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THE APPLICATION OF THE FAO/UNESCO TERMINOLOGY OF THE SOIL MAP OF THE WORLD LEGEND FOR SOIL CLASSIFICATION IN KENYA

by

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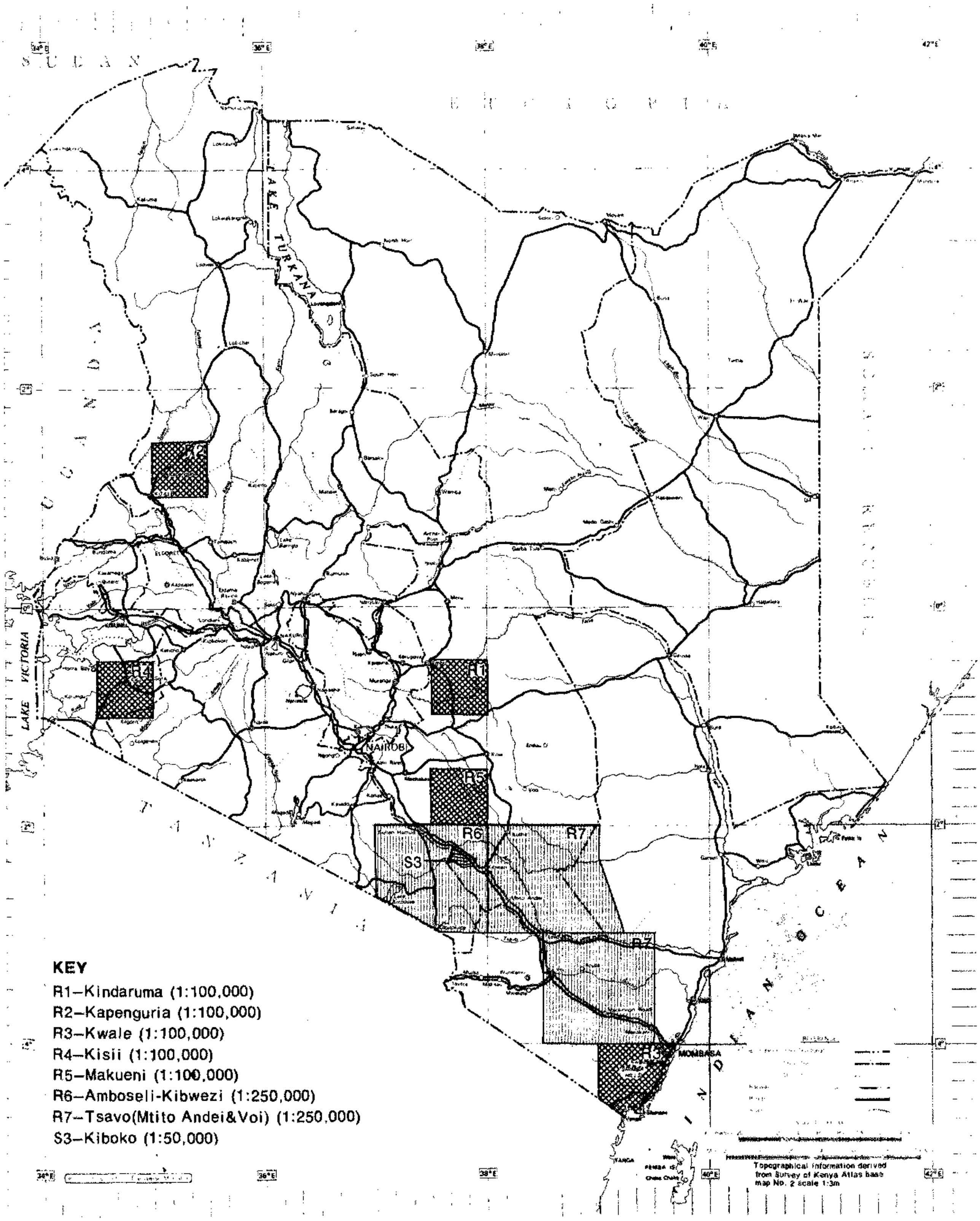
Table of Contents

Table of Contents cont'd

Fig. 1. Location of survey areas



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INTRODUCTION

Since its publication in 1974, the Kenya Soil Survey has used the FAO/Unesco Legend for the Soil Map of the World (scale 1:5,000,000) for soil classification and soil correlation purposes.

Initially this system was applied in Kenya to soil surveys carried out at reconnaissance levels (scale 1:100,000 - 1:250,000), but presently it is also used in other scales of mapping, viz. exploratory (scale 1:500,000 - 1:1,000,000) and (semi) detailed (scale larger than 1:50,000).

The FAO/Unesco Legend was designed to accommodate world soils in order to overcome gaps in national soil classification systems and to provide an internationally accepted basis for soil correlation.

Although the FAO/Unesco Legend is a monocategorical soil classification system (FAO. op.cit. p 10), commonly accepted principles of soil formation underly the system and are reflected in the nomenclature.

The identification of the soils is based on the recognition of diagnostic horizons and diagnostic properties, which are defined by measurable morphological and other criteria related to soil-forming processes.
Therefore the defined soils may not solely be regarded as members of a soil map legend but form the basis for soil classification in many (developing) countries.
It must be noted that most diagnostic concepts have been derived from the Soil Taxonomy (1975).

The original FAO/Unesco (1974) framework shows two levels of soil classification.

At the first level, which is broadly comparable to the "Great Group", 26 soils were defined, viz. FLUVISOLS, CAMBISOLS etc.
A further subdivision of the highest level led to the identification of 103 elements at the second level of classification, comparable to the "subgroup", viz. eutric FLUVISOLS, humic CAMBISOLS etc.
A third level was not recognized in the original Legend (FAO, op.cit.) however, this level was introduced during the preparation of the legend for the soil map of Europe at scale 1:1,000,000 (FAO, 1970).
At this level, which may be called "unit" level, the subgroups are further subdivided, e.g. ando-humic CAMBISOLS etc.

The use of the FAO/Unesco Legend terminology for soil surveys in Kenya has revealed the need for greater detail of the existing framework of classification (the location of the soil survey areas concerned is given in figure 1).
This has led to adaptations of the first and second level terminology, as well as the application of the "unit" (third level terminology).

.../2

The deviations from and the additions to the FAO/Unesco classification system as applied by the Kenya Soil Survey are known as the "Kenya Concept".

They may be summarized as follows:

- definition of a number of intergrades between Great Groups, viz. LUVISOLS and ACRISOLS intergrading to FERRALSOLS, and an adjusted LITHOSOL and NITOSOL concept (chapter 1),
- definition of a number of new subgroups at the second level of classification, viz. vertic Phaeozems, etc. and a narrower concept of some existing subgroups (chapter 2),
- definition of a number of units at the third level, e.g. calcaro-pellic VERTISOLS, etc. (chapter 3),
- remarks on the definition of some diagnostic properties (chapter 4),
- soil phases, particularly the introduction of some new soil phases are discussed (chapter 5),
- proposals for future adaptations of diagnostic horizons and properties are outlined in chapter 6.

A full list of the soil classification units recognised during soil reconnaissance soil surveys and one semi-detailed soil survey is given in Appendix 1.

1. FIRST LEVEL TERMINOLOGY ("GREAT GROUPS").

In the first reconnaissance soil survey carried out by the Kenya Soil Survey in the Kindaruma area (van de Weg and Mbuvi (eds.), 1975) many soils were encountered which did not satisfy the existing first level definitions.
These soils were usually intergrades [(1)] between two Great Groups, viz. LUVISOLS/ACRISOLS and FERRALSOLS.

Similar findings were reported from subsequent reconnaissance soil surveys (see Appendix 1 and references).
The nature of the intergrades between the LUVISOLS/ACRISOLS and the FERRALSOLS pertains to the concepts of the argillic B horizon and the oxic B horizon respectively.
Both diagnostic horizons are receiving attention in this respect through the recently created international commissions ICOMLAC and ICOMOX [(2)].

(1) according to the SSSA(1975) an intergrade is a soil that possesses moderately well distinguishing characteristics of two or more genetically related Great soil groups

(2) ICOMLAC-International Committee on the classification of Alfisols and Ultisols with low activity clays
ICOMOX -International Committee on the classification of Oxisols

No consensus has been reached as yet in these commissions on the parameters that define the diagnostic criteria for these horizons. It is anticipated however that their final proposals may eventually be incorporated in an updated FAO/Unesco "Legend".

1.1. Terminology for Intergrades

1.1.1. LUVISOLS intergrading to FERRALSOLS

These soils have a weakly expressed argillic B horizon with a base saturation of 50% or more (by NH_4OAc method at pH 7.0) at least in the lower part of the Bt horizon within 125 cm of the surface. In addition, they have a number of properties that point to FERRALSOL development.
The properties of these intergrades are listed below. Although a strict separation of the LUVISOL and FERRALSOL properties cannot be maintained because of their dual nature, those referring to the argillic B horizon are mentioned first, followed by those pertaining to the oxic B horizon.

argillic B mainly

- outspoken signs of an argillic B horizon are absent, viz. absence of any appreciable percentage of clay cutans
- the textural differentiation is gradual rather than clear, the clay ratio between B/A is between 1.2-1.6, unless the overall texture class is sandy clay
- clay increase is often masked by the presence of iron and/or organic compounds that cause incomplete dispersion of the soil material during textural analysis
- absence of angular blocky peds

oxic B mainly

- low percentage of weatherable minerals, just above 4%
- silt content is not very low, resulting in si/c ratios of more than 0.2
- structure stability is not very high, flocculation index(1) is between 60-80%
- silicate clay minerals are usually dominant in the clay fraction (kaolinite), but some illite (up to 10%) and some 2:1 clay minerals may be present, in addition to amorphous compounds

(1) flocculation index = 100 x (- $\frac{\text{dispersed clay}}{\text{total clay}}$)

.../4

- the CEC clay (by NH_4OAc method at pH 7.0) is usually between 20-30 me/100 g clay
- the total porosity is lower than in proper FERRALSOL, viz. expressed as bulk density 1.3 g/cm^3 Intergrades and 1.1 g/cm^3 for FERRALSOLS

general

- the consistence moist is friable to firm
- the topsoil is liable to sealing
- the structural-textural profile does not correspond very well with the chemical profile, viz. low CEC values may occur in moderately well developed argillic B horizons.

It is not clear which causes induced the development of these LUVISOLS towards FERRALSOLS. In most areas of their occurrence it is assumed that the rainfall has decreased substantially during the last centuries which may have slowed down or arrested the impoverishment of these LUVISOLS towards FERALSOLS.

The intergrades recognized so far are:

- FERRAL-ferric LUVISOLS (see remarks on "ferric" properties in chapter 4),
- FERRAL-chromic LUVISOLS (see remarks on "chromic" in chapter 2) and
- FERRAL-orthic LUVISOLS.

Their occurrence is indicated in table 1.

1.1.2. ACRISOLS intergrading to FERRALSOLS

These soils have also a weakly developed argillic B horizon, but the base saturation is less than 50% (by NH_4OAc method at pH 7.0) at least in the lower part of the Bt horizon within 125 cm of the surface.
The list of properties is similar as those outlined in chapter 1.1.1. for the LUVISOLS-FERRALSOLS intergrades (see page 3).
The main deviation is the CEC at pH 7.0 which varies usually between 16-24 me/100 g clay, in addition , the amount of weatherable minerals range between 4-7%.

It is assumed that these ACRISOLS were already more advanced on the way to FERRALSOL formation than the LUVISOL-FERRALSOL intergrades. This may be caused by poorer parent materials and/or favourable climatic conditions.

- the CEC clay (by NH_4OAc method at pH 7.0) is usually between 20-30 me/100 g clay[4]

- the total porosity is lower than in proper FERRALSOL, viz. expressed as bulk density 1.3 g/cm^3 Intergrades and 1.1 g/cm^3 for FERRALSOLS

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So far the following ACRISOLS intergrading to FERRALSOLS have been identified (see also table 1.) :

- FERRAL-humic ACRISOLS (see chapter 6 for remarks on "mollic")
- FERRAL-ferric ACRISOLS (see remarks on "ferric" properties in chapter 4)
- FERRAL-chromic ACRISOLS (see remarks on "chromic" properties in chapter 2)
- FERRAL-orthic ACRISOLS.

1.1.3. FERRALSOLS intergrading to ACRISOLS

These intergrades are "young" FERRALSOLS, that have some weakly formed properties which are usually diagnostic for ACRISOLS.
The oxic B horizon shows a clay increase but not enough to be diagnostic for a Bt, the CECclay at pH 7.0 is usually between 12-24 me/100 g clay, in addition the base saturation may be somewhat higher than is usually expected in FERRALSOLS.

In the list of properties given below an attempt is made to mention those properties concerning the oxic B horizon first, followed by those of the argillic B horizon.
Because of the ambiguous nature of the properties this division should not be adhered to rigorously.

oxic B mainly

- the oxic B horizon is 30 cm thick but not thicker than 100 cm
- the structure is not porous massive throughout but may show weakly developed peds
- the consistence is friable to very friable when moist
- the horizon has more than 15% clay, however the percentage silt is not low, e.g. the si/c ratio is more than 0.2
- the clay fraction does not exclusively consist of 1:1 lattice silicate clays, like kaolinite, but illite and some 2:1 lattice clay minerals may be present, in addition to amorphous compounds, therefore the SiO_2/R_2O_3 ratio is about 2
- the CECclay at pH 7.0 varies between 12-24 me/100 g clay
- the amount of weatherable minerals is about 4, but may be as high as 7%

argillic B

- the clay increase is not enough to be diagnostic for an argillic B
- the soil material is usually not compact and has a fairly high flocculation index
- the horizon boundaries are gradual rather than diffuse

general

- the physico-chemical activity of these soils is fairly low but not as low as in proper FERRALSOLS

These soils have reached the beginning of FERRALSOL formation and progressive weathering may ultimately lead to full FERRALSOL development.
The following intergrades have been distinguished so far (see table 1.):

- ACRI-rhodic FERRALSOLS
- ACRI-xanthic FERRALSOLS
- ACRI-orthic FERRALSOLS

1.1.4. Other Intergrades

These concern the VERTI- chromic LUVISOLS and the VERTI-eutric FLUVISOLS (see table 1).
The former intergrade is a chromic LUVISOL which has in addition vertic properties, the latter intergrade is an eutric FLUVISOL that has also vertic properties.
The applied combinations are not very satisfactory as the Great Groups concerned are not genetically related (see definition of intergrade on page 2).

A more appropriate solution would have been to introduce two new units at the third level, viz chromo-vertic LUVISOLS and verti-eutric FLUVISOLS (see also chapter 3).

Table 1. Occurrence of intergrades

survey area / intergrade	Kindaruma	Kapenguria	Kwale	Kisii	Makueni	Amboseli-Kibwezi	Tsavo	Kiboko
FERRAL-ferric LUVISOLS						x		
" -chromic "	x				x	x	x	
" -orthic "					x			
FERRAL- humic ACRISOLS		x		x				
" - ferric "	x							
" - chromic "	x	x	x		x			
" - orthic "		x	x					
ACRI- rhodic FERRALSOLS					x	x		x
" - xanthic "						x		
" - orthic "	x				x	x		x
VERTI- chromic LUVISOLS		x						
VERTI- eutric FLUVISOLS	x							

note: see references and App.1 for full details of the soil survey reports.

1.2. Redefinition of Great Groups

1.2.1. LITHOSOLS

By definition LITHOSOLS are soils which are limited in depth by continuous hard rock within 10 cm of the surface (FAO, 1974, p34). The depth limitation was found to be too narrow for Kenya conditions and has been set at 25 cm. Thus LITHOSOLS have coherent hard rock within 25 cm of the surface.
This adaptation was first applied in the Kindaruma area.

In addition, LITHOSOLS can be subdivided into calcaric, dystric and eutric subgroups if necessary (FAO, 1970).

1.2.2. NITOSOLS

The present definition of the NITOSOLS in the "Legend" does not mention the occurrence of the specific shiny ped surfaces in the B horizon, from which the name NITOSOL is derived.
The extensive occurrence of these soils in Kenya and their importance for agricultural production warrants however a further refinement of their definition to this effect.
Although the process that causes the development of these shiny ped surfaces is not fully understood, enough data are available to define a diagnostic "nitic-B" horizon (see chapter 6).
The proposal defines NITOSOLS as soils having a nitic B horizon.

2. SECOND LEVEL TERMINOLOGY ("SUBGROUPS")

In this category the main soil groups are further subdivided according to a number of properties which are directly relevant to soil behavior and plant growth.
An interpretative grouping of the FAO second level terminology is presented in table 2.

Table 2. Interpretative grouping of FAO 2nd level terminology

1. rooting impediment
   - gelic
   - plinthic
   - gleyic
   - albic
   - takyric
2. textural differentation
   - luvic
   - vertic
   - glossic
3. salts
   - gypsic
   - calcic
   - solodic
   - thionic
   - (calcaric)
4. humus content and type
   - mollic
   - humic
5. clay mineralogy
   - cambic
   - ferric
   - ferralic
   - acric
6. fertility
   - dystric
   - eutric
7. colour
   - pellic
   - rhodic
   - xanthic
   - chromic
8. other
   - ochric
   - orthic
   - haplic
   - vitric

Most of the subgroup notations have been applied without constraint to soil conditions in Kenya. However, in a number of cases new subgroups were defined, while the meaning of some terms has been altered slightly to make it more meaningful to soil occurrences in Kenya.

Table 3. Hierarchy of the existing FAO subgroup terminology and the position of the "Kenya Concepts"

sub-group \ great group	o -Histosols	i -Lithosols	v -Vertisols	j -Fluvisols	z -Solonchaks	g -Gleysols	t -Andosols	q -Arenosols	r -Regosols	u -Rankers	e -Rendzinas	f -Ferralsols	w -Planosols	s -Solonetz	m -Greyzems	c -Chernozems	k -Kastanozems	h -Phaeozems	x -Xerosols	y -Yermosols	n -Nitosols	a -Acrisols	l -Luvisols	b -Cambisols
gelic	gelic					gelic			gelic				gelic											gelic
plinthic						plinthic						plinthic										plinthic	plinthic	
gleyic					gleyic									gleyic	gleyic			gleyic				gleyic	gleyic	gleyic
albic								albic															albic	
takyric					takyric															takyric				
luvic								luvic								luvic	luvic	luvic	luvic	luvic				
vertic				vertic*		vertic*								vertic*				vertic*					vertic	vertic
glossic																glossic								
gypsic																			gypsic	gypsic				
calcic																calcic	calcic		calcic	calcic			calcic	calcic
solodic													solodic											
thionic				thionic																				
mollic					mollic	mollic	mollic						mollic	mollic							mollic*			
humic						humic	humic					humic	humic								humic	humic		humic
calcaric		calcaric		calcaric		calcaric			calcaric									calcaric						
cambic								cambic			cambic													
ferric																						ferric	ferric	
ferralic								ferralic																ferralic
acric												acric												
dystric	dystric	dystric		dystric		dystric			dystric				dystric								dystric			dystric
eutric	eutric	eutric		eutric		eutric			eutric				eutric								eutric			eutric
pellic			pellic																					
rhodic												rhodic												
xanthic												xanthic												
chromic			chromic																			chromic*	chromic	chromic
ochric							ochric																	
orthic					orthic						orthic	orthic		orthic	orthic							orthic	orthic	
haplic																haplic	haplic	haplic	haplic	haplic				
vitric							vitric																	

*"Kenya Concepts"

Drawing No. 80004

Table 3 shows the existing combinations of subgroup notations and Great Groups (including some as defined for the Soil Map of Europe) and the new combinations applied in Kenya ("Kenya Concepts"). The latter are defined below.

2.1. Definitions of new subgroups

The new subgroups identified and defined by the Kenya Soil Survey in the survey areas concerned are listed in table 4.(1)
From the six new subgroups four are "vertic" ones. In the FAO Legend the use of vertic subgroups is restricted to CAMBISOLS and LUVISOLS(2).
During soil investigations in Kenya it became evident however that other soils may have vertic properties as well, viz. FLUVISOLS, GLEYSOLS, SOLONETZ and PHAEOZEMS. Therefore the subgroup vertic was introduced for these soils.

vertic FLUVISOLS - these are FLUVISOLS which have vertic properties, they key out before the thionic FLUVISOLS (Table 3).

vertic GLEYSOLS - these are GLEYSOLS which have vertic properties, they key out immediately after the plinthic ones

cambic RENDZINAS(x) these are RENDZINAS that have less than 5% calcium carbonates in the surface horizons, the first proposal for this subgroup was made by the FAO (1970)

orthic RENDZINAS(x) these are "normal" RENDZINAS that do not meet the "cambic" criterion (FAO, 1970)

vertic SOLONETZ - these are SOLONETZ that have vertic properties, they key out immediately after the gleyic SOLONETZ

vertic PHAEOZEMS - these are PHAEOZEMS which have vertic properties, they key out after the luvic PHAEOZEMS

(1) the new subgroups used in the legend for the "Exploratory Soil Map of Kenya" at scale 1:1,000,000 (Sombroek, in prep.) are not included, but are given in Appendix 2, together with other new terminology used for this map.
(2) according to the FAO (loc.cit.1974,p31) a soil which has vertic properties shows at some period in most years cracks that are 1cm or more wide within 50cm of the upper boundary of the B horizon and extend to the surface or at least to the upper part of the B horizon.

(x) these are not strictly "Kenya Concepts" as they were already defined by the FAO (1970) mollic NITOSOLS - these are NITOSOLS that have a mollic A horizon

This definition is analogue to the one of the humic NITOSOLS (FAO, 1974, loc.cit. p51). The mollic NITOSOLS key out before the humic ones. The new subgroup was designed to accommodate those soils which have a mollic A horizon overlying a "nitic" B horizon.
According to the FAO/Unesco Legend these soils would be named "luvic PHAEOZEMS" on the presence of the mollic A, thereby disregarding completely the pronounced "nitic" B horizon.
To meet both the criteria for the mollic A as well as for the nitic B the mollic NITOSOLS bridge this gap in the existing classification satisfactorily.

chromic ACRISOLS - these are ACRISOLS with a red B horizon (e.g. moist colour of the rubbed soil has a hue of 5YR <u>and</u> a chroma of more than 4, <u>or</u> a hue redder than 5YR). The chromic subgroup keys out after the ferric one and before the orthic (see also chapter 2.2).

Table 4. Occurrence of new Subgroups

survey area / subgroup	Kindaruma	Kapenguria	Kwale	Kisii	Makueni	Amboseli-Kibwezi	Tsavo	Kiboko
vertic FLUVISOLS							x	x
vertic GLEYSOLS			x					
cambic RENDZINAS (x)			x					
orthic RENDZINAS (x)						x		
vertic SOLONETZ							x	
vertic PHAEOZEMS			x	x		x	x	
mollic NITOSOLS				x				
chromic ACRISOLS (xx)	x	x	x		x		x	

(xx): chromic ACRISOLS occur generally as intergrades, viz. FERRAL - chromic ACRISOLS, except in the Tsavo area, where chromic ACRISOLS s.s. were mapped

(x): these are not strictly "Kenya Concepts" as they were already defined by the FAO (1970)

2.2 "Kenya Concept" of existing subgroups

2.2.1 Chromic LUVISOLS and CAMBISOLS

These concern the chromic LUVISOLS and the chromic CAMBISOLS. In the FAO/Unesco Legend the term chromic refers to strong brown or red B horizons.

To differentiate between the brown and red CAMBISOLS and LUVISOLS as encountered in Kenya it was felt necessary to redefine the definition of red as follows: the rubbed moist soil has a hue of 5YR and a chroma of more than 4, or a hue redder than 5YR.

It is in this context that the chromic ACRISOLS were introduced (see chapter 2.1).

3. THIRD LEVEL TERMINOLOGY ("UNITS")

3.1 Deriviation of unit terminology

A number of terms for this category were proposed by the FAO (1970) with regard to elements for the Soil Map of Europe at scale 1:1,000,000 (table 5). Units may be distinguished when for example a luvic PHAEOZEM also has vertic properties. As the luvic subgroup keys out before the vertic one, the term vertic is used at unit level, e.g. verti-luvic PHAEOZEM.

Table 5. Origin of unit terminology

Unit	derived from	description (1)
ando	andic	low bulk density, presence of volcanic ash (ando like)
albo	albic	removal of clay and free iron oxides or light colour (albic horizon)
calcaro	calcaric	presence of carbonates (calcic horizon)
chromo	chromic	red colours (high chroma)
ferro	ferric	presence of coarse mottles and/or discrete iron nodules (presence of iron)
fluvo	fluvic	occurence in alluvial plains (flood plain)
histo	histic	high organic matter content and low base saturation (<50%), (tissue)
lepto	leptic	limited profile development (thin)
pachi	pachic	thick humic topsoil (thick)
plano	planic	occurrence on poorly drained plains (flat, level)
rhodo	rhodic	red colour and low CEC (dark red colour)
spodo	spodic	presence of organic matter and/or aluminium and iron as cementing agents or as coatings (spodic horizon)
stagno	stagnic	occurrence of perched groundwater table
vermi	vermic	fauna turbation (mixed by animals)
verti	vertic	cracking (turning)

(1) between brackets derivation according to Soil Taxonomy (1975).

In the FAO/Unesco Legend (1974) no unit level is recognized. However the necessity for this category became apparent during large scale surveys in Kenya. The unit terminology introduced in Kenya is summarized in table 6. Part of it was "borrowed" from the FAO publication (op.cit. 1970) .

The unit terminology for the "Exploratory Soil Map of Kenya" at scale 1:1,000,000 is not included but is given in Appendix 2.

Table 6. Units distinguished in Kenya

survey area / unit	Kapenguria	Kwale	Kisii	Makueni	Kiboko
andocumulic-(eutric) LITHOSOLS					x
calcaro-pellic VERTISOLS (x)		x		x	x
rhodacric FERRALSOLS		x			
andocumulic-rhodic FERRALSOLS					x
verto-luvic PHAEOZEMS (x)			x		
dystro-mollic NITOSOLS			x		
verti-gleyic LUVISOLS		x			
ferralo-humic CAMBISOLS			x		
cumulo-humic CAMBISOLS	x				

(x) Introduced by the FAO (1970)

Following the sequence of the FAO/Unesco key the following units are identified.

andocumulic -(eutric) LITHOSOLS

These soils were originally classified as andocumulic LITHOSOLS, without specifying the subgroup, which is eutric.
The term andocumulic was coined to reflect the thickened epipedon caused by a repetitive accumulation of small amounts of volcanic ash.

In analogy to the term cumulohumic, it is suggested to change the nomination andocumulic to cumuloandic.

calcaro-pellic VERTISOLS

These pellic VERTISOLS are also calcaric, viz. having a calcic horizon within 125 cm from the surface and/or are calcareous at least between 20-50 from the surface. (see also FAO, 1970).

rhodaceric FERRALSOLS

These soils occur in the Kwale area, where they were classified as transitions between the rhodic FERRALSOLS and acric FERRALSOLS. The acri-rhodic FERRALSOLS of the Kwale area would then be defined as rhodic FERRALSOLS having a cation exchange capacity (from NH_4Cl) of 1.5 me or less per 100 g clay in at least some part of the B horizon within 125 cm of the surface.

To conform to the standard third level terminology it is suggested to change the term rhodaceric to acri-rhodic.

andocumulic-rhodic FERRALSOLS

As suggested above, the term andocumulic should be changed to cumuloandic. The rhodic FERRALSOLS concerned have a thickened epipedon caused by the repetitive accumulation of volcanic ash. When the presence of volcanic ash is observed in the B horizon the term ando-rhodic may apply.

verto-luvic PHAEOZEMS

These soils are classified as luvic PHAEOZEMS which have in addition vertic properties and may be considered as transitions between the luvic and vertic PHAEOZEMS. (see also FAO, 1970). To conform to the derivation of the term vertic as suggested by the FAO (1970) verto should be changed to verti, thus verti-luvic PHAEOZEMS (see also table 5).

dystro-mollic NITOSOLS

Mollic NITOSOLS were defined in chapter 2.1. The unit terminology "dystro" indicates that these NITOSOLS have in some part of the B horizon within 125 cm of the surface a base saturation by NH_4OAc of less than 50%. The soils may be considered as transitional between the mollic NITOSOLS and the dystric NITOSOLS.

verti-gleyic LUVISOLS

These gleyic LUVISOLS have in addition vertic properties. They may be considered transitions between the gleyic and vertic LUVISOLS.

ferralo-humic CAMBISOLS

The soils of this unit have an umbric A horizon underlain by a cambic B horizon with ferralic properties (see note p 14). They can be considered transitions between humic and ferralic CAMBISOLS.

cumulo-humic CAMBISOLS

These soils are characterized by a very thick (more than 50cm) and very humic (more than 5% organic matter) topsoil.
The epipedons are thought to have been developed due to the cumulative enrichment of organic matter without the noticeable influence of volcanic ash.
To conform to already existing terminology (Soil Taxonomy, 1975) it is suggested to change the term cumulo to pachi, thus pachi-humic CAMBISOLS.

4. DIAGNOSTIC PROPERTIES

Most of the diagnostic properties as defined by the FAO (1974) have been used without change, apart from the ferric properties and weatherable minerals, whose concepts were slightly adapted.

Ferric properties

The original concept of ferric is used in connection with LUVISOLS and ACRISOLS, showing one or more of the following (FAO, op.cit. p28):

1) many coarse mottles with hues redder than 7.5YR or chromas more than 5, or both,
2) discrete nodules, up to 2 cm in diameter, the exteriors of the nodules being enriched and weakly cemented or indurated with iron and having redder hues or stronger chromas than the interior,
3) a cation exchange capacity (from NH_4Cl) of less than 24 me/100 g clay in at least a subhorizon of the argillic B horizon.

According to the "Kenya Concept" the term ferric is used exclusively for the features mentioned under "1" and "2", and does not embrace the CEC requirement.

The latter aspect is dealt with by using the term "ferralic" which in addition to CAMBISOLS and ARENOSOLS is also applied by the KSS to other Great Groups (see note).
The widening of the ferralic concept to other soils could have created situations which would conflict with the use of the term ferric (definition loc. cit.).
For this reason the CEC requirement has been waved from the definition of ferric properties in the Kenya Concept (see also Appendix 2).

Note: According to the FAO(1974, p28) the term "ferralic" properties is used in connection with CAMBISOLS and ARENOSOLS which have a cation exchange capacity (from NH_4Cl) of less than 24 me/100 g clay in, respectively, at least some subhorizon of the cambic B horizon or immediately underlying the A horizon.

Weatherable minerals

According to the FAO (op.cit.p34) weatherable minerals include clay minerals, especially 2:1 lattice clays and minerals from the sand and silt fractions (primary minerals).
In the Kenya concept muscovite is excluded from these minerals because of its resistance towards weathering, viz. it is only slightly less hard than quartz (see chapter 6 for further details).

5. SOIL PHASES

A soil phase is a subdivision of a soil type or other unit of classification having characteristics that affect the use and management of the soil but which do not vary sufficiently to differentiate it as a separate type (SSSA, 1975).
Soil phases are significant to the use and management of the land but are not diagnostic for the separation of soil units themselves (FAO, 1974,p5).
Most definitions as outlined by the FAO (loc.cit p5-7) can be applied satisfactorily. Changes and additions as used by the KSS are outlined in the following paragraphs. They concern the pisoferric, pisocalcic and paralithic phases of soils.

pisoferric phase

A "pisoferric" phase was introduced during the Kwale reconnaissance soil survey. It is mainly applicable to Ferralsols and is intended to replace partly the term petric (FAO,loc.cit.p6: the term petric is misleading as it conveys the idea of continuous layers of indurated material or rock (=petra).

The pisoferric phase is defined as follows: a soil which has a layer consisting of 40% or more by volume of discrete (loose) oxidic concretions (like hardened plinthite or ironstone), which is not continuously cemented and has a thickness of at least 25 cm, the upper part of which occurs within 100 cm of the soil surface. It allows roots to penetrate.

pisocalcic phase

During the semi-detailed soil survey of the Kiboko Research Station, the term "pisocalcic" was introduced. It was also used to describe a soil phase in the Tsavo area, although the phase designation was erroneously given as petric on the soil map.
A pisocalcic phase denotes a layer in the soil consisting of rounded, hard, discrete calcium carbonate accumulations, occupying 40% or more by volume and having a thickness of at least 25 cm, while the upper boundary occurs within 100 cm of the soil surface. The layer is penetrable by roots.

.../16

paralithic phase

The term paralithic phase was used to describe a soil phase in the Kisii and Tsavo reconnaissance soil survey areas.
In analogy to the Soil Taxonomy (loc.cit.p.49) it denotes the occurrence of weathered parent material, commonly partly consolidated (sedimentary) rock with a hardness of less than 3 by Mohr's scale, but with a high enough bulk density and/or consolidation to prevent roots from entering.

6. PROPOSALS FOR FUTURE ADAPTATIONS

A number of constraints encountered while applying the FAO terminology may be removed when a number of terms are reconsidered. It concerns the following diagnostic horizons: mollic A horizon and nitic B horizon, and also the following diagnostic properties: slickensides, vertic properties and weatherable minerals.
The definitions as outlined below are presently being tested by the Kenya Soil Survey, but have not been officially adopted.

6.1. Diagnostic horizons

6.1.1. mollic A horizon

The present definition embraces parameters such as : 1) soil structure and consistence, 2) soil colour, 3) base saturation percentage, 4) organic matter content, 5) thickness, and 6) content of soluble P_2O_5 (FAO, 1974,p24).
The application of this definition to soil conditions in Kenya has led to the classification of soils as PHAEOZEMS, GREYZEMS, mollic SOLONETZ etc. which do not have a relatively thick, dark coloured, humus rich surface horizon, in which bivalent cations are dominant on the exchange complex and the grade of structure is moderate to strong. In addition, the criterion for softness is not met (mollis=soft: Soil Taxonomy, 1975, p14).

The main constraints are formed by the present criteria for 1) the soil structure and consistence and 2) the percentage organic matter. The following amendments are proposed:

The structure of the mollic horizon shows at least a moderate grade in any size, while the consistence when dry is soft or slightly hard.

This will eliminate "mollic A" horizons that are both massive and hard. in addition, it is proposed to raise the required organic matter percentage to 2% or more, throughout the thickness of the mixed soil (=18cm), if no finely divided lime is encountered. The total organic matter content may be calculated as 2.28 x %C (Walkley-Black method). This means that a number of topsoils which just make the present requirements are disregarded and more justice is done to the original meaning of the mollic horizon.

.../17

6.1.2. nitic B horizon

According to the FAO(1974) the formerly called "Reddish-Brown Lateritic" soils have been made a separate great soil group, because:

1) they show a movement of clay within the profile but have diffuse horizon boundaries,
2) they have a deeply stretched clay bulge,
3) in general they show a low clay activity
4) they have favourable physical properties and have relatively high fertility.

These soils have been named Nitosols (nitidus=shiny, bright, lustreous: connotative of their characteristic shiny ped surfaces, FAO, loc.cit.p19).

However, in the present definition the occurrence of these shiny ped surfaces is not diagnostic. Although the process that causes the development of this phenomenom is not fully understood, the extensive occurrence of these soils in eastern Africa, and probably elsewhere, their importance for agricultural production warrant their separation upon a more refined definition.
On the basis of the available soil information mainly from Kenya (Sombroek and Siderius, 1977 and Sombroek and Muchena, 1978) the following concept for a nitic B horizon is proposed.
The nitic B horizon is an argillic horizon that has all of the following:

1) a high clay content (more than 40%) with moderate to low silt percentage (silt/clay ratio less than 0.35),
2) a gentle clay bulge (if any), no or only gradual increase in the clay percentage from the A to the B horizon (ratio less than 1.2) and no or only slight decrease from the B to the C (less than 20% clay within 150 cm from the surface),
3) moderately to strongly developed (very) fine to medium angular blocky structure (polyhedral),
4) many (more than 10% of the surface area) shiny ped paces, which can not or can only be partly ascribed to illuviation argillans,
5) friable when moist, but may be hard when dry,
6) high aggregate stability (practically no water dispersable clay in horizons with low organic matter content), structure index of more than 90.

In addition the solum of the Nitosols:

1) is well drained and extremely deep (more than 150 cm),
2) shows a gradual decrease in organic matter content down the profile.

In addition, the adjective "nitic" may be applied at unit level for those Phaeozems and Luvisols, or other soils, that show a gentle clay increase with depth and have the properties 1-6 as listed above, but do not fulfill the depth requirement (e.g. nito-luvic Phaeozems).

6.2. Diagnostic properties

6.2.1. Slickensides

The definition as given by the FAO (loc.cit.p30) has not changed. It is however proposed to introduce a size limitation to the slickenside concept e.g. they must be larger than 5 cm^2. All grooved and polished surfaces caused by stress in soil that have a surface area of 5 cm^2 or less may be called "pressure faces". They are usually bounding parallellopiped structural elements and normally occur in the upper part of the solum, while true slickensides are usually confined to the lower part of the soil.

6.2.2. vertic

The term vertic is derived from "verto" meaning "turn" and indicates the churning process dominating in true Vertisols. On subgroup and unit level however the term vertic is used to indicate that the soil material cracks only viz. "at some period in most years show cracks that are 1 cm or more wide within 50 cm of the upper boundary of the B horizon and extend to the surface or at least to the upper part of the B horizon" (FAO, loc.cit.p31).
It is misleading to use the term vertic in this context as there are many soils that may develop cracks upon drying and as such would satisfy this definition, however, the soil material does not turn in repeated cycles of wetting and drying.

It is therefore suggested to replace the term vertic with rimic (rima (Lat.) = fissure, crack). Rimic properties are not exclusively restricted to Cambisols and Luvisols, but may occur in other soils as well.

6.2.3. weatherable minerals

According to the FAO (loc.cit.p34) weatherable minerals include some clay minerals, especially 2:1 lattice clays, as well as some minerals of the sand and the silt fractions.

The property is used as one of the criteria to define the oxic B horizon viz, "which does not have more than traces of primary alumino-silicates such as feldspars, micas, glasses and ferromagnesian minerals" (FAO, loc.cit.p27, Soil Taxonomy, p39 and p64).

For practical purposes it is suggested to refer to primary weatherable minerals of the 50-250 micron sand fraction only. The amount is given as a percentage, conceived by counting 100 grains and allowing the following rating:

trace - not counted but seen in the mineral slide

very few: 1-4: few: 5-10: common: 11-20 and many: more than 20.

The minerals may be separated by means of bromoform (s.g.2.89) into light and heavy minerals.
Weatherable light primary sand minerals include: volcanic glass, anorthite, oligoclase and biotite.

Weatherable heavy primary sand minerals include: hornblende, augite, olivine and actinolite.

This list is by no means complete and indicates only some of the more common minerals. Detailed information is available in various handbooks.

Conclusions

The application of the FAO/Unesco (1974) legend as a framework for soil classification on a national level has proved its merits during soil surveys in Kenya and will continue to do so. However, as more data are gathered on larger scales of mapping, modifications to the present legend will be necessary to suit local conditions. Some of these constraints were foreseen, but could not be applied on a world scale, others were not anticipated and can stimulate international discussion to define appropriate terminology.

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ppendix 1: Adapted soil classification terminology for various survey areas in Kenya as shown on the map legends.

. Kindaruma (reconnaissance soil survey 1:100,000)

ap unit	classification
DUrc2m	FERRAL[x]-orthic ACRISOLS
3Urcl	FERRAL[x] - chromic LUVISOLS
3Urc2/BUrc2p	ACRI[x] - orthic FERRALSOLS
3Urc3/BUrc3p	FERRAL[x] - chromic [x] ACRISOLS
3Ubc1/BUrclp	FERRAL[x]-ferric ACRISOLS
AR1	VERTI[x] - eutric FLUVISOLS

2. Kapenguria (reconnaissance soil survey 1:100,000)

nap unit	classification
U2Gh2p	cumulo[x] - humic CAMBISOLS
U3GC1	FERRAL[x]- chromic ACRISOLS and FERRAL[x] - humic ACRISOLS
U3GC2	FERRAL[x] - orthic ACRISOLS and FERRAL[x] - humic ACRISOLS
YGbc1	VERTI[x] - chromic LUVISOLS

3. Kwale - Mombasa - Lungalunga (reconnaissance soil survey 1:100,000)

nap unit	classification
F1m	rhodic FERRALSOLS, partly pisoferric[x] phase
USmr	rhodacric[x] - FERRALSOLS
USs2	FERRAL[x] - chromic [x] ACRISOLS
USsC1	FERRAL[x] - orthic ACRISOLS
USsC2	FERRAL[x] - chromic [x] and FERRAL[x] - orthic ACRISOLS
PKT2p	vertic [x] PHAEOZEMS , sodic phase
PKTd	calcaro[x] - pellic VERTISOLS, saline-sodic phase
PSTD	" " " " " "
AA2	vertic[x] GLEYSOLS
PA6	gleyic and vertic[x] PHAEOZEMS, saline-sodic phase
PA7	vertic[x] - gleyic LUVISOLS and pellic VERTISOLS, sodic phase

4. Kisii (reconnaissance soil survey 1:100,000)

map unit	classification
FBh	luvic PHAEOZEMS and mollic[x] NITOSOLS
FBht	luvic and haplic PHAEOZEMS and mollic[x] NITOSOLS
FYh	luvic PHAEOZEMS and mollic[x] NITOSOLS
U1Xh	luvic PHAEOZEMS, dystro[x]- mollic[x] NITOSOLS and some humic ACRISOLS
U1Bh	luvic PHAEOZEMS and mollic[x] NITOSOLS
U11hn	dystro[x]-mollic[x] NITOSOLS
U21hn	drystro[x] - mollic[x] NITOSOLS
U3Bhn	mollic[x] - NITOSOLS
U3Bh	luvic PHAEOZEMS and mollic NITOSOLS
U? ?hn	mollic[x] and humic NITOSOLS
U3Gh	FERRAL[x] - humic ACRISOLS
U4Bh	verto[x]-luvic PHAEOZEMS
U4Gm	ferralo[x] - humic CAMBISOLS, petroferric phase etc.
Bbh	vertic[x]- PHAEOZEMS
HBhP	humic CAMBISOLS, partly paralithic[x] phase

(1) the terms marked with an "x" concern the "Kenya Concept" and are indicated as such in the text to facilitate easier recognition.

5. Kiboko (semi-detailed soil survey 1:50,000)

map unit	classification
P1	ando[x] - calcaric REGOSOL
P LF1	andocumulic[x] LITHOSOL
BUr	ACRI[x] - rhodic FERRALSOL
pBUr	andocumulic[x] rhodic FERRALSOL
BUb	ACRI[x] - orthic FERRALSOL
BUbc1	ACRI[x] - orthic FERRALSOL
FAsd	calcaro[x] - pellic VERTISOL
FAr2	vertic[x] FLUVISOL, sodic phase

6. Amboseli-Kibwezi (reconnaissance soil survey 1:250,000)

map unit	classification
FUr	ACRI[x] - rhodic FERRALSOLS
UFr1	ACRI[x] - rhodic FERRALSOLS
UFr2p	FERRAL[x] - chromic LUVISOLS
UBC	vertic[x] - PHAEOZEMS, saline-sodic phase
YLC	FERRAL[x] - ferric LUVISOLS
PU1	ACRI[x] - rhodic and ACRI[x] - orthic FERRALSOLS
PU2	FERRAL[x] - ferric and FERRAL[x] - chromic LUVISOLS
PFb	ACRI[x] - orthic and ACRI[x] - xanthic FERRALSOLS
PXr1	FERRAL[x] - ferric LUVISOLS
PU2p-PXr2	FERRAL[x] - chromic LUVISOLS
AA2	vertic[x] PHAEOZEMS

7. Tsavo area (reconnaissance soil survey 1:250,000 Voi sheet)

map unit	classification
FUr	rhodic FERRALSOLS and FERRAL[x] - chromic LUVISOLS
KXr	FERRAL[x] - chromic LUVISOLS
ULUpp	chromic[x] ACRISOLS
Pn2stbp	orthic and chromic[x] ACRISOLS, petric and pisoferric[x] phase
Pn2KTp	vertic[x] PHAEOZEMS, sodic phase
PsA22	orthic and vertic[x] SOLONETZ, partly saline phase
AArC1	eutric and vertic[x] FLUVISOLS
PdFbV/PdFrp	ferralic CAMBISOLS and chromic LUVISOLS, paralithic[x] or petric phase

8. Tsavo area (reconnaissance soil survey 1:250,000 Mtito-Andei sheet)

map unit	classification
FUr	rhodic FERRALSOLS and FERRAL^x^-chromic LUVISOLS
PnlFr	FERRAL^x^-chromic LUVISOLS
PsA23	pellic VERTISOLS, saline-sodic phase and vertic^x^ SOLONETZ, saline phase
AArCl	eutric and vertic^x^ FLUVISOLS

9. Makueni (reconnaissance soil survey 1:100,000)

map unit	classification
FUC2	FERRAL^x^ - chromic ACRISOLS
FUlrp, UlNrl	ACRI^x^ - rhodic FERRALSOLS
UlQ3, U2Nb3	FERRAL^x^ - orthic LUVISOLS
UlNr2p, UlNbl, UlNblm, UlNCl, U2Nbl	ACRI^x^ - orthic FERRALSOLS
U2Nrlp	FERRAL^x^ - chromic LUVISOLS
U2Fd, Bld	calcaro^x^ - pellic VERTISOLS

Ppendix 2. New terminology for the "Exploratory Soil Map of Kenya" at scale 1:1,000,000

- New Great Group and Subgroup terminology

murram CUIRASS soils
vertic GLEYSOLS
mollic NITOSOLS
chromic ACRISOLS

- Unit terminology

calcaro-cambic ARENOSOLS
ando-calcaric REGOSOLS
nito-humic FERRALSOLS
nito-rhodic FERRALSOLS
verti-eutric PLANOSOLS
luvo-orthic SOLONETZ
ando-gleyic SOLONETZ
verti-orthic GREYZEMS
nito-luvic PHAEOZEMS
verti-luvic PHAEOZEMS
ando-haplic PHAEOZEMS
ando-luvic PHAEOZEMS
chromo-luvic PHAEOZEMS
verti-eutric NITOSOLS
ando-humic NITOSOLS
verti-mollic NITOSOLS
(dystro)-mollic NITOSOLS
ferralo-chromic ACRISOLS
ferralo-orthic ACRISOLS
ferralo-ferric ACRISOLS
ferralo-chromic LUVISOLS
ferralo-ferric LUVISOLS
ferralo-orthic LUVISOLS
nito-ferric LUVISOLS
nito-chromic LUVISOLS
nito-chromic CAMBISOLS
ando-eutric CAMBISOLS