: from L. *nitidus,* shiny; connotative of soils with shiny peds faces.

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

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

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

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

PODZOLUVISOLS: from Podzols and Luvisols.

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

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

SOLONETZ: from Russian *sol,* salt, and *etz,* strongly expressed; connotative of salty soils (with high exchangeable sodium percent).

VERTISOLS: from L. *vertere,* to turn; connotative of soils with swelling clays in which there is turnover of surface materials.

SIMPLIFIED KEY TO THE MAJOR SOIL GROUPINGS (FAO-UNESCO

Soils having an H-horizon, or an O-horizon of 40 cm or more (60 cm or more if the organic material consists mainly of sphagnum or moss or has a bulk density of less than 0.1 Mg/m^3); the thickness of the H- or O-horizon may be less if it rests on rocks or on fragmented material of which the interstices are filled with organic matter:

HISTOSOLS (HS)

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

ANTHROSOLS (AT)

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

LEPTOSOLS (LP)

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

VERTISOLS (VR)

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

FLUVISOLS (FL)

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

SOLONCHAKS (SC)

Other soils showing gleyic properties within 50 cm of the surface; having no diagnostic horizons other than an A-horizon, a histic H-horizon, a cambic B-horizon, a calcic or a gypsic horizon; lacking plinthite within 125 cm of the surface:

GLEYSOLS (GL)

Other soils showing andic properties to a depth of 35 cm or more from the surface and having a mollic or an umbric A-horizon possibly overlying a cambic B-horizon, or an ochric A-horizon and a cambic B-horizon; having no other diagnostic horizons:

ANDOSOLS (AN)

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

ARENOSOLS (AR)

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

REGOSOLS (RG)

Other soils having a spodic B-horizon:

PODZOLS (PZ)

Other soils having 25 percent or more plinthite by volume in a horizon which is at least 15 cm thick within 50 cm of the surface or within a depth of 125 cm if underlying an albic E-horizon:

PLINTHOSOLS (PT)

Other soils having a ferralic B-horizon:

FERRALSOLS (FR)

Other soils having an E-horizon showing stagnic properties at least in part of the horizon and abruptly overlying a slowly permeable horizon within 125 cm of the surface, exclusive of a natric or a spodic B-horizon:

PLANOSOLS (PL)

Other soils having a natric B-horizon:

SOLONETZ (SN)

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

GREYZEMS (GR)

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

CHERNOZEMS (CH)

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

KASTANOZEMS (KS)

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

PHAEOZEMS (PH)

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

PODZOLUVISOLS (PD)

Other soils having a gypsic or a petrogypsic horizon within 125 cm of the surface: having no diagnostic horizons other than an ochric A-horizon, a cambic B-horizon or an argic B-horizon invaded by gypsum or calcium carbonate, a calcic or a petrocalcic horizon:

GYPSISOLS (GY)

Other soils having a calcic or a pertrocalcic horizon, or a concentration of soft powdery lime, within 125 cm of the surface; having no diagnostic horizons other than an ochric A-horizon, a cambic B-horizon or an argic B-horizon invaded by calcium carbonate:

CALCISOLS (CL)

Other soils having an argic B-horizon with a clay distribution which does not show a relative decrease from its maximum of more than 20 percent within 150 cm of the surface; showing gradual to diffuse horizon boundaries between A- and B- horizons; having nitic properties in some subhorizon within 125 cm of the surface:

NITISOLS (NT)

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

ALISOLS (AL)

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

ACRISOLS (AC)

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

LUVISOLS (LV)

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

LIXISOLS (LX)

Other soils with cambic B-horizon

CAMBISOLS (CM)

FORMATIVE ELEMENTS USED FOR NAMING LEVEL 2 SOIL UNITS

ALBIC:	from L. albus, white, connotative of strong bleaching.
ANDIC:	from Japanese an, dark and do, soil; connotative of Andosols.
ARIC:	from L, arare, to plough; connotative of plough layer.
CALCARIC:	from L. calcarius, calcareous; connotative of the presence of calcareous material.
CALCIC:	from L. calcis, lime, connotative of accumulation of calcium carbonate
CAMBIC:	from L. cambiare, to change; connotative of change in colour, structure or consistence.
CARBIC:	from L, carbo, charcoal; connotative of high organic carbon content in spodic B horizons.
CHROMIC:	from Gr. chromos, colour, connotative of soils with bright colours.
CUMULIC:	from L. cumulare, to accumulate; connotative of accumulation of sediments.
DYSTRIC:	from Gr. dys, ill, dystrophic, infertile; connotative of low base saturation.
EUTRIC:	from Gr. eu, good, eutrophic, fertile; connotative of high base saturation.
FERRALIC:	from L. ferrum and alumen; connotative of a high content of sesquioxides.
FERRIC:	from L. ferrum, iron; connotative of ferruginous mottling or an accumulation of iron
FIBRIC:	from L. fibra, fibre; connotative of weakly decomposed organic material.
FIMIC:	from L. fimum, manure, slurry, mud; connotative of a horizon formed by long continued manuring.
FOLIC:	from L. folium, leaf; connotative of undecomposed organic material.
GELIC:	from L. gelu, frost; connotative of permafrost.
GERIC:	from Gr. geraios, old; connotative of strong weathering
GLEYIC	from Russian local name gley, mucky soil mass.
GLOSSIC:	from Gr. glossa, tongue; connotative of tonguing of a horizon into the underlying layers.
GYPSIC:	from L. gypsum; connotative of an accumulation of gypsum
HAPLIC:	from Gr. haplos, simple; connotative of soils with a simple, normal horizon sequence.
HUMIC:	from L. humus, earth; rich in organic matter.
LITHIC:	from Gr. lithos, rock; connotative of very thin soils.
LUVIC:	from L. luere, to wash, 'lessiver', connotative of accumulation of clay.
MOLLIC:	from L. mollis, soft; connotative of good surface structure.
PETRIC:	from L, petra, stone; connotative of the presence of an indurated layer at shallow depth.
PLINTHIC:	from Gr. plinthos, brick; connotative of mottled clay materials which harden irreversibly upon exposure.
RENDZIC	from Polish colloquial rzedzic, connotative of noise made by plough over shallow stony soil.
RHODIC:	from Gr. rhodon, rose; connotative of red coloured soils.
SALIC:	from L. sal, salt; connotative of high salinity.
SODIC:	from L. sodium connotative of high content of exchangeable sodium.
STAGNIC:	from L. stagnare, to flood; connotative of surface waterlogging.
TERRIC:	from L. terra, earth; connotative of well decomposed and humified organic materials.
THIONIC:	from Gr. theion, sulfur, denoting the presence of sulfidic materials.
UMBRIC:	from L. umbra, shade; denoting the presence of an umbric A horizon.
URBIC:	from L. urbis, town; connotative of disposal of wastes.
VERTIC:	from L. vertere, to turn; connotative of turnover over of surface soil.
VITRIC:	from L. vitrum, glass; connotative of soils rich in vitric material.
XANTHIC:	from Gr. xanthos, yellow; connotative of yellow coloured soils.

SUMMARY OF LEVEL-1 AND LEVEL-2 SOIL UNITS

1. Histosols
Gelic
Thionic
Folic
Fibric
Terric

2. Anthrosols
Aric
Fimic
Cumulic
Urbic

3. Leptosols
Lithic
Gelic
Rendzic
Mollic
Umbric
Dystric
Eutric

4. Vertisols
Gypsic
Calcic
Dystric
Eutric

5. Fluvisols
Thionic
Mollic
Calcaric
Umbric
Dystric
Salic
Eutric

6. Solonchaks
Gelic
Gleyic
Mollic
Gypsic
Calcic
Sodic
Haplic

7. Gleysols
Gelic
Thionic
Andic
Mollic
Umbric
Calcic
Dystric
Eutric

8. Andosols
Gelic
Gleyic
Vitric
Mollic
Umbric
Haplic

9. Arenosols
Gleyic
Albic
Calcaric
Luvic
Ferralic
Cambic
Haplic

10. Regosols
Gelic
Umbric
Gypsic
Calcaric
Dystric
Eutric

11. Podzols
Gelic
Gleyic
Carbic
Ferric
Cambic
Haplic

12. Plinthosols
Albic
Humic
Dystric
Eutric

13. Ferralsols
Plinthic
Geric
Humic
Rhodic
Xanthic
Haplic

14. Planosols
Gelic
Mollic
Umbric
Dystric
Eutric

15. Solonetz
Gleyic
Stagnic
Mollic
Gypsic
Calcic
Haplic

16. Greyzems
Gleyic
Haplic

17. Chernozems
Gleyic
Luvic
Glossic
Calcic
Haplic

18. Kastanozems
Gypsic
Luvic
Calcic
Haplic

19. Phaeozems
Gleyic
Stagnic
Luvic
Calcaric
Haplic

20. Podzoluvisols
Gelic
Gleyic
Stagnic
Dystric
Eutric

21. Gypsisols
Petric
Calcic
Luvic
Haplic

22. Calcisols
Petric
Luvic
Haplic

23. Nitisols
Humic
Rhodic
Haplic

24. Alisols
Plinthic
Gleyic
Stagnic
Humic
Ferric
Haplic

25. Acrisols
Plinthic
Gleyic
Humic
Ferric
Haplic

26. Luvisols
Gleyic
Stagnic
Albic
Vertic
Calcic
Ferric
Chromic
Haplic

27. Lixisols
Plinthic
Gleyic
Stagnic
Albic
Ferric
Haplic

28. Cambisols
Gelic
Gleyic
Vertic
Humic
Calcaric
Ferralic
Dystric
Chromic
Eutric

PHASES

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

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

1. ANTHRAQUIC PHASE
   The anthraquic phase marks soils showing stagnic properties within 50 cm of the surface due to surface waterloggling associated with long continued irrigation, particularly of rice.

2. DURIPAN PHASE
   A duripan is a subsurface horizon that is cemented by silica so that dry fragments do not slake during prolonged soaking in water or in hydrochloric acid. The duripan phase marks soils in which the upper level of a duripan occurs within 100 cm of the surface. Duripans vary in the degree of cementation by silica and, in addition, they commonly contain accessory cements, mainly iron oxides and calcium carbonate, As a result, duripans vary in appearance but all of them have a very firm or extremely firm moist consistency, and they are always brittle even after prolonged wetting.

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

   A fragipan is low in organic matter, slowly or very slowly permeable and often shows bleached fracture planes that are faces of coarse or very coarse polyhedrons or prisms. clay skins may occur as patches or discontinuous streaks both on the faces and in the interiors of the prisms. A fragipan commonly, but not necessarily, underlines a B horizon. It may be form 15 to 200 cm thick with commonly an abrupt or clear upper boundary, while the lower boundary is mostly gradual or diffuse.

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

5. GILGAI PHASE

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

6. INUNDIC PHASE

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

7. LITHIC PHASE

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

8. PETROFERRIC PHASE

The petroferric phase refers to the occurrence of a continuous layer of indurated material, in which iron is an important cement and in which organic matter is absent, or present only in traces. The petroferric layer differs from a thin iron pan and from an indurated spodic B horizon in containing little or no organic matter. The petroferric phase marks soils in which the upper part of the indurated layer occurs within 100 cm of the surface.

9. PHREATIC PHASE

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

10. PLACIC PHASE

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

11. RUDIC PHASE

The rudic phase marks areas where the presence of gravel, stones, boulders or rock outcrops in the surface layers or at the surface makes the use of mechanized agricultural equipment impracticable. Hand tools can normally be used and also simple mechanical equipment if other conditions are particularly favourable. Fragments with a diameter up to 7.5 cm are considered as gravel; larger fragments are called stones or boulders.

12. SALIC PHASE

The salic phase marks soils which, in some horizons within 100 cm of the surface, show electric conductivity values of the saturation extract higher than 4 dS/m at 25°C. The salic phase is not shown for Solonchaks because their definition implies a high salt content. Salinity in a soil may show seasonal variations or may fluctuate as a result of irrigation practice. Though the salic phase indicates present or potential salinization, it should be realized that the effect of salinity varies greatly with the type of salts present, the permeability of the soil, the climatic conditions, and the kind of crops grown.

13. SKELETIC PHASE

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

14. SODIC PHASE

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

15. TAKYRIC PHASE

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

16. YERMIC PHASE

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

i. presence in the surface horizon of gravels or stones shaped by the wind.
ii. presence of 2 percent or more palygorskite in the clay fraction in at least some subhorizon within 50 cm of the surface.
iii. surface cracks filled with in-blown sand or silt.
iv. accumulation of blown sand on a stable surface.

HORIZON SEQUENCES FOR THE DIFERENT SOIL UNITS- LEVEL 1 (FAO UNESCO CLASSIFICATION SYSTEM)

Histosols: Mostly H or HCr profile
Anthrosols: Very variable; human influence mostly restricted to the surface horizon(s); a buried soil can still be intact at some depth.
Leptosols: Mostly A(B)R or A(B)C profiles. Leptosols in calcareous weathering material have commonly a mollic A-horizon with high degree of biological activity.
Vertisols: A(B)C profiles. Presence of deep wide cracks; slikensides and wedge-shaped aggregates present in the subsoil.
Fluvisols: AC profiles; a distinct Ah may be present. Lower horizons have stratification and have no or only a weak structure. Gley is common in the lower part of profile.
Solonchaks: Mostly AC or ABC profiles; salt accumulation.
Gleysols: Mostly A(Bg)Cr or H(Bg)Cr profiles. Evidence of reduction within 50 cm of the surface.
Andosols: AC or ABC profiles.
Arenosols: Mostly AC profiles. In dry areas, an ochric A-horizon is the only diagnostic horizon.
Regosols: AC profiles, with no other diagnostic horizons than an ochric or umbric A-horizon. Profile development is minimal.
Podzols: Mostly AhEBhsC profiles. The eluvial albic E-horizon is evidently bleached.
Plinthosols: Mostly ABC or AEBC profiles. The B could be qualified as Bsq.
Ferralsols: ABC profiles. Deep and intensive weathering evident in the ferralic B-horizon.
Planosols: Mostly AEBC profiles. Impeded downward movement of water is evident.
Solonetz: Mostly ABtnC profiles with a black or brown A-horizon over a natric B-horizon.
Greyzems: Mostly AhBtC profiles with mollic A-horizon over an argic B-horizon.
Chernozems: AhBC profiles with dark brown to black mollic A-horizon over a cambic or argic B-horizon.
Kastanozems: Mostly AhBC profiles with a brown Ah-horizon of medium depth over a brown cambic or argic B-horizon.
Phaeozems: Mostly AhBC profiles with a mollic A-horizon over a cambic or argic B-horizon.
Podzoluvisols: Mostly AEBtC profiles with a dark but thin ochric A-horizon over an albic E-horizon that tongues into a brown argic B-horizon.
Gypsisols: ABC profiles with a yellowish brown ochric A-horizon over a cambic or argic B-horizon. Accumulation of calcium sulphate is concentrated in and below the B-horizon.
Calcisols: ABC profiles with a pale brown ochric A-horizon over a cambic or argic B-horizon. Accumulation of carbonates at some depth below the surface.
Nitisols: ABtC profiles. Reddish brown clayey soils with a deeply developed clay illuviation horizon of high structural stability.
Alisols: Mostly ABtC profiles.
Acrisols: Mostly ABtC profiles.
Luvisols: Mostly ABtC profiles.
Lixisols: Mostly ABtC profiles.
Cambisols: ABwC profiles.

PRACTICAL EXERCISES ON SOIL CLASSIFICATION- USDA SOIL TAXONOMY

Name: .....

1. You are provided with both field morphological data and analytical data of a soil profile. Using the data make an inventory of the diagnostic horizons and features of the profile and tabulate the information as follows:

Diagnostic epipedons/ surface horizon(s)	Diagnostic subsurface horizon(s)	Any other diagnostic features/materials
USDA Soil Taxonomy	USDA Soil Taxonomy	USDA Soil Taxonomy

2. Classify the profile up to Family level (USDA Soil Taxonomy) and tabulate your results as follows:

USDA Soil Taxonomy (Soil Survey Staff, 1990)				
Order	*Suborder*	*Greatgroup*	*Subgroup*	*Family*

3. Comment on the potentials and constraints of the soil

Name: .....

Profile number : MIK-P1 Mapping unit: Agro-ecol. zone:
Region : Morogoro District : Morogoro
Map sheet no. : 183/2 & 4
Coordinates : 37° 56' 8.5" E / 6° 45' 33.8" S
Location : Mikese farm STR: isohyperthermic SMR: ustic
Elevation : m asl. Parent material: alluvio-colluvium derived from metamorphic rocks gneisses). Landform: in-filled valleys (depressions).
Slope: 2 %; concave Surface characteristics : Erosion: none or slight. Deposition: evident.Natural drainage class : well drained.Vegetation: Miombo savannah with *Brachystegia spp., Combretum sp., Acacia spp., Pterocarpus angolensis* etc. Land use: forest / woodland.
Described by B.M. Msanya and D.N. Kimaro on 28/11/98

Ah 0 - 18/33 cm: black (7.5YR2.5/1) moist; sandy clay loam; friable moist, slightly sticky and slightly plastic wet; moderate medium and coarse subangular blocks; many fine and very fine pores, few medium pores; few coarse and many fine roots; clear wavy boundary to

Bw 18/33 - 40/51 cm: dark brown (7.5YR3/2) moist; sandy clay loam; friable moist, sticky and plastic wet; weak fine and medium subangular blocks; many fine and very fine pores, few medium pores; frequent small spherical hard nodules; few coarse and fine roots; clear wavy boundary to

Ab 40/51 - 82/94 cm: very dark grey (7.5YR3/1) moist; sandy clay loam; friable moist, sticky and plastic wet; weak fine subangular blocks and medium subangular blocks; many fine and very fine pores, few medium pores; frequent small spherical hard nodules; fine and very few very fine roots; clear wavy boundary to

Bwb 82/94 - 150 cm: dark reddish brown (5YR3/2) moist; sandy clay; friable moist, sticky and plastic wet; moderate fine and medium subangular blocks; many fine and very fine pores, few medium pores; frequent small spherical hard nodules; few fine and very fine roots

Mineralogy: kaolinite (30%), smectite (40%); illite (20%), others (10%)

SOIL CLASSIFICATION:
USDA Soil Taxonomy:

ANALYTICAL DATA FOR PROFILE MIK-P1

Horizon	Ah	Bw	Ab	Bwb
Depth (cm)	0-18/33	18/33-40/51	40/51-82/94	82/94-150+
Clay %	25	29	32	42
Silt %	10	6	2	6
Sand %	65	65	66	52
Texture class	SCL	SCL	SCL	SC
pH H_2O 1:2.5	6.6	6.2	6.1	6.3
pH KCl 1:2.5	5.5	4.8	4.8	4.9
EC mS/cm	0.08	0.04	0.03	0.05
Organic C %	3.04	2.83	1.41	1.13
Total N %	0.24	0.19	0.17	0.16
C/N	13	15	8	7
Avail. P Bray mg/kg	5.46	1.03	0.70	0.32
CEC soil cmol(+)/kg	7.22	8.31	10.38	13.35
Ca cmol(+)/kg	2.9	5.0	4.3	6.5
Mg cmol(+)/kg	2.3	2.8	2.9	3.7
K cmol(+)/kg	1.10	0.30	0.19	0.13
Na cmol(+)/kg	0.05	0.05	0.08	0.11
TEB cmol(+)/kg	6.35	8.15	7.49	10.44
Base sat. %	88	98	72	78
ECe mS/cm	0.31	0.16	0.13	0.19
CEC clay cmol(+)/kg	28.9	28.7	32.3	31.8

Name: .....

Profile number : SUAP-1 Mapping unit: 24C1(ET) Agro-ecol. zone:
Region : Morogoro District : Morogoro
Map sheet no. : 183/3 Coordinates : 37° 38′ 50.3″ E/ 6° 50′ 34.4″ S
Location : SUA Botanical Garden, 450 west of Morogoro-Mzinga Road
Elevation : 630 m asl. Parent material: colluvium derived from mafic metamorphic rocks (hornblende pyroxene granulites) of the Uluguru mountains. Landform: plain; flat or almost flat. Slope: 0.5 %; straight Surface characteristics : Erosion: slight sheet erosion. Deposition: none. Natural drainage class : well drained
Described by B.M. Msanya and S. Maliondo on 13/07/98

Ah 0 - 16 cm: dark reddish brown (2.5YR3/4) dry, dark reddish brown (2.5YR3/3) moist; clay; slightly hard dry, friable moist, slightly sticky and slightly plastic wet; moderate fine subangular blocks; common coarse and few medium pores; many fine and few coarse roots; clear wavy boundary to
Bs1 16 - 40 cm: red (2.5YR4/8) dry, dark red (2.5YR3/6) moist; clay; slightly hard dry, very friable moist, slightly sticky and slightly plastic wet; weak fine and medium subangular blocks; common fine and many very fine pores; many fine and few coarse roots; few crotovinas present; gradual smooth boundary to
Bs2 40 - 75 cm: red (2.5YR4/8) dry, dark red (2.5YR3/6) moist; clay; soft dry, very friable moist, slightly sticky and slightly plastic wet; weak fine and medium subangular blocks; common medium and many very fine pores; few medium spherical soft nodules; common fine and few coarse roots; few crotovinas present; diffuse smooth boundary to
Bs3 75 - 130 cm: dark red (2.5YR3/6) moist; clay; very friable moist, slightly sticky and slightly plastic wet; weak fine subangular blocks; many very fine and few fine pores; frequent medium irregular soft nodules; few fine and coarse roots; diffuse smooth boundary to
Bs4 130 - 205 cm: dark red (2.5YR3/6) moist; clay; very friable moist, slightly sticky and slightly plastic wet; weak fine subangular blocks; many very fine and few fine pores; frequent medium irregular soft nodules; few fine roots

Mineralogy: kaolinite (95%)., sesquioxides (5%)

SOIL CLASSIFICATION:
USDA Soil Taxonomy:

ANALYTICAL DATA FOR PROFILE SUAP-1

Horizon	Ah	Bs1	Bs2	Bs3	Bs4	Composite
Depth (cm)	0 -16	16 - 40	40 - 75	75- 130	130 - 205	0 - 30
Clay %	58	62	64	65	62	52
Silt %	10	9	9	10	10	11
Sand %	32	29	27	25	28	37
Texture class	C	C	C	C	C	C
Silt/clay ratio	0.17	0.15	0.14	0.15	0.16	0.21
Bulk density g/cc	1.12	nd	1.13	1.22	nd	nd
pH H_2O	5.83	5.13	5.51	5.51	5.95	5.9
pH KCl	4.47	4.00	4.02	4.08	4.01	4.44
Organic C %	1.32	0.64	0.42	0.30	0.20	1.24
Total N %	0.10	0.05	0.04	0.06	0.03	0.11
C/N	13	13	11	5	7	11
Avail. P mg/kg	2.11	1.05	0.53	0.46	0.46	1.54
CEC NH_4OAc cmol(+)/kg	9.20	9.80	6.40	6.20	6.00	8.40
Exch. Ca cmol(+)/kg	2.23	0.61	0.61	0.32	0.51	1.99
Exch. Mg cmol(+)/kg	2.46	1.49	2.05	1.88	1.53	2.03
Exch. K cmol(+)/kg	0.46	0.29	0.16	0.14	0.14	0.40
Exch. Na cmol(+)/kg	0.28	0.26	0.21	0.19	0.19	0.30
TEB cmol(+)/kg	5.43	2.65	3.03	2.53	2.37	4.72
Base saturation %	59	27	47	41	40	56
CEC clay cmol(+)/kg	15.9	15.8	10	9.5	9.7	16.2

Name: .....

Profile number : SUA-P2 Mapping unit: 14B1(HT) Agro-ecol. zone:
Region : Morogoro District : Morogoro
Map sheet no. : 183/3 Coordinates : 37° 38' 35.5" E/ 6° 50' 58.9" S
Location : SUA- Magadu Farm, 300 m west of Morogoro-Mzinga Road
Elevation : 623 m asl. Parent material: colluvium derived from mafic metamorphic rocks (hornblende pyroxene granulites) of the Uluguru mountains. Landform: plain; very gently undulating. Slope: 2 %; straight Surface characteristics : Erosion: slight sheet erosion. Deposition: none.
Natural drainage class : well drained SMR: usticSTR: isohyperthermic
Described by S. Maliondo and B.M. Msanya on 27/07/98

Ah 0 - 16 cm: dark brown (7.5YR3/4) dry, very dark brown (7.5YR2.5/3) moist; clay; hard dry, firm moist, sticky and plastic wet; weak fine subangular blocks falling into moderate fine subangular blocks; common fine and few medium pores; common medium and many fine roots; abrupt wavy boundary to

Bt1 16 - 36 cm: strong brown (7.5YR4/6) dry, brown (7.5YR4/4) moist; clay; slightly hard dry, friable moist, sticky and plastic wet; moderate medium subangular blocks; patchy thin clay cutans; many fine and few medium pores; many fine and common medium roots; few ant nests present; clear smooth boundary to

Bt2 36 - 71 cm: strong brown (7.5YR5/6) dry, strong brown (7.5YR4/6) moist; clay; slightly hard dry, friable moist, sticky and plastic wet; moderate medium and fine subangular blocks; broken thin clay cutans; many fine and very fine pores; few small irregular slightly weathered quartz fragments; common fine and few medium roots; common ant nests present; clear smooth boundary to

Bt3 71 - 132 cm: strong brown (7.5YR5/6) dry, strong brown (7.5YR4/6) moist; clay; slightly hard dry, friable moist, sticky and plastic wet; moderate medium and fine subangular blocks; broken thin clay cutans; many very fine and few medium pores; few small irregular weathered quartz fragments; frequent medium irregular soft nodules; few fine roots; clear smooth boundary to

Bt4 132 - 192 cm: strong brown (7.5YR4/6) dry, brown (7.5YR4/4) moist; clay; slightly hard dry, friable moist, sticky and plastic wet; strong fine and medium angular blocks; broken thin clay cutans; many very fine and common medium pores; few small irregular weathered quartz fragments; frequent small spherical soft manganese nodules

Mineralogy: kaolinite (85%), illite (10%), goethite (5%)
SOIL CLASSIFICATION:

USDA Soil Taxonomy:

ANALYTICAL DATA FOR PROFILE SUAP-2

Horizon	Ah	Bt1	Bt2	Bt3	Bt4	Composite
Depth (cm)	0 - 16/18	16 - 36	36 - 71	71 - 132	132 - 192	0 - 30
Clay %	46	54	53	55	54	49
Silt %	15	12	12	13	13	12
Sand %	39	34	35	32	33	39
Texture class	C	C	C	C	C	C
Silt/clay ratio	0.32	0.22	0.23	0.24	0.24	0.24
Bulk density g/cc	1.53	nd	1.26	1.32	nd	nd
pH H_2O	6.78	5.99	6.36	5.92	6.50	6.72
pH KCl	4.97	4.49	4.86	4.81	5.02	5.08
Organic C %	1.30	1.06	0.44	0.30	0.20	1.20
Total N %	0.11	0.08	0.06	0.05	0.03	0.12
C/N	12	13	7	6	7	10
Avail. P mg/kg	1.42	1.12	0.53	0.38	0.53	1.89
CEC NH_4OAc cmol(+)/kg	11.40	10.00	10.20	10.31	12.52	11.00
Exch. Ca cmol(+)/kg	4.40	3.74	3.27	2.96	3.53	3.23
Exch. Mg cmol(+)/kg	1.56	1.44	1.95	1.82	2.45	1.65
Exch. K cmol(+)/kg	1.21	0.56	0.36	0.35	0.30	1.24
Exch. Na cmol(+)/kg	0.27	0.25	0.20	0.21	0.22	0.24
TEB cmol(+)/kg	7.44	5.99	5.78	5.34	6.50	6.36
Base saturation %	65.3	55.9	56.7	51.8	53.5	57.8
CEC clay cmol(+)/kg	24.8	18.5	19.2	18.7	22.5	22.4

PRACTICAL EXERCISES ON SOIL CLASSIFICATION- FAO-UNESCO SYSTEM

Name: .....

1. You are provided with both field morphological data and analytical data of a soil profile. Using the data make an inventory of the diagnostic horizons and features of the profile and tabulate the information as follows:

Diagnostic horizon(s)	Any other diagnostic features/materials
FAO-UNESCO Soil Classification (FAO, 1988)	FAO-UNESCO Soil Classification

2. Classify the profile up to level-2 soil unit name and tabulate your results as follows:

Level-1 soil name	*Level-2 soil name*	*Phase ?*

Name: .....

Profile number : MIK-P1 Mapping unit: Agro-ecol. zone:
Region : Morogoro District : Morogoro
Map sheet no. : 183/2 & 4
Coordinates : 37° 56' 8.5" E / 6° 45' 33.8" S
Location : Mikese farm STR: isohyperthermic SMR: ustic
Elevation : m asl. Parent material: alluvio-colluvium derived from metamorphic rocks gneisses). Landform: in-filled valleys (depressions).
Slope: 2 %; concave Surface characteristics : Erosion: none or slight. Deposition: evident.
Natural drainage class : well drained. Vegetation: Miombo savannah with *Brachystegia spp., Combretum sp., Acacia spp., Pterocarpus angolensis* etc. Land use: forest / woodland.
Described by B.M. Msanya and D.N. Kimaro on 28/11/98

Ah 0 - 18/33 cm: black (7.5YR2.5/1) moist; sandy clay loam; friable moist, slightly sticky and slightly plastic wet; moderate medium and coarse subangular blocks; many fine and very fine pores, few medium pores; few coarse and many fine roots; clear wavy boundary to

Bw 18/33 - 40/51 cm: dark brown (7.5YR3/2) moist; sandy clay loam; friable moist, sticky and plastic wet; weak fine and medium subangular blocks; many fine and very fine pores, few medium pores; frequent small spherical hard nodules; few coarse and fine roots; clear wavy boundary to

Ab 40/51 - 82/94 cm: very dark grey (7.5YR3/1) moist; sandy clay loam; friable moist, sticky and plastic wet; weak fine subangular blocks and medium subangular blocks; many fine and very fine pores, few medium pores; frequent small spherical hard nodules; fine and very few very fine roots; clear wavy boundary to

Bwb 82/94 - 150 cm: dark reddish brown (5YR3/2) moist; sandy clay; friable moist, sticky and plastic wet; moderate fine and medium subangular blocks; many fine and very fine pores, few medium pores; frequent small spherical hard nodules; few fine and very fine roots

Mineralogy: kaolinite (30%), smectite (40%); illite (20%), others (10%)

SOIL CLASSIFICATION:
USDA Soil Taxonomy:

ANALYTICAL DATA FOR PROFILE MIK-P1

Horizon	Ah	Bw	Ab	Bwb
Depth (cm)	0-18/33	18/33-40/51	40/51-82/94	82/94-150+
Clay %	25	29	32	42
Silt %	10	6	2	6
Sand %	65	65	66	52
Texture class	SCL	SCL	SCL	SC
pH H_2O 1:2.5	6.6	6.2	6.1	6.3
pH KCl 1:2.5	5.5	4.8	4.8	4.9
EC mS/cm	0.08	0.04	0.03	0.05
Organic C %	3.04	2.83	1.41	1.13
Total N %	0.24	0.19	0.17	0.16
C/N	13	15	8	7
Avail. P Bray mg/kg	5.46	1.03	0.70	0.32
CEC soil cmol(+)/kg	7.22	8.31	10.38	13.35
Ca cmol(+)/kg	2.9	5.0	4.3	6.5
Mg cmol(+)/kg	2.3	2.8	2.9	3.7
K cmol(+)/kg	1.10	0.30	0.19	0.13
Na cmol(+)/kg	0.05	0.05	0.08	0.11
TEB cmol(+)/kg	6.35	8.15	7.49	10.44
Base sat. %	88	98	72	78
ECe mS/cm	0.31	0.16	0.13	0.19
CEC clay cmol(+)/kg	28.9	28.7	32.3	31.8

Name: .....

Profile number : SUAP-1 Mapping unit: 24C1(ET) Agro-ecol. zone:
Region : Morogoro District : Morogoro
Map sheet no. : 183/3 Coordinates : 37° 38′ 50.3″ E/ 6° 50′ 34.4″ S
Location : SUA Botanical Garden, 450 west of Morogoro-Mzinga Road
Elevation : 630 m asl. Parent material: colluvium derived from mafic metamorphic rocks (hornblende pyroxene granulites) of the Uluguru mountains. Landform: plain; flat or almost flat. Slope: 0.5 %; straight Surface characteristics : Erosion: slight sheet erosion. Deposition: none. Natural drainage class : well drained
Described by B.M. Msanya and S. Maliondo on 13/07/98

Ah 0 - 16 cm: dark reddish brown (2.5YR3/4) dry, dark reddish brown (2.5YR3/3) moist; clay; slightly hard dry, friable moist, slightly sticky and slightly plastic wet; moderate fine subangular blocks; common coarse and few medium pores; many fine and few coarse roots; clear wavy boundary to
Bs1 16 - 40 cm: red (2.5YR4/8) dry, dark red (2.5YR3/6) moist; clay; slightly hard dry, very friable moist, slightly sticky and slightly plastic wet; weak fine and medium subangular blocks; common fine and many very fine pores; many fine and few coarse roots; few crotovinas present; gradual smooth boundary to
Bs2 40 - 75 cm: red (2.5YR4/8) dry, dark red (2.5YR3/6) moist; clay; soft dry, very friable moist, slightly sticky and slightly plastic wet; weak fine and medium subangular blocks; common medium and many very fine pores; few medium spherical soft nodules; common fine and few coarse roots; few crotovinas present; diffuse smooth boundary to
Bs3 75 - 130 cm: dark red (2.5YR3/6) moist; clay; very friable moist, slightly sticky and slightly plastic wet; weak fine subangular blocks; many very fine and few fine pores; frequent medium irregular soft nodules; few fine and coarse roots; diffuse smooth boundary to
Bs4 130 - 205 cm: dark red (2.5YR3/6) moist; clay; very friable moist, slightly sticky and slightly plastic wet; weak fine subangular blocks; many very fine and few fine pores; frequent medium irregular soft nodules; few fine roots

Mineralogy: kaolinite (95%)., sesquioxides (5%)

SOIL CLASSIFICATION:
USDA Soil Taxonomy:

ANALYTICAL DATA FOR PROFILE SUAP-1

Horizon	Ah	Bs1	Bs2	Bs3	Bs4	Composite
Depth (cm)	0 -16	16 - 40	40 - 75	75- 130	130 - 205	0 - 30
Clay %	58	62	64	65	62	52
Silt %	10	9	9	10	10	11
Sand %	32	29	27	25	28	37
Texture class	C	C	C	C	C	C
Silt/clay ratio	0.17	0.15	0.14	0.15	0.16	0.21
Bulk density g/cc	1.12	nd	1.13	1.22	nd	nd
pH H_2O	5.83	5.13	5.51	5.51	5.95	5.9
pH KCl	4.47	4.00	4.02	4.08	4.01	4.44
Organic C %	1.32	0.64	0.42	0.30	0.20	1.24
Total N %	0.10	0.05	0.04	0.06	0.03	0.11
C/N	13	13	11	5	7	11
Avail. P mg/kg	2.11	1.05	0.53	0.46	0.46	1.54
CEC NH_4OAc cmol(+)/kg	9.20	9.80	6.40	6.20	6.00	8.40
Exch. Ca cmol(+)/kg	2.23	0.61	0.61	0.32	0.51	1.99
Exch. Mg cmol(+)/kg	2.46	1.49	2.05	1.88	1.53	2.03
Exch. K cmol(+)/kg	0.46	0.29	0.16	0.14	0.14	0.40
Exch. Na cmol(+)/kg	0.28	0.26	0.21	0.19	0.19	0.30
TEB cmol(+)/kg	5.43	2.65	3.03	2.53	2.37	4.72
Base saturation %	59	27	47	41	40	56
CEC clay cmol(+)/kg	15.9	15.8	10	9.5	9.7	16.2

Name: .....

Profile number : SUA-P2 Mapping unit: 14B1(HT) Agro-ecol. zone:
Region : Morogoro District : Morogoro
Map sheet no. : 183/3 Coordinates : 37° 38′ 35.5″ E/ 6° 50′ 58.9″ S
Location : SUA- Magadu Farm, 300 m west of Morogoro-Mzinga Road
Elevation : 623 m asl. Parent material: colluvium derived from mafic metamorphic rocks (hornblende pyroxene granulites) of the Uluguru mountains. Landform: plain; very gently undulating. Slope: 2 %; straight Surface characteristics :
Erosion: slight sheet erosion. Deposition: none.
Natural drainage class : well drained SMR: ustic STR: isohyperthermic
Described by S. Maliondo and B.M. Msanya on 27/07/98

Ah 0 - 16 cm: dark brown (7.5YR3/4) dry, very dark brown (7.5YR2.5/3) moist; clay; hard dry, firm moist, sticky and plastic wet; weak fine subangular blocks falling into moderate fine subangular blocks; common fine and few medium pores; common medium and many fine roots; abrupt wavy boundary to

Bt1 16 - 36 cm: strong brown (7.5YR4/6) dry, brown (7.5YR4/4) moist; clay; slightly hard dry, friable moist, sticky and plastic wet; moderate medium subangular blocks; patchy thin clay cutans; many fine and few medium pores; many fine and common medium roots; few ant nests present; clear smooth boundary to

Bt2 36 - 71 cm: strong brown (7.5YR5/6) dry, strong brown (7.5YR4/6) moist; clay; slightly hard dry, friable moist, sticky and plastic wet; moderate medium and fine subangular blocks; broken thin clay cutans; many fine and very fine pores; few small irregular slightly weathered quartz fragments; common fine and few medium roots; common ant nests present; clear smooth boundary to

Bt3 71 - 132 cm: strong brown (7.5YR5/6) dry, strong brown (7.5YR4/6) moist; clay; slightly hard dry, friable moist, sticky and plastic wet; moderate medium and fine subangular blocks; broken thin clay cutans; many very fine and few medium pores; few small irregular weathered quartz fragments; frequent medium irregular soft nodules; few fine roots; clear smooth boundary to

Bt4 132 - 192 cm: strong brown (7.5YR4/6) dry, brown (7.5YR4/4) moist; clay; slightly hard dry, friable moist, sticky and plastic wet; strong fine and medium angular blocks; broken thin clay cutans; many very fine and common medium pores; few small irregular weathered quartz fragments; frequent small spherical soft manganese nodules

Mineralogy: kaolinite (85%), illite (10%), goethite (5%)
SOIL CLASSIFICATION: USDA Soil Taxonomy:

ANALYTICAL DATA FOR PROFILE SUAP-2

Horizon	Ah	Bt1	Bt2	Bt3	Bt4	Composite
Depth (cm)	0 - 16/18	16 - 36	36 - 71	71 - 132	132 - 192	0 - 30
Clay %	46	54	53	55	54	49
Silt %	15	12	12	13	13	12
Sand %	39	34	35	32	33	39
Texture class	C	C	C	C	C	C
Silt/clay ratio	0.32	0.22	0.23	0.24	0.24	0.24
Bulk density g/cc	1.53	nd	1.26	1.32	nd	nd
pH H_2O	6.78	5.99	6.36	5.92	6.50	6.72
pH KCl	4.97	4.49	4.86	4.81	5.02	5.08
Organic C %	1.30	1.06	0.44	0.30	0.20	1.20
Total N %	0.11	0.08	0.06	0.05	0.03	0.12
C/N	12	13	7	6	7	10
Avail. P mg/kg	1.42	1.12	0.53	0.38	0.53	1.89
CEC NH_4OAc cmol(+)/kg	11.40	10.00	10.20	10.31	12.52	11.00
Exch. Ca cmol(+)/kg	4.40	3.74	3.27	2.96	3.53	3.23
Exch. Mg cmol(+)/kg	1.56	1.44	1.95	1.82	2.45	1.65
Exch. K cmol(+)/kg	1.21	0.56	0.36	0.35	0.30	1.24
Exch. Na cmol(+)/kg	0.27	0.25	0.20	0.21	0.22	0.24
TEB cmol(+)/kg	7.44	5.99	5.78	5.34	6.50	6.36
Base saturation %	65.3	55.9	56.7	51.8	53.5	57.8
CEC clay cmol(+)/kg	24.8	18.5	19.2	18.7	22.5	22.4

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