REVISION OF SOIL TAXONOMY IN THE CLASSIFICATION OF LOW ACTIVITY CLAY SOILS

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ABSTRACT

The dominant soils of the intertropical region are Oxisols and low activity clay (LAC) Ultisols and Alfisols, which are collectively termed LAC soils. Due to insufficient knowledge of these soils, their classification was not as satisfactorily developed as the soils of the temperate areas, and consequently, two International Committees (International Committee on Classification of Alfisols and Ultisols with Low Activity Clays and International Committee on Classification of Oxisols) were set up in 1975 and 1977, respectively, to develop proposals for the refinement of Soil Taxonomy.

Through circular letters and classification workshops, these International Committees have proposed several changes in the classification. The purpose of this dissertation was to evaluate these proposals, test their appropriateness and validity and where necessary, to suggest alternatives for consideration.

The review draft of a proposal for reclassification of Ultisols and Alfisols with low activity clays which constitute the final report of the ICOMLAC by the SCS and ICOMOX Circular Letter No. 10, dated June 1, 1983 and January 11, 1983, respectively, were the basis for the final discussion and suggestions in this study.

The methodology consisted of fitting 163 test pedons from the intertropical region into the ICOM's proposals through specially developed flow-diagrams. From these tests, suggestions were made for refinement.

The basis for proposing any modifications were:

(a) the modifications should result in marked improvements in the

interpretation which could be derived in the taxa names;

(b) the modification should result to a better expression of the soil-landscape relationships;

(c) the modification should introduce significant advantage either or both in the field or laboratory evaluations;

(d) the modification should result in mutually exclusive classes and should not conflict with the other parts of the system; and

(e) the modification should not result in any soil in a landscape from not being classified.

The criteria set in evaluating the impact of revision on agrotechnology transfer were:

(a) revision should achieve groupings of soils having closely similar crop production potential; and

(b) revision should stratify agroenvironment into distinct agroproduction niches.

The ICOM's proposals improved the taxonomic placements of the LAC soils, but there were pedons that could be placed in more than one taxa. Amendments were suggested to overcome these limitations. Some of the diagnostic class limits were refined. Certain criteria were also recommended for deletion and/or addition.

Finally, all the proposed changes were included in a key for the classification of these soils.

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I. INTRODUCTION

Soil classification probably dates back as early as when man began to sort out and classify objects around him. The early attempts were as simple as grouping soils based on properties such as color or texture or other characteristics that are easily observable and are of importance to individuals using them. With time, the growing sophistication in agriculture and the demanding complexity and diversity of soil uses prompted the need to modernize the system.

The purposes of soil classification, according to Cline (1949) are to organize our knowledge about the soils so that we may be able to remember their properties, understand their relationships, learn new relationships as well, and finally be able to establish groupings that are useful to predict their behaviour, identify their best uses, estimate their productivity and transfer technology.

Soil Taxonomy (Soil Survey Staff, 1975) is a classification system that has potential for worldwide application. One of its advantages over the other systems of classification is that it is quantitative and permits individuals familiar with the system to arrive at the same classification of a given soil and extract the same kinds of information from the taxa. The data base which the taxonomic names were derived makes the system meaningful for land use at the level of individual farm units (Cline, 1979).

Its appeal is evidenced by countries adopting it to classify their soils. Cline (1980) found many countries using it as a primary system of classification, some others using it as a secondary system, while many more are beginning to use it.

1.1. The Problem

As other countries begin to fit their soils into the system, some limitations were uncovered. This is not surprising because our knowledge of soils is still incomplete (Beinroth, 1978) and at the time that Soil Taxonomy was being developed, there were limited data on soils with low activity clay (LAC); there was limited knowledge about the methods of their study; and the pressing need to use the system to classify the soils of the U.S.A. left little time and limited funds for the study of tropical soils with low activity clays.

Hence, Soil Taxonomy needed refinement in the classification of low activity clay soils (Soil Survey Staff, 1975).

Soil Taxonomy classifies the LAC soils at three categorical levels. They are recognized at the order level in the Oxisols where LAC is one of the requirements of the oxic horizon. The LAC Ultisols and Alfisols including the LAC Inceptisols and Mollisols are assigned to the oxic and orthoxic subgroups and finally their presence are recognized in the mineralogy classes of the family category.

1.1.1. Classification Problems with the Oxisols

The limitation of Soil Taxonomy in the classification of the Oxisols is reflected on p 323 which reads, "The classification of Oxisols that follow seems to produce satisfactory groups of the few Oxisols in Hawaii and Puerto Rico. It needs to be tested more widely, for it is far from completion and is certain to have many shortcomings."

Many criticisms evidently point to the need for a thorough revision of the taxonomy of the Oxisols which Cline (1980) described as a compromise of conflicting judgements that was of no satisfaction to anyone. The boundary between the Oxisols and LAC Ultisols is very vague (Moormann, 1979). According to Cline, the definition of Oxisols and the soils it should encompass remain debatable, the class limits are not precise (Isbell, 1979) and the number of taxa is limited (Regasami, et al., 1978).

1.1.2. Classification Problems with the LAC Ultisols and Alfisols

The categorical level at which the LAC Ultisols and Alfisols are distinguished is too low to permit meaningful taxonomic groupings (Moormann, 1979). Consequently, the limited number of taxa inhibit the freedom to make further separation, resulting in the grouping of unlike soils in the same taxon.

Upgrading the classification of these soils to a higher category appears to be a simple matter. But a proposed change which may appear logical and meaningful for one part of the system, may be undesirable on the other part. The diagnostic criteria to define the proposed taxa have to be selected on the basis of their relevance to taxonomy, to management, and their placement in the key. The subdivision of the new taxa in the lower ladder of the hierarchy requires enormous amount of reliable field and laboratory data.

The Alfisols and the Ultisols are identified by an argillic horizon or a horizon with accumulation of clay as described in Soil Taxonomy. The pedogenetic significance of this criteria has been challenged (Isbell, 1979). An argillic horizon is defined by the presence of illuvial layer lattice clays, that has a specified clay increase compared to the eluvial horizon and by the presence of clay skins or oriented clay or both. The amount of clay increase from the overlying coarser textured horizon to the finer textured subsurface horizon and the vertical distance within which this clay increase should be reached are measured in order to define an argillic horizon. The near presence or near absence of clay skins in the LAC Ultisols and Alfisols is very subjective and clay skin is not unique to the LAC Ultisols in the wet equatorial udic and perudic climates (ICOMLAC CL No. 3, 1976). This problem will continue to be debated, and unless one has an access to equipment for micromorphological analysis (Eswaran, 1979), it would be difficult to confirm the presence of clay skins. There is also the problem of ascertaining whether a clay "bulge" is a result of clay illuviation or some other processes (Moormann, 1979).

Clay skins or clay orientation are indicators of clay movement from the upper to the lower horizons. Lack of clay skins, however, may not necessarily mean that there was no movement of clay (Beinroth, et al., 1974) because the high biological activity in warm humid tropics could lead to the destruction of clay skins faster than they are formed (Gile and Grossman, 1968).

On the other hand, the clay "bulge" may be a result of selective erosion of the clay-sized particles from the surface layer or by deposition layering, or both. These may be mistaken for an argillic horizon.

The difficulties of ascertaining clay illuviation and the positive identification of clay skins are complicated by an argillic horizon that has oxic properties. This problem is common in the tropical and subtropical countries (Cline, 1980).

In many instances, separation of taxa are pragmatic and many of the suggested limits to define the differentiating properties of diagnostic criteria are emperical values. Therefore, the proposals should be tested in the field and in as many environments of LAC soils as possible.

It was for this purpose that this dissertation was initiated.

1.2. Objectives

The objectives of the study are:

1.2.1 To test the adequacy of the proposed definition of diagnostic criteria and the proposed key definitions of the Oxisols and the LAC Alfisols and Ultisols as proposed by the International Soil Classification Committees;

1.2.2 To determine the impact of the revision of Soil Taxonomy on the principle of agrotechnology transfer; and

1.2.3 To recommend, if necessary, improvements to the proposed classification schemes.

II. REVIEW OF LITERATURE

Soils in the warm humid tropics are more prone to intensive weathering, leaving a clay fraction that is dominantly of the 1:1 layered clay minerals and the oxides-hydroxides of Fe and/or Al. These clays are referred to as the low activity clays (LAC), which pertains to a low cation exchange capacity (CEC) value of less than 16 meq per 100 g clay (ICOMLAC CL No. 13, 1980).

Uehara, (1978) recognized two classes of LAC: (a) those having high specific surface containing allophane and imogolite and other non-crystalline or poorly crystalline soil colloids, and (2) those with crystalline, low specific surface minerals such as kaolin, Al-interlayered secondary chlorites and oxides and hydrous oxides of Fe, Al, Ti and Si. According to Uehara, the former class behave differently due to their high specific surface that accounts for a high variable charge. Here, their CEC by NH_4OAc is high, but generally unrelated to the cation retention capacity in the field. Uehara explained that these soils have high water retention capacity, high water permeability, and low bulk density.

Low activity clays differ from high activity clays (HAC) in the origin of their surface charge (Uehara, 1975) and in their management requirements. The surface charge density of the LAC arises from the adsorption of potential determining ions (p.d.i.). In these soils, the most important p.d.i.'s are the H^+ and the OH^- (Uehara and Gillman, 1981). Uehara and Gillman explained that an acid medium causes an excess of H^+ and an alkaline medium causes an excess of OH^- to be adsorbed. Hence, soils with LAC are referred to as pH-dependent charge soils, owing to the dependency of the surface charge on the pH of the soil solution. The CEC of these soils may be increased by increasing the electrolyte concentration, the counter ion valence and the pH, or by lowering the zero point of charge (Uehara, 1975). According to Uehara, the zero point of charge corresponds to soil pH at which net surface charge is zero and this could be lowered by P fertilization or raised by high Fe oxide in the clay fraction. Hence, highly weathered soils can be rejuvenated through manipulation and management of the sign and magnitude of the surface charge.

2.1. Concept of Oxisol

Oxisols in various regions of the world have been investigated in considerable detail. Paramananthan and Lim (1979) investigated the Oxisols in Malaysia; Rojanasoonthon and Panichapong (1979) in Thailand; Isbell (1979) in Tropical Australia; Ikawa (1979) in Hawaii; Sys and Tavernier (1979) in Africa; Bennema and Camargo (1979) and Lepsch and Buol (1974) in Brazil; and Beinroth (1979) in Puerto Rico. Uehara (1979) provided considerable information on the mineralo-chemical properties of the Oxisols; Buol (1979) gave the geomorphology; and Eswaran (1979) discussed the micromorphology. Reports of these investigators are contained in a series of proceedings of the International Soil Classification Workshops of the ICOM'S. Performance of a network of family of Oxisols was investigated by the Benchmark Soils Project (BSP) of the Universities of Hawaii and Puerto Rico.

The general ideas of the above researchers commonly describe the Oxisols as reddish, yellowish, or grayish soils on old surfaces or the preweathered and transported sediments of ancient age on younger surfaces (Smith, 1965) in the tropical and sub-tropical regions.

They occur on old stable geomorphic surfaces (Eswaran, 1980) where deep weathering and almost complete pedological transformation have occurred resulting in almost no variation in profile, color, and texture. Thus, there is the absence of clear boundaries between horizons (Latham, 1981).

Extreme weathering has reduced the Oxisols to a mixture of 1:1 alumino-silicate clays, free oxides, and quartz, leaving almost no minerals that can weather to release plant nutrients (Uehara and Gillman, 1981). This process of weathering is related to the hot and humid climate in the tropics that enhance the removal of the more soluble elements of the rocks, i.e., Ca, Na, Mg, and K in solution (Latham, 1981). Latham explained that the destruction of the primary minerals results in the liberation of silica, iron, and aluminum and the reorganization into a more stable form which is the kaolinite or the 1:1 lattice alumino-silicates. With time, the silica continues to leach, leaving only the Fe and some Al that eventually precipitate as oxides or hydroxides.

The Oxisols are on the upper part of the landscape so that there is no chance for them to receive bases from laterally moving ground water (ICOMOX CL No. 6, 1980). The continuous leaching of silica, therefore, does not permit the synthesis of clay minerals (Eswaran, 1980). According to Eswaran, the mineralogy and the tendency of the oxic soil materials to shift in pH corresponding to net zero surface charge could lead to severe leaching of cations and fixation fo anions.

Given the proper management input, however, and with their excellent physical properties, they can be very productive. Some of the most productive soils of the world are Oxisols, i.e., the Molokai, Lahaina, Wahiawa, and the Lihue soil series of Hawaii (Uehara, personal communication).

2.2. Concept of Oxic Horizon

The oxic horizon is used to identify the soils belonging to the order Oxisols. It is a mineral subsurface horizon that has been more or less mineralogically completely weathered (Latham, 1981) and has been reduced to kaolin and free oxides (Uehara and Gillman, 1981). The state of weathering is so advanced that the enormous length of time has led to the formation of a horizon that is no less than 30 cm thick (Smith, 1979) and that is practically devoid of weatherable minerals (Uehara and Gillman, 1981). Experiences in other countries, however, show that the oxic material may have as much as 10 percent weatherable minerals in the 50 to 150 micron fraction (ICOMOX CL No. 9, 1982) or may contain as much but no more than 40 meq of K, Ca, Mg and Na per 100 g soil on a total elemental analysis after gravel removal (Herbillon, 1980). Such low weatherable mineral contents of the oxic horizon emphasizes also the advanced state of weathering of the oxic horizon. It is further reflected by limiting the rock structure content to no more than 5 percent (Soil Taxonomy, pp 36-37) because the rock fragments are also potential sources of clay.

The charge properties of the oxic horizon are very low. Here, the effective cation exchange capacity (ECEC) is $\leq$10 meq per 100 g clay (Soil Taxonomy). The class limit ensures a low permanent charge by excluding from the oxic horizon the 2:1 lattice clay minerals and alumino-silicate clay minerals. The CEC by NH_4OAc at pH 7 of ≤ 16 meq per 100 g clay is also imposed to exclude from the oxic horizon the short range order alumino-silicate clay minerals such as allophane and imogolite (Eswaran, personal communication).

In this case, the allophane and imogolite possess pH-dependent charge characteristics of crystalline LAC, but they behave differently because of high specific surface (Uehara, 1978).

The oxic horizon has a sandy loam or finer texture in the fine earth fraction and has >15 percent clay (Soil Taxonomy, p 39). This excludes the sands and sand-size particles which have low specific surface, thus low CEC, to become oxic materials. The intent is that the low charge in the oxic material is due to the clay resulting from intense weathering rather than the low charge of the sand particles (Uehara, personal communication).

The oxic horizon is also characterized with gradual change in profile color and texture which is indicative of prolonged weathering and that no other pedogenetic processes operated. Andic materials may be present as contaminants, but not enough to react with NaF to a pH more than 9.4 (ICOMOX CL No. 10, 1983).

Clay skins are not more than 1 percent of the column of the horizon or they are not thick and continuous (Moormann, personal communication). The upper textural boundary is usually diffuse (Buol, 1983) or has gradual or diffuse boundaries between its sub-horizons (Soil Survey Staff, 1975). Abrupt textural boundaries between sub-horizons are not permitted because they connote processes that did not operate in the formation of the oxic horizon (Paramananthan and Eswaran, 1980). The upper boundary is at the least depth where the mineralogy (ICOMOX CL No. 7, 1981) and the charge characteristics (Soil Taxonomy, p 36) are met but not above 15 cm or the base of the Ap horizon, or may be the soil surface if the profile is truncated (ICOMOX CL No. 7, 1981).

2.3. The ICOMOX Proposals

The International Committee on the Classification of Oxisols was organized in January 1978 (Eswaran, 1979). The mandate was to develop a clear concept of an Oxisol, redefine the oxic horizon, examine the validity of the present taxa, and propose improvement (Proc. 1st ISCW, 1978). Since its creation, various approximations, succeeding changes and refinements of the definition of the oxic horizon, and the key definition of the order Oxisols have been made. The progressive development of the proposed definition of the oxic horizon is shown in Table 1. One can see the proposed modifications, such as the adjustments of the quantitative limits of some of the diagnostic properties, introduction of additional criteria, and modification of statements of the provisions.

The thickness requirement, for instance, has been increased to 50 cm because work in Malaysia (Eswaran, 1979) indicated that feeder roots only begin to decrease at about 60 to 70 cm. Increasing the thickness to 50 cm, however, would exclude many Oxisols in the South Pacific region (Proc. 2nd ISCW, Part II, 1979). Hence, the 30 cm limit was restored (ICOMOX CL Nos. 8, 9, and 10).

Table 2 shows the deletion, retention, and/or addition of taxa at the suborder and great group levels. It can be seen that the first

Table 1. Proposed changes of the parameters defining the oxic horizon by ICOMOX.

Diagnostic Properties	1975*	1978	1980	1981	1982
1. Thickness (cm)	30	50	50	50	30
2. ECEC in meq/100g clay	10	12	12	12	12
and/or					
CEC in meq/100 g clay	16	16	16	16	16
3. pH in NaF (1:50)	-	9.4	9.4	9.4	9.4
4. Percent weatherable minerals	t	t	1	1**	10.0***
5. Percent clay with sandy loam or finer texture	15	-	15	8	8
6. Textural boundaries between its subhorizons and adjacent horizons	G or D	G or D	G or D	G or D	G or D
7. Percent rock structure by volume	5	5	5	5	5
8. Percent gravel by volume	-	-	-	-	85

* Sources: 1975, Soil Taxonomy ; 1978, Proc, 1st ISCW; 1980, ICOMOX CL No. 6; 1981, ICOMOX CL No. 7; 1982, ICOMOX CL No. 8.

** Percent weatherable minerals in the 20-200 micron fraction.

*** Percent weatherable minerals in the 50-250 micron fraction.

G = gradual, D = diffuse

Table 2. Chronology of changes in the proposed taxa in the order Oxisols by the ICOMOX.

Category	Soil Taxonomy	1978	1980	1981	1982	1983
SUBORDER	Aquox	Aquox	Aquox	Aquox	Aquox	Aquox
	Torrox	Humox	Acrox	Acrox	Acrox	Torrox
	Humox	Torrox	Humox	Torrox	Torrox	Ustox
	Ustox	Ustox	Torrox	Ustox	Humox	Orthox
	Orthox	Orthox	Ustox	Orthox	Ustox	
			Orthox		Orthox	
GREAT GROUP	Sombr	Sombr	Sombr	Sombr	Gibbsi	Gibbsi
	Gibbsi	Gibbsi	Gibbsi	Gibbsi	Acr	Acr
	Plinth	Acr	Pale	Pale	Eutr	Eutr
	Acr	Lat	Kur	Kur	Hapl	Kur
	Eutr	Umbr	Rhod	Eutr		Hapl
	Ochr	Eutr	Eutr	Rhod		
	Umbr	Melan	Psamm	Psamm		
	Hapl	Rhod	Hapl	Hapl		
		Xanth				
		Hapl				

ICOMOX approximation key in 1978 retained the five suborders (Aquox, Humox, Torrox, Ustox, and Orthox) in Soil Taxonomy, but keyed out the Humox before the Torrox. It was increased to six in 1980 with the addition of suborder Acrox to recognize soils having ECEC <1.5 meq per 100 g clay and a positive delta pH (ICOMOX CL No. 6, 1980). The great group in Soil Taxonomy was also increased from eight to ten in 1978. Here, three new taxa were introduced such as the Lathorthox or those having 20 percent by volume of petroplinthite or lithoplinthite, the Melanorthox for those having chroma, moist, <4 and the Xanthorthox for those having a hue of 10YR or redder. However, it was again reduced to eight in 1980 (ICOMOX CL No. 6, 1980) by eliminating the above three taxa and introduced the "Kur" taxon which was defined with a clay content >40 percent and a clay content increase of an argillic horizon.

Major changes were made in 1983 (ICOMOX CL No. 10, 1983) under a new chairmanship of the committee. The suborders Humox and Acrox were deleted retaining only four suborders and eight great groups.

2.3.1. Definition of the Oxic Horizon

The proposal that follows was taken from ICOMOX CL No. 8, 1982 as amended in ICOMOX CL Nos. 9 (1982) and 10 (1983), respectively. It reads:

1. Is at least 30 cm thick;
2. Has a fine-earth fraction (<2 mm) that has an apparent ECEC (NH_4OAc bases plus N KCl extractable Al/% clay) less than 12 meq per 100 g clay or has an apparent CEC (NH_4OAc at pH 7 CEC/% clay) of 16 meq per 100 g clay or less, whichever is lower;
3. Has a pH value in N NaF (1:50 of less than 9.4;
4. Has a weatherable mineral content less than 10 percent of the 50-250 micron fraction if that size fraction constitute at

least 20 percent of the soil material less than 2 mm in diameter or contains less than 40 meq of K + Mg + Ca + Na per 100 g soil on a total elemental analysis basis after coated gravel removal, if soils have less than 20 percent fine sand and very fine sand (50-250 microns);

5. Has a texture of sandy loam or finer in the fine-earth fraction and has 8 percent or more clay;
6. Has a diffuse upper textural boundary (i.e., less than 1.2 x clay increase within a vertical distance of 12 cm);
7. Has less than 5 percent by volume that shows rock structure unless the lithorelics containing weatherable minerals are coated with sesquioxides;
8. No soil material with 85 percent gravel, by volume, is considered an oxic horizon."

Explanations of the proposed changes in the definition are abstracted below from ICOMOX CL Nos. 8 (1982) and 10 (1983).

Item 2 of the proposal deletes the cation retention capacity by $\underline{N}$ NH_4Cl in Soil Taxonomy; increases the limit of the ECEC from 10 to 12 meq per 100 g clay; and uses the CEC by NH_4OAc at pH 7 as an alternate of the effective CEC, rather than requiring both properties to define the oxic horizon in Soil Taxonomy.

Item 3 requires a pH in NaF of less than 9.4 to provide a dividing line between the Oxisols and the Andisols.

Item 4 provides a limit of 10 percent weatherable minerals in the 50 to 250 micron fraction to remove the qualitative and subjective term "trace" in Soil Taxonomy. It is in close agreement with the limit of the "Pale" great groups of Ultisols and permits a size fractionation that can be counted with an optical microscope (ICOMOX CL No. 8, 1982).

Item 5 lowers the percentage limit from 15 to 8 percent clay to make it closer to the midrange of the sandy/loamy family unit (ICOMOX CL No. 10, 1983) or to make the lower texture limit of the oxic to correspond to the upper limit of the Psamments (ICOMOX CL No. 7, 1981).

Item 6 specifies a diffuse upper textural boundary to provide a mutually exclusive definition with the argillic, especially the kandic horizon.

Item 7 requires the oxic horizon to have less than 5 percent by volume that show rock structure as in Soil Taxonomy, but adds the condition, "unless the rocks containing weatherable minerals are coated with sesquioxides." The 5 percent limit is set to ensure the advanced stage of weathering of the oxic horizon by excluding the rock fragments that are the source of weatherable minerals.

Item 8 is an additional requirement which does not permit the oxic horizon to have more than 85 percent gravel, by volume.

2.3.2. Key Definition to the Oxisols

The suggested improvement of the definition of the soil order Oxisols on page 92 is in ICOMOX CL No. 10 (1983). It reads as follows:

"Key Statement C. Other soils that either:

1. Have less than 40 percent clay in the upper 18 cm, after mixing, and an oxic horizon with its upper boundary within 1m of the soil surface and not overlain by an argillic or kandic horizon, or
2. Have 40 percent or more clay in the upper 18 cm of the soil surface, after mixing, and either an oxic horizon or a kandic horizon with an apparent CEC of the clay fraction ≤ 16 meq per 100 g clay (NH_4OAc, at pH 7 method), the upper boundary of which is within 1 m of the soil surface."

The above proposal is intended to include in the order Oxisols the heavy textured LAC soils and exclude the light textured LAC soils (Uehara, personal communication).

The reduction of the number of suborders is based on the proposal to use only moisture regime as a diagnostic criteria at that category (ICOMOX CL No. 10, 1983).

The "Pale" great group was deleted to give preference on the morphology rather than the pedogenetic concept of age (Buol, 1983). Buol further explained the drastic reduction of taxa at the great group level, saying: (a) the "sombr" feature probably occur only in Oxisols so that it could be a unique feature that could be recognized at the subgroup level, (b) the "rhod" taxon has been used both as great group and subgroup names and it seems less important to accessory characteristics than "eutr", "acr", etc. and (c) the "psamm" taxon is proposed to be recognized at the family level and at the subgroup intergrades to Psamments.

In 1981, the acric soil material was introduced as a diagnostic criterion of the key definition of the order Oxisols (ICOMOX CL No. 7, 1981).

The 1983 ICOMOX approximation is presented in the results and discussion to provide immediate reference in the taxonomic tests.

2.4. Concept of the LAC Ultisols and Alfisols

These soils were extensively studied in detail in many parts of the world. Moncharoen and Vijarnsorn (1979) investigated the LAC Alfisols and Ultisols in Thailand; Lim et al., (1979) in Malaysia; de Alwis (1979) in Sri Lanka; Sombroek and Muchena (1979) in Eastern Africa; Comerma (1979) in Venezuela; and Buol (1979) in the United States of America and Puerto Rico. The concept of the argillic horizon and problems of its identification were discussed by Arnold (1979), Cline (1980), and Eswaran (1981); Herbillon and Rodrigues (1979) published the mineralogy of the low activity clay soils; and the micromorphology was studied by Eswaran (1979). The performance of selected LAC Ultisols was tested by the Benchmark Soils Project (BSP) of the Universities of Hawaii and Puerto Rico.

The above workers reported that soils dominated by low activity clays occur extensively in Southeast Asia, small portions of the Indian Sub-continent, a major part of moist Tropical Africa, South America and the Southeastern United States. They are also common in Australia and East Asia.

Most of these LAC soils have B horizons with the clay content increase of an argillic horizon. They are presently placed in the order Ultisols and Alfisols (ICOMLAC CL No. 13, 1980).

The predominance of low activity clays in the soil is important because it is an indication of an advanced state of weathering (Moormann, personal communication).

The management properties of these soils are different from soils having 2:1 type clays that have high activity (Uehara, personal communication). For example, the problems with the availabilty of Al and Ca are usually associated with low activity clays, but not with high activity clays. The LAC soils have also limited response to fertilizer and lime.

The LAC Ultisols and Alfisols have low cation exchange capacity and possess some characteristics of an oxic material. They are differentiated mainly by the base saturation by sum of cations at certain specified depths.

The LAC Ultisols and Alfisols, are separated from the LAC Inceptisols by the presence of the clay content increase of an argillic horizon in the former, while the LAC Mollisols are those that have a mollic epipedon (ICOMLAC CL No. 13, 1980).

2.5. Concept of the Argillic Horizon

The argillic horizon differentiates the Alfisols and the Ultisols from the other taxa of the system. Its use, however, is being criticized (Isbell, 1977) but, Arnold (1978) explained that the clay movement may not bear significance although it is the cause and effect that tells a lot of information about the soil. In fact, Eswaran (1981) considered the argillic horizon in terms of the sets of conditions that lead to its formation viz, (1) the conditions in the surface horizon should be conducive to dispersion, (b) the dispersed clay should be translocated to the subhorizon, and (c) the translocated clay should be able to deposit and form clay skins.

In soil management, the coarser textured overlying horizon provides better tilth and favorable root proliferation while the finer textured subsurface horizon increases the water holding capacity of the soil (Eswaran, 1981). Smith, in an interview by Leamy (1981)[a], added that the clay skins which are the evidence of clay illuviation have a marked influence on the amount of nutrient elements that are cycled by plants. According to Smith, the clay skins contain more N, P, and K than in the ped interiors.

However, the advantage of higher nutrients cycled by plant on ped coating of the argillic horizon, may be annulled when the clay skins cover almost all the ped surfaces and root channels, restricting nutrient uptake by plant roots (Soleon *et al.*, 1964).

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a/: Leamy (1981). Conversation on Soil Taxonomy. New Zealand Soil News, Vol. 29, No.5, 1981.

Smith viewed it differently in that the Ca content of the coatings on ped draws the roots deeper in the subsurface horizon for more available water during periods of droughts. This is not the case, however, if the finer textured subsurface horizon is not due to clay illuviation.

Experiences in the tropical and subtropical region also indicate that the clay skins, as defined in Soil Taxonomy, pp 21-24, are not unique to soils of LAC, particularly the Ultisols with udic or perudic moisture regime (ICOMLAC CL No. 3, 1976). For example, the subsurface horizon may have the chemical and mineralogical properties of the Oxisols and the clay bulge of an argillic horizon with no clay skins. This makes the distinction between the Oxisols and the LAC Alfisols and Ultisols very vague.

2.6. Concept of Kandic Horizon

A kandic horizon is a subsurface horizon that has a much higher percentage of clay than the overlying horizon(s), Moormann (1981). The higher clay content may be associated with one or more processes acting simultaneously or sequentially on the surface or subsurface horizon or both causing textural differentiation.

The most important processes are (a) clay eluviation and illuviation. Here, the higher clay content in the B horizon cannot be shown by micromorphological analyses to have accumulated by illuviation. The clay skins that are evidences of illuviation may be completely absent because of (a) lack of orientation of clay-size particles as a result of a high amount of Fe oxy-hydroxides in the clay fraction or the destruction of clay skins by biological activity, (b) destruction of clay as a result of the weathering of layered-lattice clay silicates,

(c) selective erosion, in which the finer soil particle may be moved further from a point of origin due to rain drop splash, leaving a coarser surface material (d) sedimentation of coarser textured surface materials, in which it may overlie a fine textured strata, and (e) biological activity, where earthworms, termites, and ants rework the soil resulting to a coarser textured surface soil (ICOMOX CL No. 13, 1980).

The textural differentiation resulting from the above processes can not be associated with the argillic horizon because it is difficult to show that the higher clay content in the subsurface horizon came from the overlying horizon.

The kandic horizon has a CEC by NH_4OAc at pH 7 <16 meq per 100 g clay or an ECEC of <12 meq per 100 g clay within 50 cm below the top of the finer textured subsurface horizon (ICOMLAC CL No. 13, 1980).

The significance of the kandic horizon is related to its use as a basis for differentiating soils with clay accumulation in the subsoil where the argillic horizon alone is not adequate to differentiate some Ultisols and Alfisols from Oxisols and Inceptisols (ICOMLAC Final Report, 1983). Here, it is used to separate the LAC Ultisols and Alfisols from the Oxisols and Inceptisols. ICOMLAC, however, suggests that the kandic horizon should not be used as a diagnostic horizon in soils having >40 percent clay in the surface because in soils with clayey surface, the increase of clay content losses much of its significance. The presence of a kandic horizon is an indication of a high degree of weathering of a soil and the high degree of weathering relates to the dominance of 1:1 layered-lattice clays and sesquioxides of Fe and Al and the absence of 2:1 layer lattice clays.

The nomenclature proposed for the soils with the LAC at the great group level was derived from the formative element "kandi", as proposed by Eswaran (ICOMLAC CL No. 14, 1981). It connotes kandites which refer to the 1:1 lattice clays and more specifically the kaolinite with varying amounts of the oxy-hydrates of Fe and Al (Moormann, personal communication).

2.7. The ICOMLAC Proposals

The International Committee on Classification of Alfisols and Ultisols with low activity clays was organized in 1975 to recommend changes in the classification of Alfisols and Ultisols with LAC and recommend diagnostic properties to define new taxa (ICOMLAC CL No. 13, 1980).

There have been several proposals in upgrading the LAC taxa in the key. One is the introduction of a new order for the LAC soils. The other is to define the Alfisols and the Ultisols with dominance of high and low activity clays respectively or to exclude from the Alfisols all soils dominated by LAC and the Ultisols will be defined to contain HAC and low base saturation as well as soils with LAC irrespective of base saturation (Proc. 1st ISCW, 1978). These were ruled out because they would require an overhaul of the major parts of Soil Taxonomy (Moormann, 1978).

The consensus in the Committee was to upgrade the "kandi" taxa to the great group level. Here, the required changes both in the overall taxa, are kept to the minimum (ICOMLAC CL No. 14, 1981).

2.7.1. Summary of Properties of the Kandic Horizon

The following was taken verbatim from the review draft of a proposal for reclassification of Ultisols and Alfisols with LAC by the

SCS based on the final report of the ICOMLAC, dated June 1, 1983.

The kandic horizon is a subsurface horizon which has a CEC <16 meq per 100 g clay (by NH_4OAc) or have ECEC <12 (sum of bases plus KCl extractable Al) in the fine earth fraction at a depth of 50 cm below the top of the horizon or immediately above a lithic, paralithic, or petroferric contact that is shallower.

The kandic horizon has the following properties:

1. A coarser textured surface horizon. The minimum thickness of the surface horizon is 18 cm after mixing or 5 cm if the transition to the kandic horizon is abrupt.

2. More total clay than the overlying horizon and the increased clay content is reached within a vertical distance at 12 cm or less as follows:

    a. If the surface horizon has less than 20 percent total clay, the kandic horizon must contain at least 4 percent more clay; or

    b. If the surface horizon has more than 20 percent total clay, the kandic horizon must have 1.2 times more clay than the overlying horizon or at least 8 percent more clay.

3. A thickness of at least 30 cm, or at least 15 cm if a lithic, paralithic, or petroferric contact occur within 50 cm of the mineral soil surface.

4. The layers or horizons overlying the kandic horizon do not show fine stratification and the content of organic carbon does not decrease irregularly with increasing depth.

5. Lacks clay skins that are thick and continuous in all parts, and the cross section has <5 percent oriented clay to a depth of 125 cm below the mineral soil surface or 75 cm below the top of the kandic horizon, whichever is deeper.

III. MATERIALS AND METHODS

The initial activity was a review of the low activity clay soils and their corresponding diagnostic horizons in order to arrive at a firm idea of what were to be tested. The concepts developed in Soil Taxonomy and the concepts developed by the ICOM's were collated.

3.1. Data Assemblage

The soils of the Benchmark Soils Project (BSP) of the Universities of Hawaii and Puerto Rico were used because they have adequate soil characterization data and some performance data as well. Obviously, the number is small to test the entire ICOMOX and ICOMLAC proposals. It was therefore, necessary to add more pedons. Existing data are available and necessary parameters are adequate.

The 163 test pedons are presented in alphabetical arrangement by soil order in Appendix 1. They represented many environments of soils with low activity clays from the higher latitudes in the United States to the lower latitudes in Hawaii, Puerto Rico, Brazil, Sumatra, Thailand, Malaysia, Philippines, the South Pacific Region, Cameroon, the Ivory Coast, Kenya, Indonesia, and Southwest Africa (Figure 1). A profile/pedon code number is provided as reference for the different soils particularly those soil series that are represented by more than one pedon. The alphabetic portion of the code represents the last syllable of the order name and the numerical part is the number in the listing. Selected data needed for specific tests are also appended.

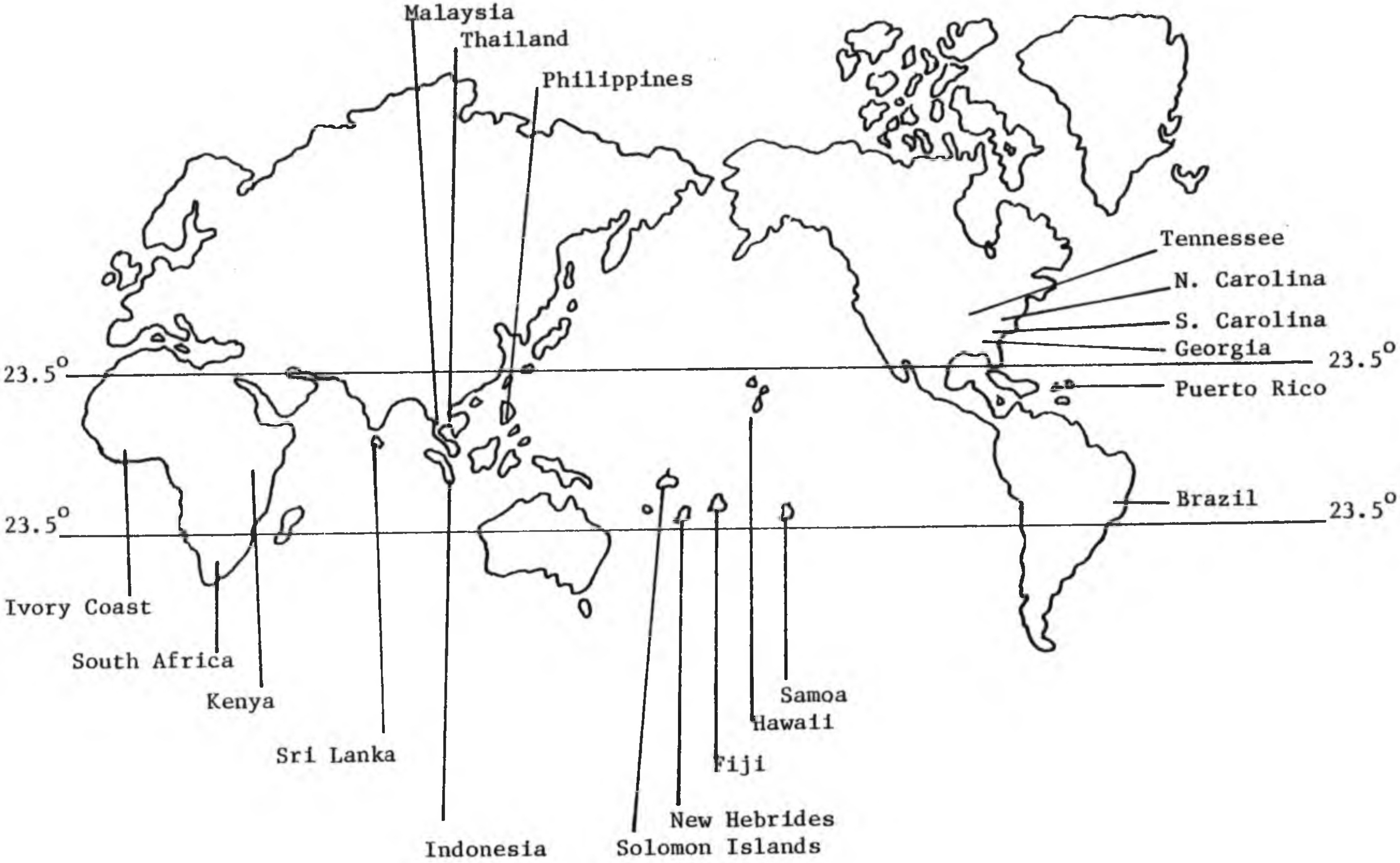

Figure 1. Distribution of test pedons.

Some data were analyzed with different procedures. These were standardized to conform with procedures described in Soil Taxonomy. It was done by establishing correlations between the data obtained by other countries with those obtained by the National Soil Survey Laboratory (NSSL) of the Soil Conservation Service (SCS) in Lincoln, Nebraska on the same pedons.

Correlation, however, was not possible on a few pedons because they were not analyzed by the NSSL. Nevertheless, the laboratory data of these pedons were used in the tests, but with caution.

3.2. Methodology

The methodology is illustrated in Figure 2.

3.2.1. Analytical Methods

3.2.1.1. Particle Size Analysis:

Some pedons classified as Oxisols from the BSP were re-analyzed for particle size distribution because of suspiciously low clay content. A modification of the method of Kilmer and Alexander (1949) was made by using ultrasonic vibration with increased amount of Na-hexametaphosphate solution in order to enhance dispersion. This modification consisted chiefly of adding 50 ml of sodium hexametaphosphate solution to a 10 g air dried soil sample. It was shaken overnight and subjected to ultrasonic vibration, using the BIOSONIK IV Model by Bronwill, VW Scientific. The ultrasonic treatment was first calibrated by testing various time and energy inputs. The treatment that gave reproducible dispersion values was selected and referred to as the modified treatment. It was coded HI-70-20, where the HI was for high energy input; 70 was for the scale of the vibration tuning; and 20 was the time in

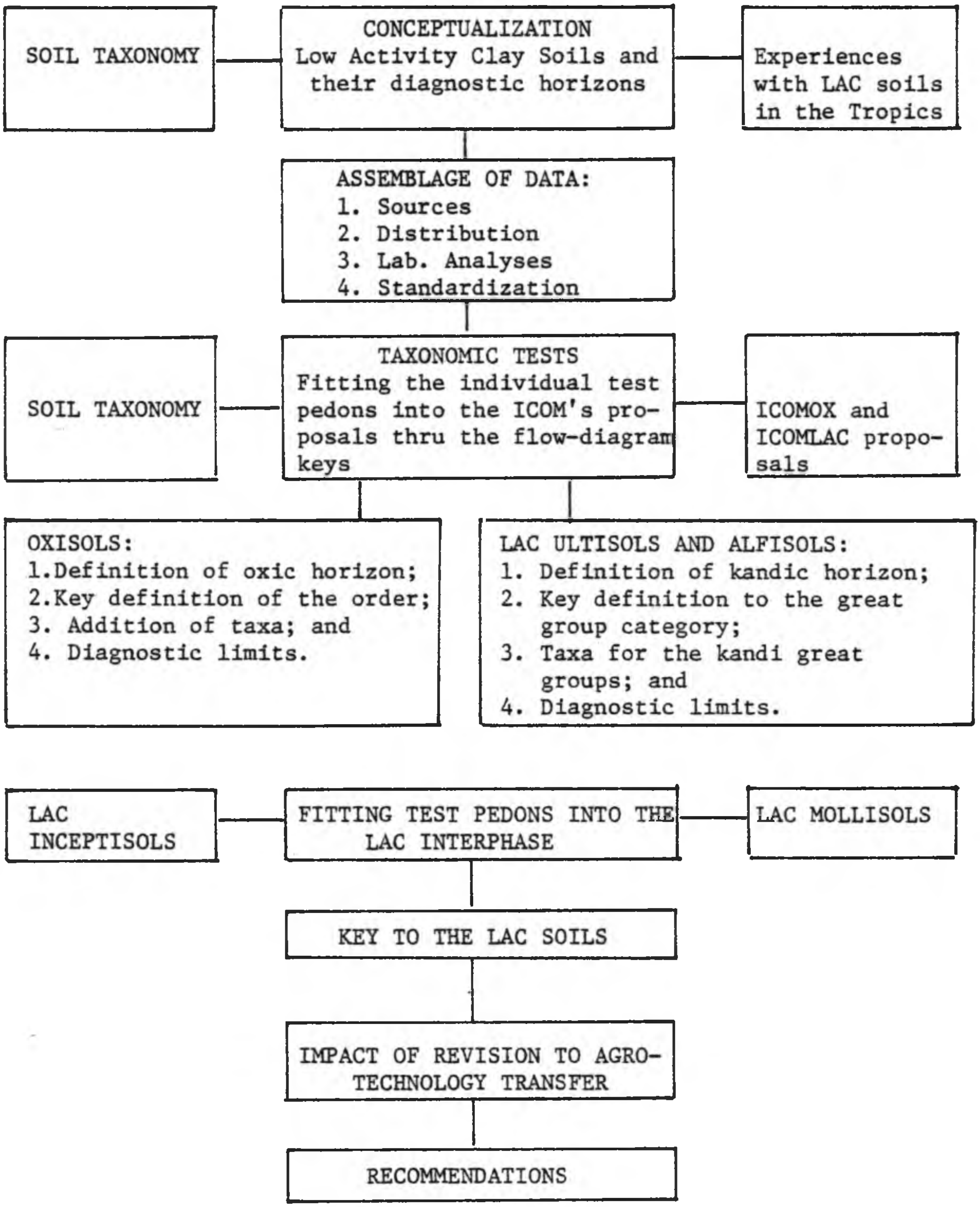

Figure 2. Diagram of methodology.

minutes. Iron oxide removal was dispensed with, because the oxides are important parts of the oxic materials.

3.2.2. X-Ray Diffraction Analysis

Mineralogical analyses were conducted for some of the BSP profile samples. The soil samples were prepared following the guidelines of Jones (1977)[b]. Preferentially oriented silt and clay specimens were prepared on glass slides for Mg-saturated, Mg-saturated and glycol-solvated, K-saturated, and K-saturated and heated to 100°-, 300°-, and 550°C. The glass mounted samples were analyzed by means of the Philips (XEG-3100) X-Ray Diffractometer equipped with long-fine-focus copper tube (Kα, 1.5418Å) and a high voltage generator operating at 40Kv and 40mA. Diffractograms were produced by scanning the samples from 2 to 64° 2Θ. A theta compensating divergence slit was used in place of a stationary divergence slit and a curved graphite crystal monochrometer was used in lew of a nickel filter.

Randomly oriented powdered sand-size aggregates of clay samples obtained by the pipette method of Kilmer and Alexander (1949) were also examined by X-ray diffraction analysis.

3.2.3. Testing of Proposals

All the 163 test pedons (Appendix 1) were used in testing and in developing the concepts. The taxonomic test was done by fitting the individual pedons into the ICOM's proposals with the use of flow-diagram keys. Here, the proposals were tested as illustrated by the test pedons. From these tests, suggestions were made for refinement.

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b/ Jones (1977). Laboratory Guidelines on Soil Mineralogical Analysis by X-ray Diffraction.

Each item in the proposed definitions of the diagnostic horizon was tested, first on soils currently classified in the order in which that horizon is used as a differentiae and second, on the other LAC soils. At each stage, the pedons were checked to see the validity of the proposals. Similar tests were done on the proposed key definitions.

The taxonomic tests proceeded in the following sequence:

3.2.3.1. On the ICOMOX Proposals:

- a. Definition of the oxic horizon;
- b. Key definition of the order Oxisols; and
- c. Revision of keys to the lower categories.

3.2.3.2. On the ICOMLAC Proposals:

- a. Definition of the kandic horizon;
- b. Key definitions of the order Ultisols and Alfisols to accommodate the LAC taxa; and
- c. Key definition of the LAC great groups.

As part of the test, performance data, whenever available, were used to strengthen the result of the taxonomic test.

There are few guidelines to evaluate the quality of a classification system. The principles adopted in this study are the basic principles employed in Soil Taxonomy that were based on the conceptual work of John Stewart Mill (1891). In this respect, the specific section in Soil Taxonomy, pp 8-11 on (a) the attributes desired, (b) selection of differentiae; and (c) forming and defining taxa were closely adhered to.

The conditions set in this study, that should be satisfied in the evaluation of any proposed change were:

a. The modifications should result to a marked improvement in the interpretations which could be derived from taxa names;

b. The modifications should result in a better expression of soil-landscape relationships;

c. The modifications should introduce some significant advantages either in the field identification of the soil or in the laboratory evaluation;

d. The modification should at all times result in mutually exclusive classes and should not conflict with the other parts of the system; and

e. The modification should not result in any soil in a landscape from not being classified.

The criteria set in evaluating the impact of revision on agrotechnology transfer were:

a. Revision should achieve groupings of soils having closely similar crop production potential; and

b. Revision should stratify agroenvironment into distinct agroproduction niches.

Because the test pedons originated from different parts of the world (Figure 1), one of the problems encountered in this study was the determination of the appropriateness of the proposed classification to the soils with respect to the above requirements. This was partially overcomed by a detailed evaluation of published reports on these soils and by personal communication with individuals familiar with the test pedons.

IV. RESULTS AND DISCUSSION-OXISOLS

The ICOMOX's proposed definition of the oxic horizon and the proposed key to the lower categories were tested. Flow-diagrams were used to test the criteria in a step-by-step fashion. The test pedons are in Appendix I, and the selected pedons listed in the flow-diagrams were those that illustrated certain concepts.

4.1. Testing the Criteria of the Oxic Horizon

The proposed diagnostic criteria for the oxic horizon are listed in Table 3, columns 3 and 4. The current definition of the oxic horizon in Soil Taxonomy is also presented in columns 1 and 2 and column 5 gives the result of the taxonomic test.

The flow-diagram key is in Figure 3 and the criteria were tested against the data of 4 pedons of LAC Ultisols, 7 Oxisols and 4 LAC Inceptisols. The LAC Ultisols and the LAC Inceptisols that did not qualify for an oxic horizon, indicated that the proposed definition did not adversely affect the other parts of the system. However, failure of 7 pedons of Oxisols suggested certain limitations of the proposal.

4.1.1. The Charge Properties

Item 2 deleted the cation retention criterion by 1N unbuffered NH_4Cl solution in Soil Taxonomy. Since the cation retention capacity by NH_4Cl approximates the ECEC in non-calcareous soils (Soil Taxonomy, p 39) and since the ECEC is more commonly measured than the former, the deletion of the latter seemed reasonable.

Table 3. Result of tests of ICOMOX proposed properties to define the oxic horizon of Oxisols.

ITEM NO.	SOIL TAXONOMY	ITEM NO.	ICOMOX'S PROPOSAL	RESULT OF TAXONOMIC TESTS OF 70 PEDONS
1	Is at least 30 cm thick;	1	Is at least 30 cm thick;	All test pedons met the criteria.
2	Has a fine-earth fraction that retains 10 meq or less ammonium ions per 100 g clay from an unbuffered 1N NH_4Cl solution (meq of NH_4 retained per 100 g soil x 100 ÷ clay percentage ≤ 10) or has ≤ 10 meq of bases extractable with NH_4OAc plus aluminum extractable with 1N KCl per 100 g clay;	2	Has a fine earth fraction (<2mm) that has an apparent ECEC (NH_4OAc bases plus N KCl extractable Al/% clay) less than 12 meq per 100 g clay or has an apparent CEC (NH_4OAc, pH 7 CEC/% clay) of ≤ 16.meq/ 100 g clay or less, whichever is lower;	All the test pedons met the criteria.
3	Has an apparent cation-exchange capacity of fine-earth fraction of 16 meq or less per 100 g clay by NH_4OAc unless there is appreciable content of aluminum interlayered chlorite (meq CEC per 100 g soil x 100 ÷ clay percentage ≤ 16, clay percentage as in footnote 15);			

Table 3 (Continued)

ITEM NO.	SOIL TAXONOMY	ITEM NO.	ICOMOX'S PROPOSAL	RESULT OF TAXONOMIC TESTS OF 70 PEDONS
		3	Has a pH value in N NaF (1:50) of less than 9.4;	4 Oxisols, 2 LAC Ultisols, and 3 Inceptisols did not meet the criterion.
4	Does not have more than traces of primary aluminosilicates such as feldspars, micas, glass, and ferro-magnesian minerals, as discussed earlier;	4	Has less than 10% of the 50-250 micron fraction if that size fraction constitute at least 20% of the soil material less than 2mm in diameter. For soils with less than 20% fine sand and very fine sand (50-250 microns) the oxic horizons contain less than 40 meq K + Mn + Ca + N/100g of soil on a total elemental analysis basis after gravel removal;	1 Oxisol and 1 Inceptisol did not meet the criteria.
5	Has texture of sandy loam or finer in the fine-earth fraction and has >15 percent clay;	5	Has a texture of sandy loam or finer in the fine earth fraction and contains 8 percent or more clay;	All test pdeons met the criteria.
6	Has mostly gradual or diffuse boundaries between its subhorizons; and	6	Has a diffuse upper textural boundary (i.e. <1.2x clay increase within a vertical distance of 12 cm);	2 Oxisols and 1 LAC Ultisol did not meet the criterion.

Table 3 (Continued)

ITEM NO.	SOIL TAXONOMY	ITEM NO.	ICOMOX'S PROPOSAL	RESULTS OF TAXONOMIC TESTS OF 70 PEDONS
7	Has <5 percent by volume that show rock structure.	7	Has <5 percent by volume that show rock structure unless the lithorelcits containing weatherable minerals are coated with sesquioxides;	All test pedons met the criteria.
		8	Does not have more than 80 percent by volume of gravel.	All test pedons met the criteria.

Figure 3. Fitting the test pedons into the flow-diagram key of the ICOMOX's definition of the oxic horizon.

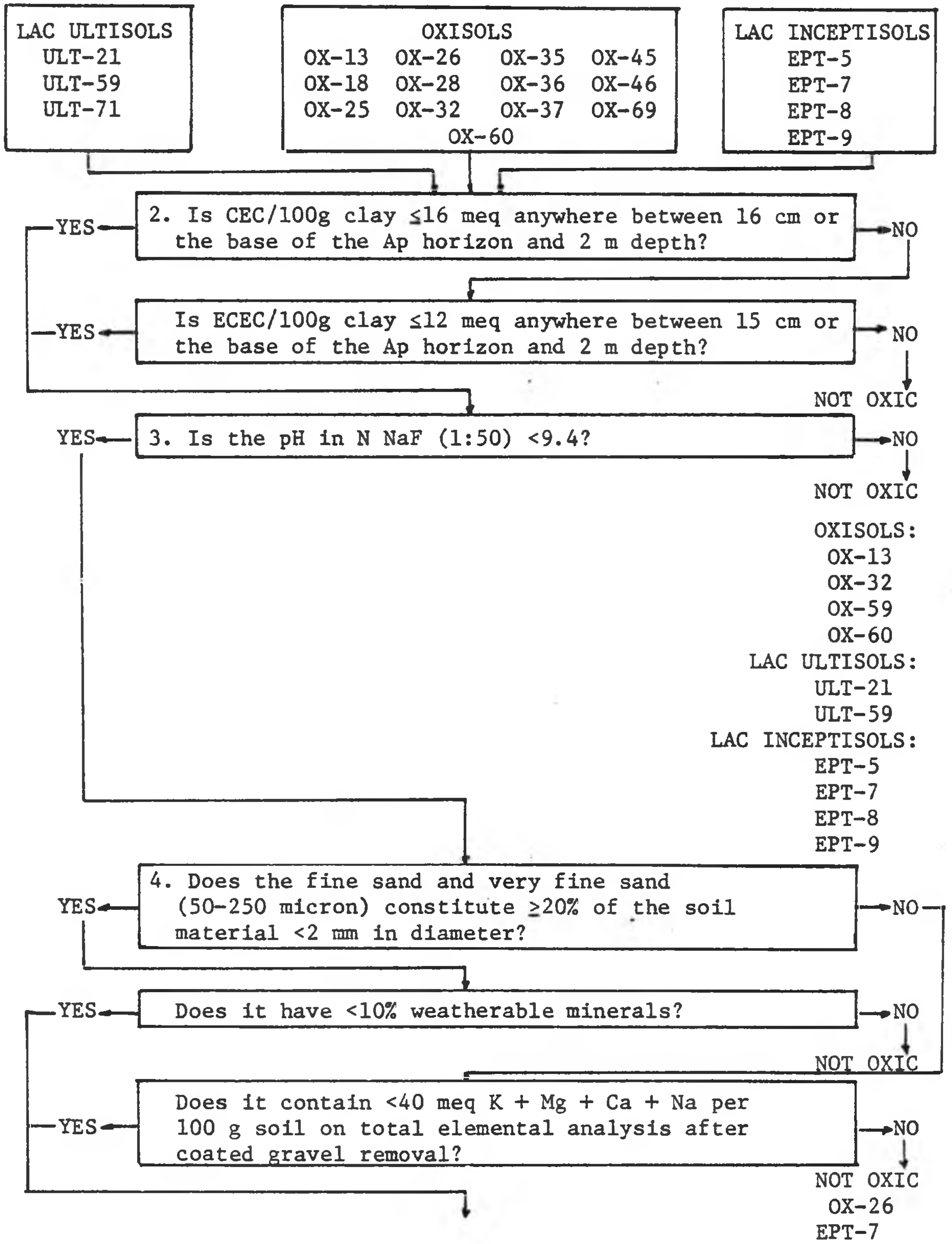
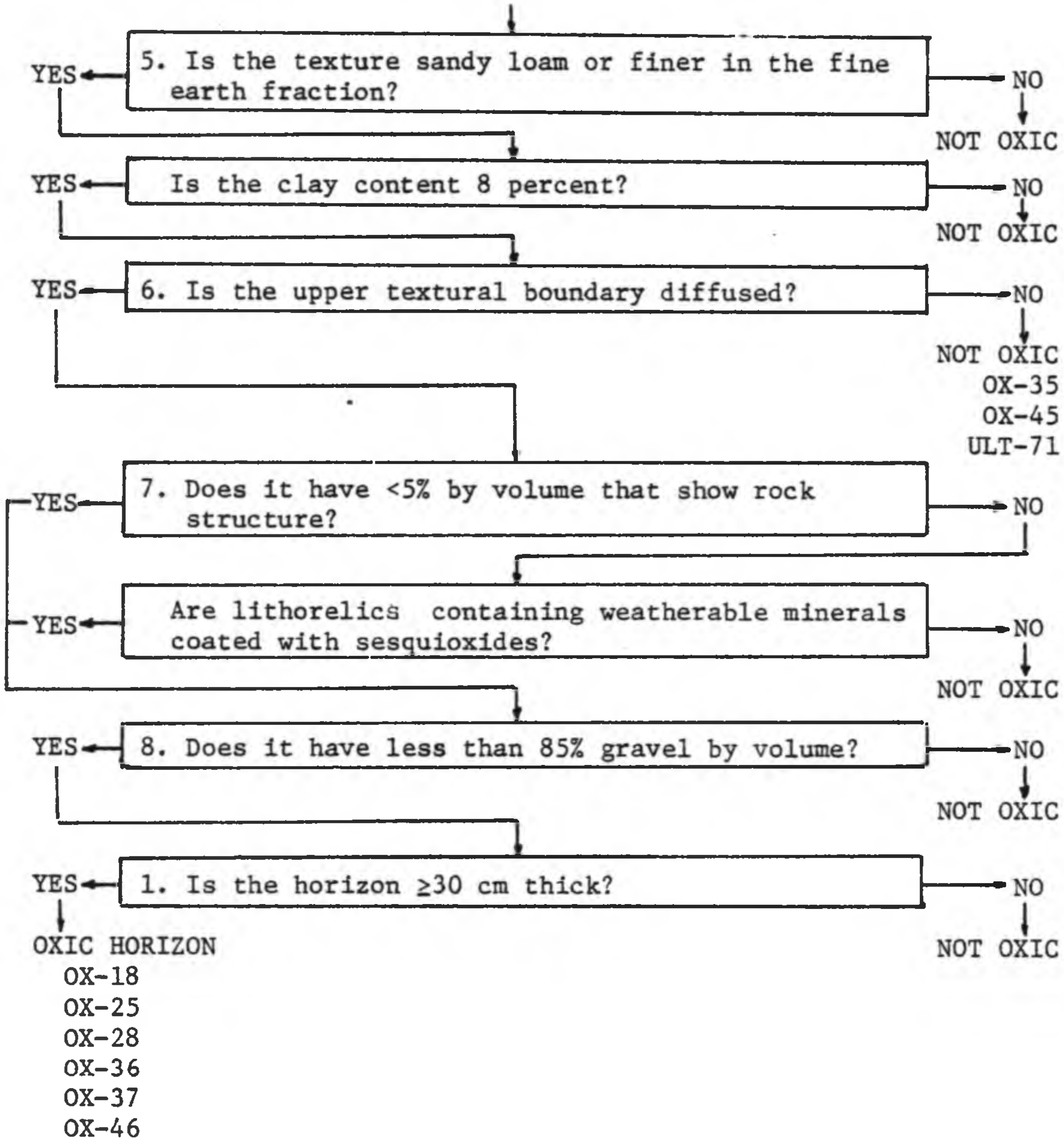


Figure 3. (Continued)



Item 2 uses CEC at pH 7 as an alternate to the ECEC rather than an additional criterion as in Items 2 and 3 in Soil Taxonomy. This was met by the 4 pedons of LAC Ultisols, 7 pedons of Oxisols and 4 pedons of Inceptisols.

The value of the ECEC that corresponded to 16 meq of CEC was also tested using the data of 23 pedons of LAC soils consisting of 154 horizons that have CEC <24 meq per 100 g clay in Hawaii, Puerto Rico, Indonesia, Cameroon, Philippines, Thailand, and Brazil. This was done by regressing the CEC by NH_4OAc at pH 7 with the ECEC by sum of extractable bases plus KCl extractable Al.

The relationship was expressed in the equation

$$Y = 7.8956 + 1.2265X$$

where Y was the CEC and X was the ECEC in meq per 100 g clay. A plot of the relationship is shown in Figure 4 with an R^2 of 0.69. It indicated that at the CEC limit of 16 meq per 100 g clay, the corresponding ECEC value was 7 meq. This was much lower than ICOMOX'S proposed value of 12 meq per 100 g clay.

4.1.2. Contamination with Andic Materials

The flow-diagram key in Figure 3 show that 3 LAC Inceptisols, 4 Oxisols and 2 LAC Ultisols did not meet Item 3. Failure of the LAC Inceptisols and LAC Ultisols to satisfy the provision of Item 3 meant that the criterion did not adversely affect the other parts of the system. This was illustrated by the Maile series (Table 4). It has bulk densities <0.84 g per cc, abundant (3x) allophane and >100 percent 15-bar water content. These are properties of an exchange complex dominated by amorphous materials (ECDAM) to which a pH_{NaF}>9.4 may be inferred.

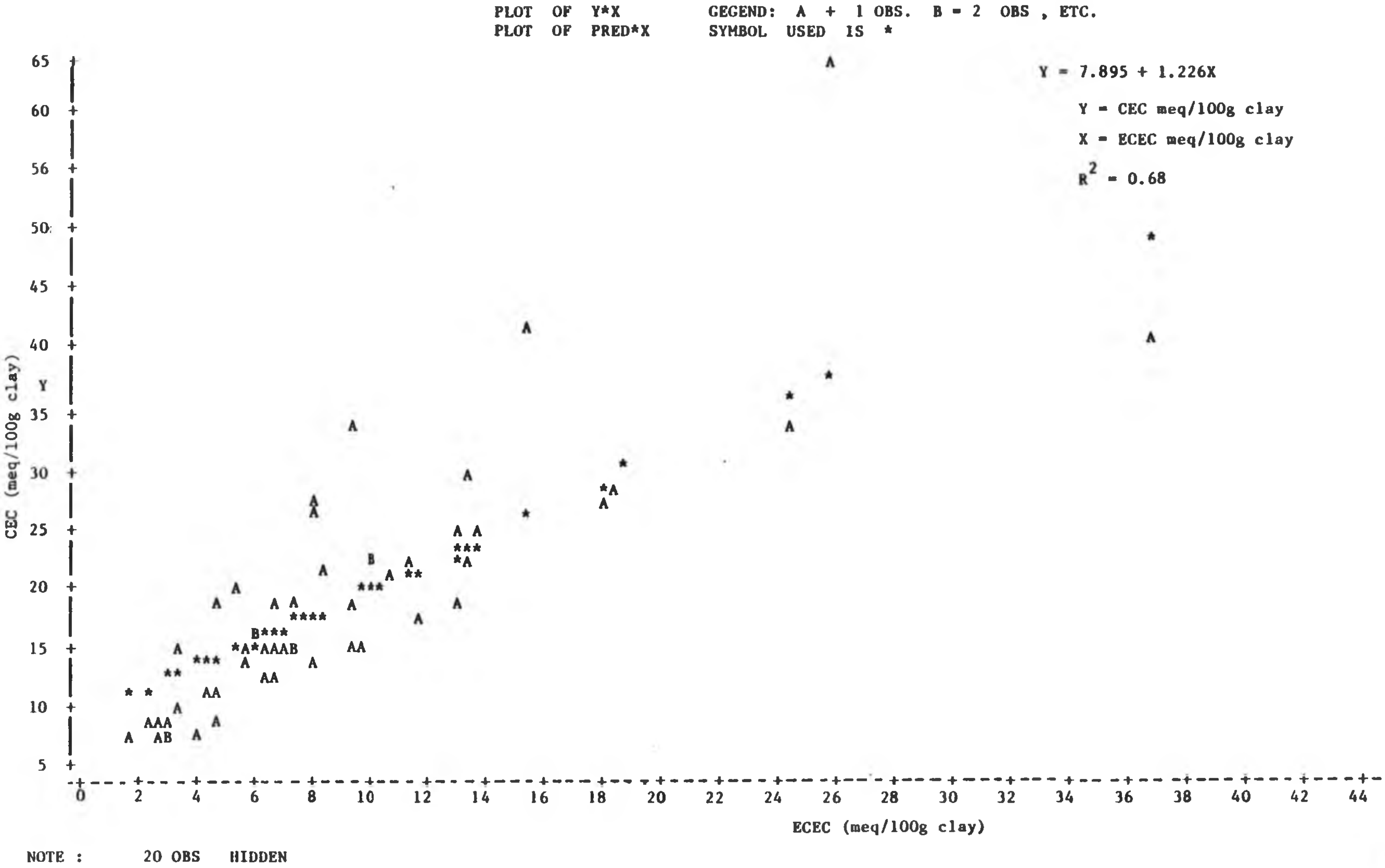


Figure 4. The relationship between CEC and ECEC in Oxisols.

Table 4. Characteristics of the Maile series, (EPT-8) an Inceptisol used to test ICOMOX's proposed definition of the Oxic horizon

Depth (cm)	Horizon	ECEC meq/100g clay	CEC meq/100g clay	Bulk Density (g/cc)	Allo-phane (%)	15-Bar Water (%)	ΔpH $pH_{KCl} - pH_{H_2O}$
0-5	A11	13.5	56.2	0.52	3X		-0.1
10-35	A13	1.0	56.1			132	-0.3
43-50	B22	0.8	38.2	0.32			-0.1
60-73	IIC	0.2	36.7	0.30			0.0
90-120	IIIB25b	0.4	50.5	0.30	3X	193	+0.1
120-150	IIIB26b	0.4	31.1	0.45	3X	126	+0.3

Source: SSIR No. 29, 1976, p 30.

The Koolau series lends support to the above illustration (Table 5). It has a very low sum of bases to which a low ECEC could be inferred but has CEC ranging from 169.7 to 217.5 meq per 100 g clay in the same horizons. The bulk densities, field moist, of 0.86 and 0.76 g per cc in the B21g and C horizons, respectively, are indicative of ECDAM. Such properties were apparently influenced by the parent material derived from melilite basalt of the Koloa flow which has low amount of silica and volcanic ash (SSIR No. 29, - 25). According to Uehara (1978) soils developed from volcanic ash deposit possess pH dependent charge characteristics of crystalline low activity clays but behave differently because of their high specific surface. He explained that their CEC by NH_4OAc is high and generally unrelated to cation retention in the field which is low.

Item 3, however, is a constraint in some Oxisols. This was illustrated by the data of Pedon OX-59 of the Wahiawa series in Hawaii (Table 6). It has $pH_{NaF} \geq 9.4$ in the B horizons. This was supported by the data of Pedons OX-60, OX-33 of the Molokai series in Hawaii and OX-13 of the Farmhill series in South Africa (Table 6).

However, it has been shown by Perrott et al. (1976) that there are also strong reactions of NaF with amorphous iron and disordered aluminum oxides that release OH^-. They illustrated the reaction as

$$(Fe,Al)OH + F \longrightarrow (Fe,Al)F + OH^-$$

which leads to a $pH_{NaF} > 9.4$. Parfitt (1978) also reported the chemistry of amorphous materials that are dominated by the reactions of NaF with large amounts of free (Fe)-OH and (Al)-OH groups on charge surfaces.

Table 5. Characteristics of the Koolau series, (EPT-7) a Plinthic Tropaquept, fine, halloysitic, acid, isothermic, used to test the ICOMOX's proposed definition of the oxic horizon.

Depth	Horizon	Sum OF bases	CEC (sum)	Bulk density	15-Bar Water	ΔpH (pH_{KCl} - pH_{H_2O})
(cm)		(meq/100g clay)		(g/cc)	(%)	
0-15	A11	2.7	63.5	0.37	56.6	-0.2
15-28	A12g	0.7	33.5		34.7	-0.3
28-40	A2g	1.9	40.1		38.9	-0.7
40-100	A21g	2.2	42.6	0.86	36.7	-0.7
100-130	B22g	1.8	54.8		46.6	-0.5
130-180	C	2.3	55.2	0.78	42.4	-1.0

Source: SSIR No. 29 (1976).

Table 6. The pH in NaF of some pedons of Oxisols.

Depth -cm-	Horizon	pH_{NaF}
Pedon OX-59, Wahiawa series, Eutrustox, Waipio, Oahu, Hawaii (BSP original pit)		
0-10	Ap1	8.7
10-27	Ap2	8.8
27-40	B	9.3
40-65	Bw	9.3
65-90	Bw1	9.4
90-120	Bw2	9.5
120-150	Bw2	9.5
Pedon OX-60, Wahiawa series, Eutrustox, Waipio, Oahu, Hawaii (BSP new pit)		
0-23	Ap1	9.3
23-38	Ap2	9.0
38-53	B	8.9
53-91	Bw	9.2
91-125	Bw1	9.5
125-147	Bw2	9.4
147-178	Bw2	9.4
Pedon OX-33, Molokai series, Torrox, Molokai, Hawaii (BSP experimental survey pit)		
0-23		9.5
23-47		9.6
47-64		9.5
64-87		9.4
87-104		9.2
Pedon OX-13, Farmhill series, Acrohumox, South Africa.*		
0-16	A1	10.6
16-28	A2	10.9
28-62	B1	9.7
62-113	Bt1	9.4
113-149	Bt2	9.4
149-165	Bt3	9.4
Pedon OX-46, Haplohumox, Aneityum Island, New Hebrides.**		
0-10	A1	8.4
10-120	B2	9.1

* Analyzed by the NSSL, Soil Conservation Service, USDA.

** Source: Leamy *et al*. (1979).

The available data indicated that the pH_{NaF} limit of 9.4 was too low for some Oxisols. The pH_{NaF} values of some Andisols were examined in order to establish a mutual boundary between the oxic and the "andic" horizons. Table 7 shows that these soils have pH_{NaF} $\geq$10.0. Evidently, a value of 10.0 appeared to be the appropriate breaking point. Andepts in drier environement like the Waimea series may have pH_{NaF} less than 10.0 (Table 8). But this soil has CEC greater than 16 meq per 100 g clay and the sum of bases are very high to which a high ECEC may be inferred. This was illustrated by a pedon of Waimea series that was sampled from a profile pit close to the pedons in Table 8. It has CEC greater than 16 meq per 100 g clay and the sum of bases are very high to which a high ECEC may be inferred (Table 9). Hence, the Waimea series can not have an oxic horizon. On the basis of the available data, therefore, Item 3 may be refined in the following manner: "Have a pH value in $\underline{N}$ NaF (1:50) of less than 10.0."

4.1.3. Weatherable Mineral Content

The Kohala series illustrated the significance of the provision of Item 4 that prevented the LAC Inceptisols to qualify for an oxic horizon by virtue of its high weatherable mineral content (Table 10).

The Kapaa, Makapili, and the Puhi series in Hawaii, the Segamat, Kuantan and the Kuala Pilah series in Malaysia showed that the provision of Item 4 was in accord with the test pedons of Oxisols (Table 1, Appendix II).

The Lihue series, a Tropeptic Eutrustox, however, had more than 40 meq per 100 g soil, total elemental analysis (Table 1, Appendix II) and the total elemental analysis was mostly contributed by MgO and K_2O.

Table 7. The pH_{NaF} of selected pedons of Andisols.

Depth -cm-	Horizon	pH_{NaF}
Hilo series, Typic Hydrandepts, thixotropic, isohyperthermic, Hawaii.[a]		
0-17	Ap	9.7
17-39	B21	8.7
39-65	B22	10.5
65-70	IIC	10.8
70-85	IIIAb1	10.7
85-110	IIIAb2	10.7
110-125	IIIAb21b	10.2
Akaka series, Typic Hydrandepts, thixotropic, isomesic, Hawaii.[a]		
0-25	Ap	10.4
25-60	B21	10.4
60-85	B22	10.1
85-95	IIApB	10.5
95-105	IIB21b	10.1
105-120	IIB22b	10.0
Kukaiau series, Hydric Dystrandepts, thixotropic, isothermic, Hawaii.[a]		
0-22	Ap	10.4
22-43	B21	10.8
43-66	B22	10.6
66-80	B23	10.6
80-97	B24	10.5
97-118	B25	10.3
Waimea series, Typic Eutrandepts, medial, isothermic, Hawaii.[a]		
0-18	Ap	9.9
18-36	B21	10.3
36-61	B22	10.0
61-99	B23	10.2
99-132	B24	10.4
132-152	C	10.8
"PUC" soil, Hydric Dystrandepts, thixotropic,isothermic,Philippines.[b]		
0-20	Ap	11.4
20-45	BA	11.1
45-80	BW1	10.9
80-115	BW2	10.9
115-160	BW3	10.8
160-190	BW4	10.7
"ITKA" soil, Hydric Dystrandepts, thixotropic, isothermic, Indonesia.[b]		
0-23	Ap	10.9
23-42	BW	11.0
42-66	AB1	11.1
66-92	AB2	11.2
92-125+	AB3	11.2

Sources: a= Recel (1981); b= Hawaii BSP as analyzed by the SCS.

Table 8. The pH_{NaF} of two pedons of the Waimea series, a Typic Eutrandepts, medial, isothermic, in Hawaii.

Depth -cm-	Horizon	pH_{NaF}	15-Bar Water Content - - - pct - -
Waimea very fine sandy loam, Typic Eutrandepts, medial, isothermic.			
0-18	A11	9.0	32.2
18-40	A12	9.5	36.4
40-71	B21	9.5	40.5
71-99	B22	9.4	38.7
99-127	C1	9.4	36.9
Waimea silt loam, Typic Eutrandepts, medial, isothermic.			
0-18	Ap	9.3	31.7
18-25	B1	9.6	52.4
25-51	B21	9.7	48.9
51-81	B22	9.8	40.2

Source: Recel (1981).

Table 9. Characteristics of the Waimea series, a Typic Eutrandept, in Hawaii. Source: SSIR No. 29, 1976, p 46.

Depth	Horizon	CEC*	Sum of Bases	Bulk Density	15-Bar Water Content	Allophane
-cm-		- meq/100g -		g/cc	- - - - -pct- - - - -	
0-5	A11	80.8	46.9		29.9	
5-13	A12	71.8	46.1	0.71	29.1	4X
13-20	A13	74.1	50.0		32.8	
20-58	B21	80.8	57.5		48.3	4X
58-88	B22	90.8	59.2	0.66	59.2	
88-118	B23	79.2	51.4		60.8	4X

* CEC by sum of cations.

4X= dominant

Table 10. Characteristics of the Kohala series in Hawaii, used to test the proposed definition of the oxic horizon by ICOMOX.

Depth	Horizon	Ca	Mg	Na	K	Total	Mica
-cm-		- - - -meq/100g clay- - - - - - - - - -					-%-
0-18	Ap1	1.43	53.32	3.55	20.85	81.15	15
18-35	Ap2	2.43	51.83	6.13	20.85	80.24	15
35-68	B22	t	49.34	3.23	21.06	73.42	15
68-98	B23	-	44.86	3.23	21.28	69.15	15
98-113	C1	1.07	47.35	2.90	9.15	60.47	5
113-133	C2	t	44.86	3.23	3.83	51.92	2

Source: SSIR No. 29 (1976).

In this regard Swindale and Uehara (1966) found a direct relationship between the amount of mica and the amount of exchangeable K in the soil. But Juang and Uehara (1967) found that the Hawaiian Latossolic soils are derived from parent material free of mica and they concluded that mica is of tropospheric origin. It is, therefore, possible to suppose that the K_2O and some MgO originated from mica. This mica was reported to be a K-bearing 2:1 layer silicate which is common in small amounts in many soils in Hawaii and is made up of muscovite and vermiculite layers (SSIR No. 29, 1976, p 207).

The mica, however, is in the clay fraction, and therefore, the Lihue series is permitted to have an oxic horizon.

4.1.4. Texture and Clay Content

The intent of Item 5 is to exclude the sands and sandy particles from the oxic horizon, because they too have low CEC. The clay content limit of >8 percent replaces the 15 percent in Soil Taxonomy that was originally used to keep the Quartzipsamments that have clay consisting of kaolinite and free oxides from having an oxic horizon. Here, 8 percent is the highest limit of clay content of the Quartzipsamments and it is thus proposed to be the lower limit of clay content of the Oxisols by ICOMOX.

The texture and clay content criteria is explained by Smith (as interviewed by Leamy, 1981) that the 15 percent clay limit in Soil Taxonomy was originally intended to make a break between the sandy loams (>15 percent clay) and the sands (<10 percent clay) or loamy

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Leamy (1981). Conversation in Taxonomy. New Zealand Soils News. Volume 29, No. 3 pages 80-81.

sands (<15 percent clay) on the assumption that the highly weathered soils have virtually no silt. Smith explained that the management implication of separating the Oxisols from the Psamments is based on the presumption that Psamments are subjected to blowing and drifting and are very difficult to traverse with wheeled vehicles when dry, while the Oxisols are not. Here, the 15-percent limit in Soil Taxonomy was presumed to be the point where trafficability and blowing problems develop. It was, however, found later that this value needed refinement for the reason that the presence of the appreciable amount of silt plus clay did not produce the peculiar property.

Pedon OX-43 of the Sadao series in Thailand was used for the test. It has no weatherable minerals, has less than 15 percent clay, and has enough silt to have a sandy loam texture, (Table 2, Appendix II). It could be placed neither in the Quartzipsamments because of the sandy loam texture, nor in the Oxisols because it has <15 percent clay, if Soil Taxonomy is applied. Smith reported soils of this characteristics in Venezuela, supporting the idea that the 15 percent clay content limit must be refined, hence, the 8 percent proposal of the ICOMOX.

If the clay content is too low, however, it is thought to exaggerate or increase abruptly the CEC/% clay ratio. But Figure 5 seems to show that the CEC/% clay ratio gradually increase with decreasing percentage clay content indicating that it is feasible to lower the clay content limit such as the Sadao series to permit an oxic horizon. The available data show that the lowest clay content for a sandy loam texture is 11.6 percent. Perhaps a value of 10 percent may be a better compromise between the 8 percent clay proposed ICOMOX and the 15

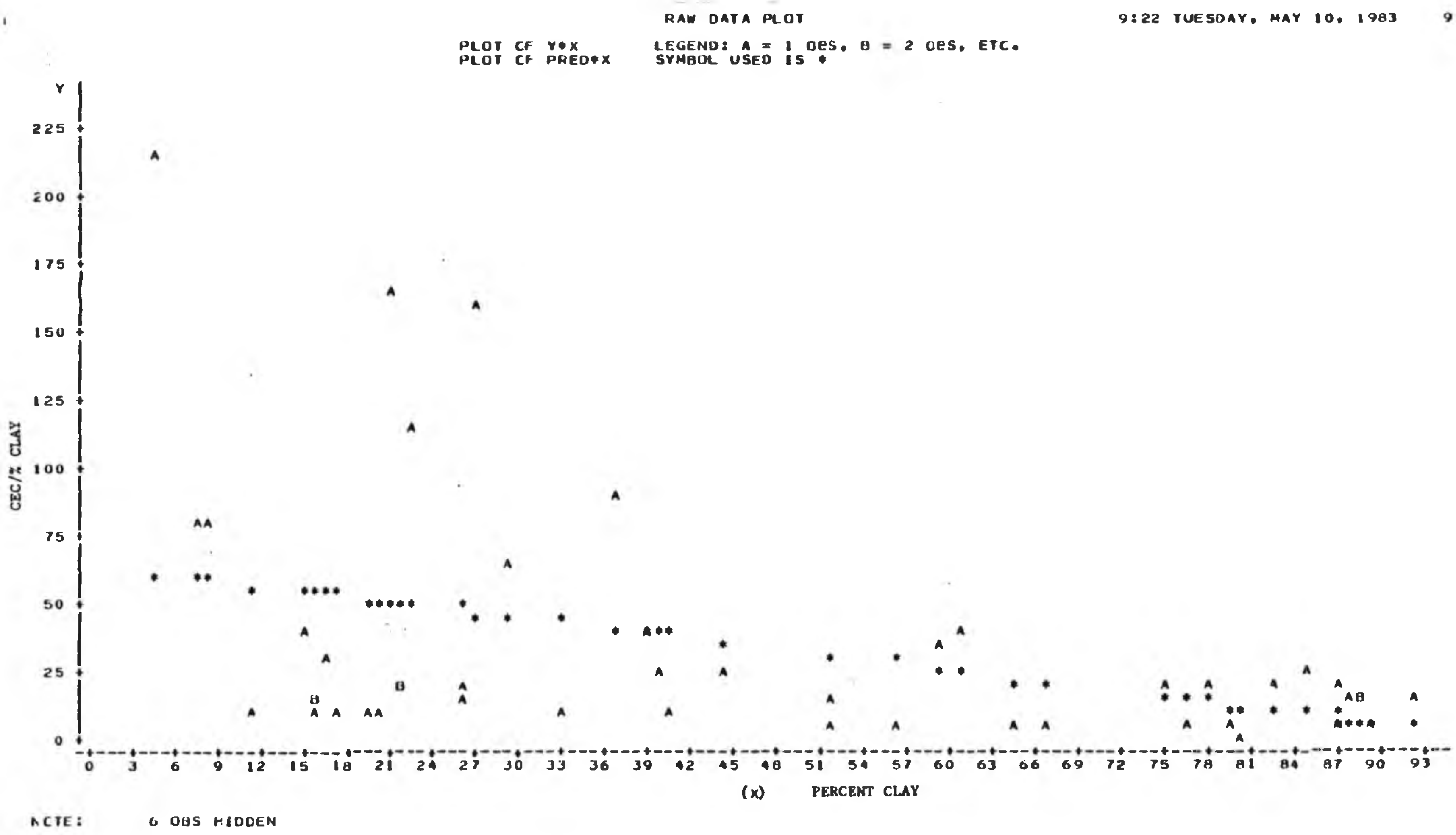


Figure 5. The relationship of the ratio of cation exchange capacity to clay versus the percent clay of selected pedons of Oxisols.

percent in Soil Taxonomy. More data, however, are needed to test the suggestion particularly soils in Zaire and other parts of South Africa where Oxisols and Quartzipsamments grade into each other.

4.1.5. Stability of the Clay Fraction

Item 6 requires the oxic horizon to have a diffused upper textural boundary (i.e., 1.2 times clay increase within a vertical distance of 12 cm.).

Figure 3 shows that Item 6 was not satisfied by the Senai series and pedon SOR. Such failure to meet Item 6 was appropriate for the LAC Ultisols as their placement was not affected, but may not be for the Oxisols.

The Phuket series in Thailand illustrated the appropriateness of the placement of an Oxisol to the Ultisols by virtue of Item 6. Here the clay content increase at a vertical distance of 12 cm to the upper part of the oxic horizon is greater than 1.2 x clay content of the overlying horizon (Table 3, Appendix II). The new placement of the Phuket series was in accord with the presence of some weatherable minerals viz few mica flakes at the B23t and few feldspars at the B24t horizons that were confirmed in the mineralogy of the sand fraction as having relative amounts of 17 percent potassium feldspars in its fine sand fraction (0.1 - 0.25 mm) and 19 percent in the coarse sand fraction (1.0 - 0.5mm) (Proc. 2nd ISCW, Part II, 1978, pp 359-364).

Pedon OX-45 of the Senai series (Appendix I) did not qualify for an oxic horizon due to its abrupt upper textural boundary. It has, therefore, a kandic horizon. Being a light soil and having a kandic horizon, it could be placed in the order Ultisols. It has an ECEC of less than 1.5 meq per 100 g clay and also has positive delta pH in some horizons, that makes it one of the poorest soils in the world. It has an abrupt upper textural boundary which suggested that Item 6 needed to be refined to retain an oxic horizon for this pedon.

Two possible suggestions may be made to accommodate these soils in the order Oxisols. Either Item 6 may be modified with the addendum, "...unless there is an acric soil material within 1.25 m of the soil surface" or impose this provision in the ICOMOX'S key definition of the order Oxisols. This will be discussed further in the tests on the key definition of the order Oxisols.

4.1.6. Volume of Rock Structure

Item 7 defines the oxic horizon as one that has less than 5 percent by volume that shows rock structure unless the lithorelics containing materials are coated with sesquioxides.

The significance of this provision was illustrated by the Kapaa series (Table 4, Appendix II). It had a CEC by NH_4OAc less than 16 meq per 100 g clay from B21 to B25 horizons (115 cm thick). It had more than 5 percent weathered gravel. But because they were impregnated with gibbsite, they were permitted to have an oxic horizon as per Item 7. Other Orthox in Hawaii that lent support were the Makapili series (Table 4, Appendix II) and Pedons OX-37 of the Puhi taxadjunct, OX-25 of the Lawai, and OX-36 of the Pooku series. The latter 3 pedons have also >15 percent by volume of saprolite coated with goethite or gibbsite within varying depths and thicknesses.

The retention of these soils in the Oxisols was strengthened by the net positive delta pH in some parts of the oxic horizon. These are features of an extremely weathered soil that defines an acric soil material, whose adverse characteristics take precedence over the argillic or kandic horizon.

4.1.7. Amount of Gravel in Coarser Materials

Item 8 is an additional item proposed by ICOMOX to distinguish an oxic horizon (ICOMOX CL No. 8, 1982). The proposal reads, "Does not have more than 85 percent by volume of gravel or coarser materials."

The available pedon of Oxisols that contain considerable coarse materials such as stones, rock fragments and boulders were found in the South Pacific. The amounts of these materials were not quantified (Table 5, Appendix II, column 6), hence, they could not be used for testing. However, the absence of roots in the soils having these materials seem to suggest the significance of this criteria.

4.1.8. Application of Suggested Amendments to test Pedons

The summary of recommendations based on the preceding tests is in Table 11.

The suggested amendment of Item 3 recognized the presence of an oxic horizon for the pedons that were slightly contaminated with volcanic ash or have amorphous Fe and Al oxides that were not sufficient to alter their properties. It also prevented the LAC Inceptisols from having oxic horizons.

The suggested amendment of Item 5 refined the class limit from 8 to 10 percent in accordance with available data.

4.2. Testing Criteria of Oxisols

The ICOMOX'S proposed key definition of Oxisols that was tested reads:

Table 11. Recommended amendments to ICOMOX's proposals and their impact.

ITEM NO.	RECOMMENDED AMENDMENTS	IMPACT OF SUGGESTIONS	AMENDED DEFINITION OF THE OXIC HORIZON
1	None	None	None
2	None	None	None
3	Change pH in NaF limit from 9.4 to 10.0	1. Retained the Oxisols that are slightly contaminated with volcanic ash or have amorphous Fe and Al but not sufficient to alter gross properties; 2. The LAC Inceptisols were excluded.	Has a pH value in N NaF (1:50) of less than 10.0.
4	None	None	None
5	Change clay percentage from 8 to 10.	Refinement of class limit.	Has a texture of sandy loam or finer in the fine earth fraction and contains 10 percent more clay;
6	Include addendum, "Unless it has acric soil materials in any part to a depth of 1.5 m"*.	Accommodated the Oxisols that met the clay content increase of a kandic horizon and have acric soil materials.	Has a diffuse upper textural boundary, "unless it has acric soil materials within 1.5 m from the surface.
7	None	None	None
8	None	None	None

* Addendum may be made in Item 6 or in Item C.1 of the key definition of the order Oxisols.

"C.1. Other soils that either have less than 40 percent clay in the upper 18 cm, after mixing, and an oxic horizon with its upper boundary within 1 m of the soil surface and not overlain by an argillic or kandic horizon; or

C.2. Have 40 percent or more clay in the upper 18 cm of the soil, after mixing, and either an oxic or a kandic horizon with an apparent CEC of the clay fraction <16 meq per 100 g clay (NH_4OAc, pH 7 method), the upper boundary of which is within 1 m of the soil surface."

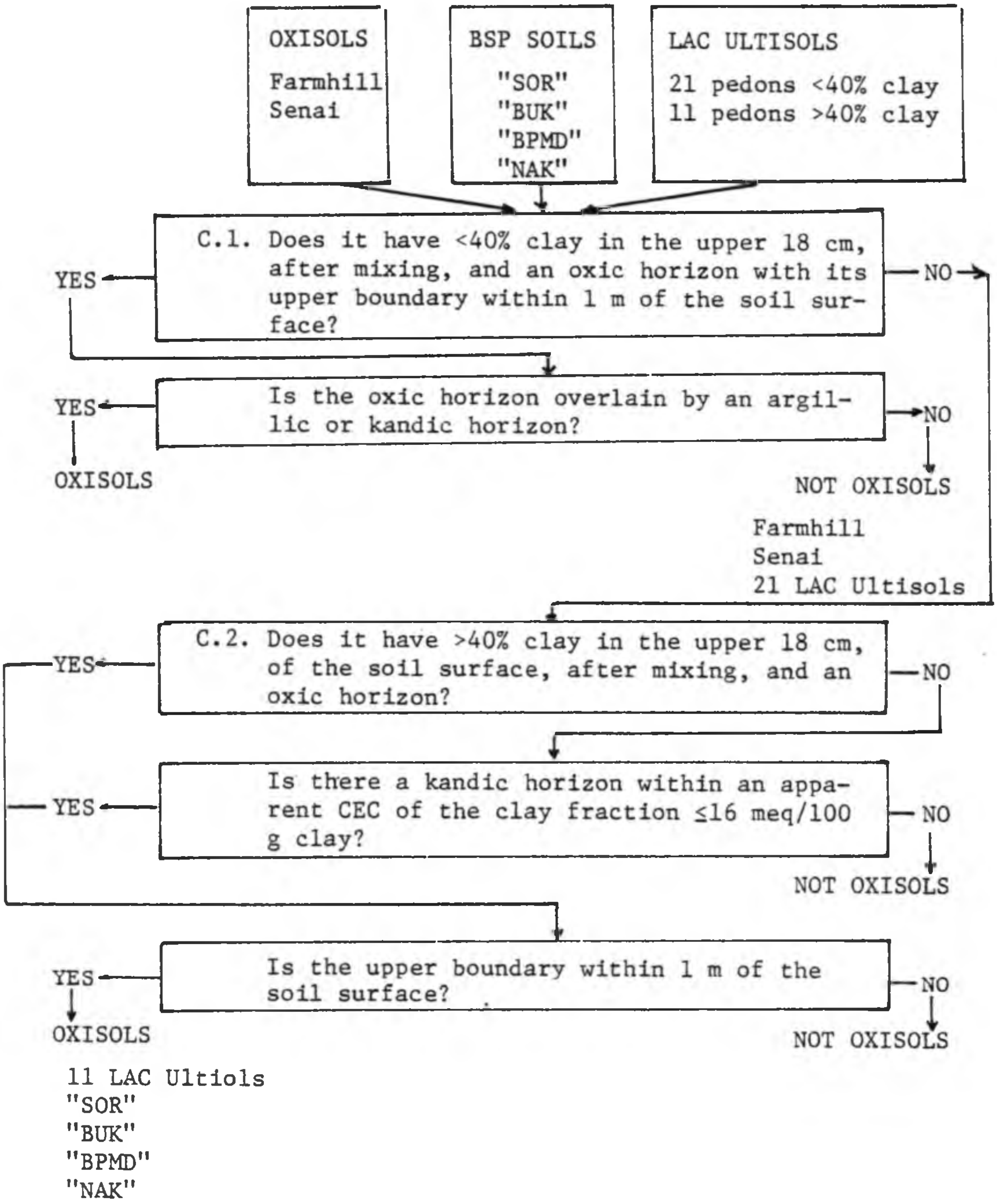
4.2.1. The Light Textured LAC Soils

The rationale for the 40 percent clay content limit are that the idenfitication of clay films in high clay soils is less certain than in low clay soils and the increase in clay content is much more important in ligth soils. The argillic horizon, therefore, takes precedence over the oxic characteristics (Uehara, personal communication).

The management implication is that the coarser textured overlying horizon in light soils have excellent features for cultivation and root proliferation, while the finer textured subsurface horizon(s) increases the capacity of the soil to retain more moisture and plant nutrients (Eswaran, personal communication).

Item C.1 was tested against the data of some Oxisols, LAC Inceptisols and LAC Ultisols having clay content <40 percent in the upper 18 cm, after mixing, in accordance with the flow-diagram in Figure 6. The test pedons of two Oxisols and the 21 LAC Ultisols were excluded from the Oxisols. The exclusion of the LAC Ultisols having low clay content is appropriate as it conformed with the rationale for Item C.1. This was illustrated particularly by the LAC Ultisols in Mainland, U.S.A. such as Pedons ULT-24, -32, -33, -36, -38, and -53. But the exclusion of the test pedons of Oxisols seem to indicated certain limitations of this item.

Figure 6. Fitting the test pedons into the flow-diagram key of the ICOMOX's definition of the order Oxisols.



The problem was illustrated by the Farmhill series in South Africa. It has less than 40 percent clay in the upper 18 cm, after mixing (Table 12). A plot of the clay content and CEC as a function of depth showed a kandic horizon with its upper boundary at about 62 cm from the soil surface (Figure 7). The CEC is <16 meq per 100 g clay at that depth and the ECEC is <12 meq in all horizons. However, it did not qualify for an oxic horizon due to the provision of Item 6 of the ICOMOX's definition that requires a diffuse upper textural boundary. The absence of an oxic, the presence of a kandic horizon and a base saturation <35 percent could place this pedon in the LAC Ultisols, by virtue of Item C.1.

But the adverse physico-chemical properties of the acric soil materials appear to be more important than a textural clay content increase of the kandic horizon. Here, the soils with acric materials are some of the poorest soils in the world on account of their inability to hold on to cations (Uehara, personal communication), imbalance between nutrient cations, deficiencies and/or toxicities, of some trace elements, low water holding capacity, and ability to fix high amount of phosphate (ICOMOX CL No. 7, 1981).

Hence, Item C.1 may be modified so that it could retain light textured (<40 percent clay) LAC soils that have acric soil materials in the Oxisols.

The suggested amendment reads, "Other soils that have acric soil materials within 1.25 m of the soil surface or have <40 percent clay in the upper 18 cm, after mixing and an oxic horizon within its upper

Table 12. Characteristics of the Farmhill series in South Africa that were used to test Item C.1 of the proposed ICOMOX's key definition of the Oxisols.

Depth	Horizon	Organic Carbon	Clay (<.002 mm)	Sum of Bases (meq/100 g soil)	CEC	ECEC	Base Sat. (sum)	pH			15-Bar Water
-cm-		- - - % - - -			(meq/100g clay)		- % -	H_2O	KCl	ΔpH	- % -
0-16	A1	11.70	16.8	2.5	38.3	7.6	5	5.2	4.4	-0.8	38.4
16-28	A2	7.34	10.0	0.6	35.0	1.5	1	5.4	4.8	-0.6	32.0
28-62	B1	1.98	11.5	0.5	16.9	0.9	3	5.7	5.3	-0.4	20.3
62-113	Bt1	0.20	20.0	0.5	7.8	1.6	7	5.9	6.3	+0.4	15.5
113-144	Bt2	0.13	22.4	0.5	7.9	1.2	7	5.9	5.7	-0.2	17.2
144-165	Bt3	0.10	20.4	0.7	8.0	1.7	8	5.8	5.7	-0.1	16.9

Source: Soil Management Support Services, SCS, USDA (1983).

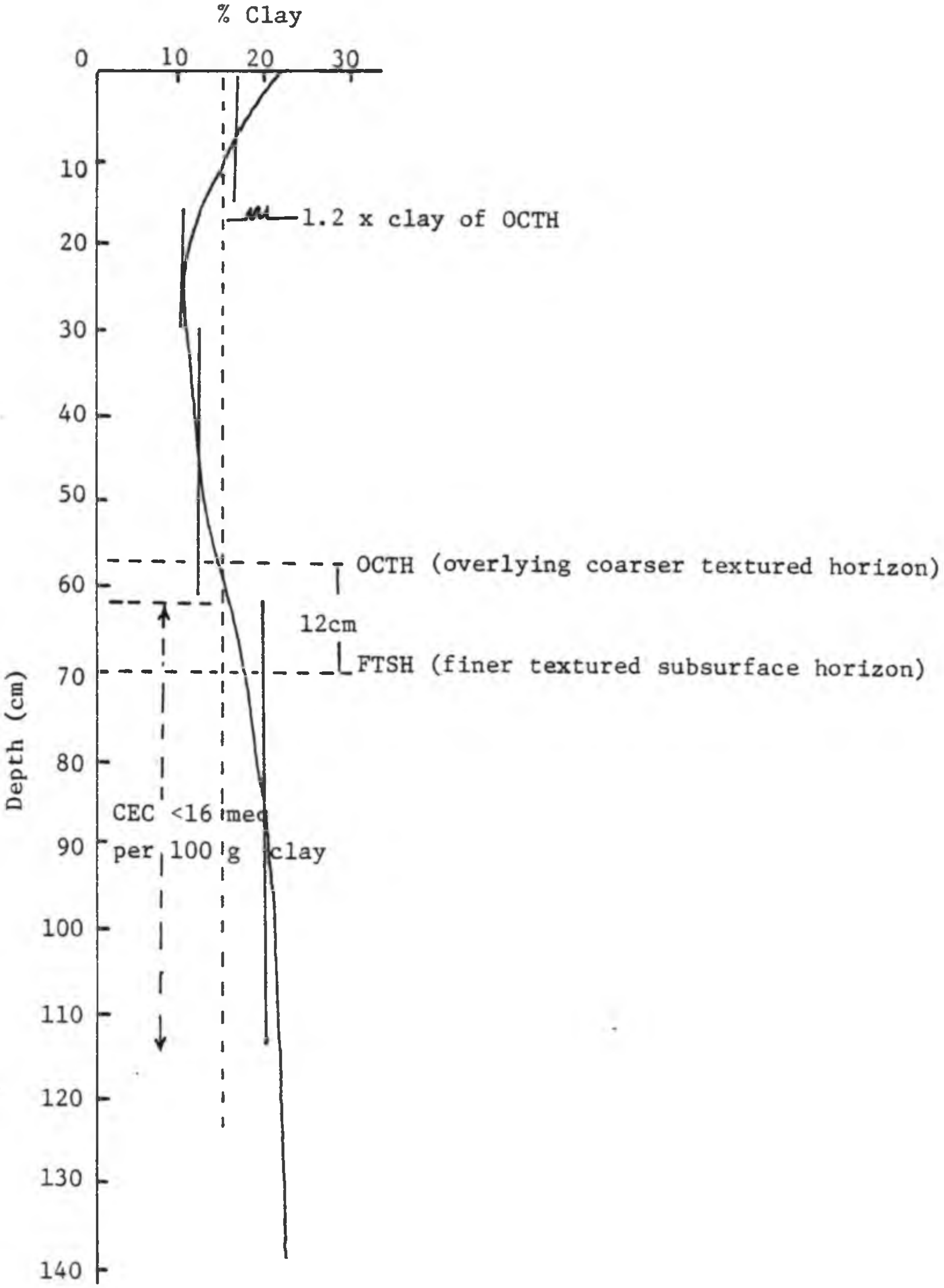


Figure 7. Clay content of the Farmhill series as a function of depth, showing the kandic horizon with a clear upper textural boundary.

boundary within 1.5 m of the soil surface and which do not meet the clay increase requirements of an argillic or kandic horizon, "or ...

The LAC Inceptisols having a delta pH of -0.2 or more positive like the Maile series (Table 13) will not be affected because the Andisols will key out before the Oxisols (Eswaran, personal communication).

Item C.1 was further tested with 21 selected pedons of the LAC Ultisols and Alfisols that have <40 percent clay in the upper 18 cm, after mixing, and a kandic horizon to assess its effect on the other parts of the system (Table 1, Appendix III). The result did not disturb their current placement which means that the criterion is appropriate.

The depth of the control section is suggested to be changed from 1.25 m to 1.5 m because the latter is the common depth for soil survey observations. It also parallels the proposed depth of the kandic horizon and it will be easier to remember only one value for the depth of the diagnostic horizons.

4.2.2. The Heavy Textured LAC Soils

Item C.2 permitted the entry of the 15 pedons of fine textured (>40 percent clay) LAC Ultisols that have kandic horizon into the Oxisols (Figure 6).

The rationale was that the high degree of weathering as evidenced by the low activity of the clay was more important to soil behaviour than the evidence of clay movement. Furthermore, a soil with a high clay content, yet very low CEC (≤16 meq per 100 g clay) ensure the dominance of oxic materials in the soil. Here, the extremely low nutrient retention capacity, and the low nutrient supplying capacity of the oxic

Table 13. Characteristics of a soil with ECEC less than 1.5 meq per 100 g clay and a positive ΔpH (Maile series, Hydric Dystrandept). Source: SSIR No. 29, 1976, p 30.

Depth	Horizon	Organic Carbon	Sum of Bases	KCl Extr.	ECEC	CEC	pH		
-cm-		--%--	- - - meq/100g clay- - - - -				H_2O	KCl	ΔpH
0-5	A11	18.00	12.3	1.2	13.5	56.2	5.5	4.5	-1.0
5-10	A12	5.12	1.3	1.1		25.5	5.4	4.5	-0.9
10-35	A13	11.74	0.3	0.7	0.8	56.1	5.2	4.9	-0.3
33-43	B21	10.55	0.4	0.2		43.2	5.3	5.1	-0.2
43-50	B22	9.75	0.6	0.2	0.4	38.2	5.4	5.3	-0.1
50-60	B23	9.04	0.2	0.2		43.6	5.5	5.3	-0.1
60-73	IIC	8.32	0.2		0.4	36.7	5.3	5.3	0
73-90	IIIB24b	8.89	0.4			42.5	5.1	5.3	+0.2
90-120+	IIIB26b	9.15	0.3	0.2	0.4	50.5	5.2	5.5	+0.3

soil materials override the benefits of the clay increase with depth of the argillic horizon or the kandic horizon.

Other advantages in the placement of some test pedons from the Ultisols to the Oxisols are related to the clay mineralogy that is predominantly of the variable charge type. According to Uehara (personal communication, 1983), the Al and Fe oxides in these soils are stable minerals at very low pH so that they pose no toxicity problems. However, they become toxic when the pH is too low because the oxides are dissolved and Al is released into the soil solution in toxic amounts. The difference in correcting this problem with other soils is an important consideration that should be reflected in the soil name. For example, a relatively small amount of lime is enough to bring the pH to about 3.5 as compared to the permanent charge soils, that requires a considerable amount of lime to raise the pH.

Item C.2 applied very well with the available test pedons of Oxisols. Its effect with the other parts of the system was tested with 11 representative pedons of LAC Ultisols (Table 2, Appendix IV). It was illustrated by the Pauwela and Paaloa series and the Haiku taxadjunct in Hawaii. These pedons have more than 40 percent clay in the upper 18 cm of the surface, after mixing, and a kandic horizon. Therefore, they could be placed in the order Oxisols. The appropriateness of their new placement may be viewed in terms of properties. Cline et al. (1955), described these soils as strongly acid to very strongly acid. They are leached of bases and silica resulting in the increased concentration of Fe, Ti, and Al. The sesquioxides cement the clay fraction into sand or silt-sized aggregates resulting in reduced water holding capacity and subsequent droughtiness after a few rainless periods. These properties greatly influence the management of these soils. Such properties indeed seemed to be more associated with the oxic materials than they are with the clay content increase in the argillic or kandic horizon.

Hence, they may be more appropriately classified as Oxisols. This was further illustrated by the Pauwela (Ultisol) and the Kapaa (Oxisols) series (Figure 8). According to de Datta et al. (1963), the rate of P immobilization by the two soils were similar. Hence, in terms of management, it seemed reasonable to suppose that the LAC Ultisols, having clay content $\geq$40 percent as illustrated by the Pauwela series are behaving more as Oxisols than as Ultisols.

The Pak Chong, Ban Chong, and the Kabin Buri series in Thailand illustrated the difficulty in ascertaining the presence or absence of the clay skins which are very vital in the identification of an argillic or kandic horizon.

The field morphological description of the Pak Chong series showed broken moderate cutans on ped faces (Proc. 2nd ISCW, Part II, 1979). The discontinuous clay skins and the CEC <16 meq per 100 g clay supported the presence of a kandic horizon. The kandic horizon and clay content >40 percent placed this soil in the Oxisols by virtue of Item C.2. Its micromorphological analysis, however, showed well oriented ferri-argillans that occupied about 15 percent of the area at 30 cm depth. This suggested instead the presence of an argillic horizon which was thought to have developed in the oxic material as a result of a large scale deforestation that changed the climate and the process of

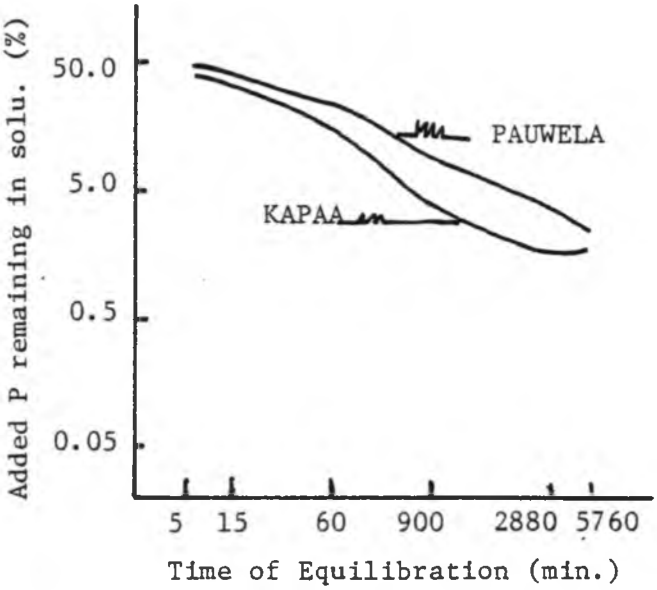


Figure 8 Immobilization of P by Pauwela and Kapaa soils during 4-day equilibration of soils with a P solution. Source: DeDatta et al. (1964)

soil formation (Proc. 2nd ISCW, Part II, 1979, p 265).

A plot of the clay content with depth of Pak Chong series showed that the upper boundary of the oxic horizon was above the argillic horizon (Figure 9). Here, preference was given the horizon nearest the surface on the assumption that the more recent process that dominate the soils' genesis produce the diagnostic horizons closer to the surface than the older process which produced the horizons at greater depths (Smith, 1980). This confirmed the placement of the Pak Chong series in the Oxisols.

The Ban Chong series was another pedon lending support to the change in classification of heavy textured LAC Ultisols to the order Oxisols (Table 1, Appendix III).

The new placement was viewed in terms of its management properties. It is droughty and the natural fertility is medium but will decline when cultivated without corrective measures (Scholten and Boonyawat, 1972). Here the problem of droughtiness perhaps is more associated with oxic characteristics of the Oxisols than with the clay increase in the kandic horizon of the LAC Ultisols.

4.2.3. Application of Suggested Amendments to the Test Pedons

The preceding test indicated the need to refine Item C.1 in order to accommodate the LAC soils with acric soil materials. The impact of the suggested amendments is shown in Table 14.

Item C.2 accommodated the heavy textured LAC Ultisols in the order Oxisols. Here, more importance is given to the effects of high degree of weathering than the evidence of clay movement.

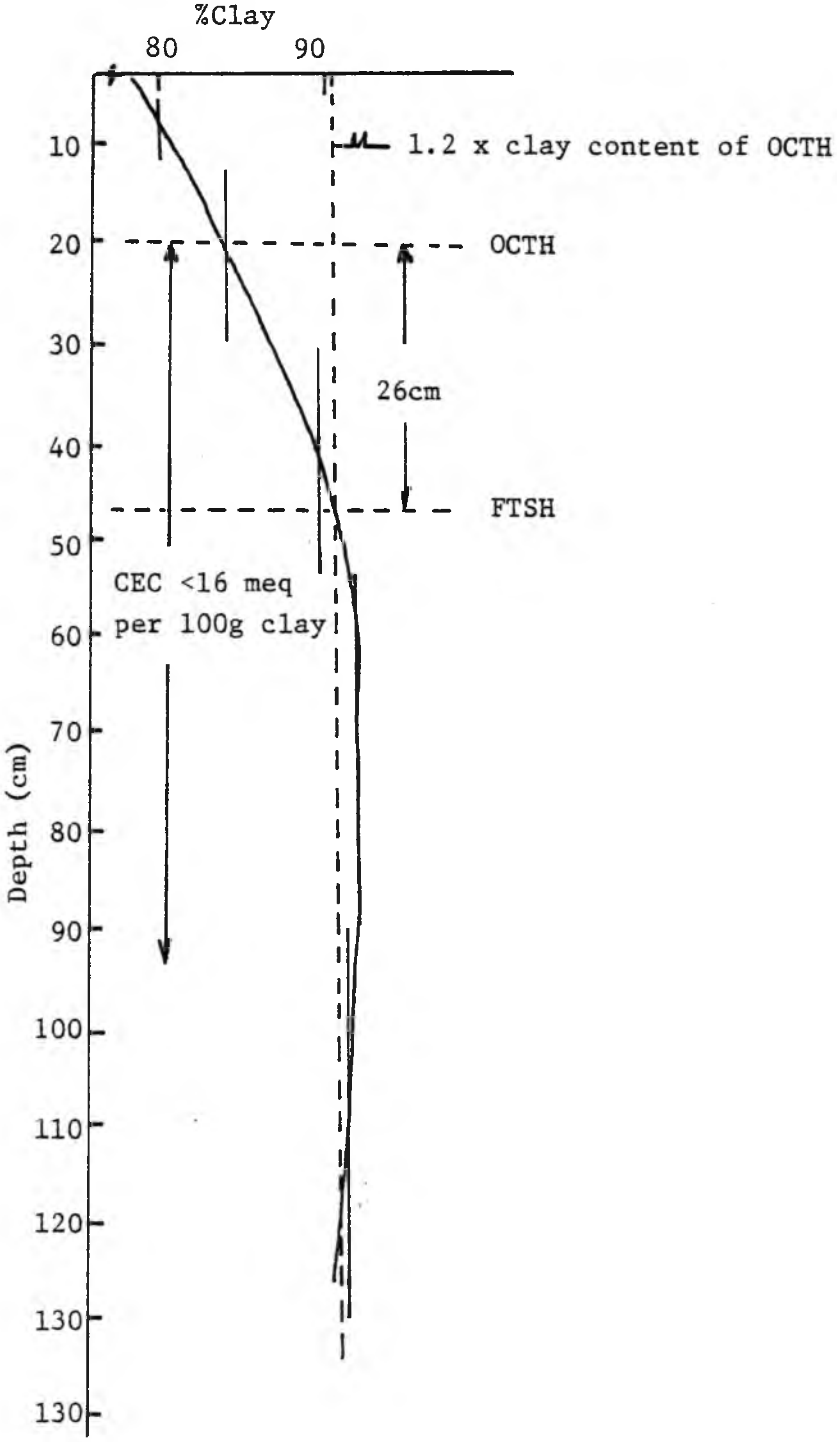


Figure 9. Clay content of the Pak Chong series as a function of depth, showing the oxic material on top of the argillic horizon.

Table 14. Result of taxonomic tests on the suggested amendments.

ITEM NO.	AMENDED DEFINITION	RESULT OF TESTS[*]
C.1	Other soils that 1. Have acric soil materials within 1.25 m of the mineral soil surface; and/or	1 pedon having acric soil material that did did not meet Item 6 of definition of oxic horizon was retained in the Oxisols.
	2. Have less than 40 percent clay in the upper 18 cm, after mixing, and an oxic horizon with its upper boundary within 1.25 m of the soil surface and which do not meet the clay content increase of an argillic or kandic horizon; or	21 LAC Ultisols were kept out of Oxisols.
C.2	Have 40 percent or more clay in the upper 18 cm of the soil surface, after mixing, and an oxic horizon.	11 LAC Ultisols and the 4 BSP pedons were placed in the Oxisols.

[*] 63 pedons of Oxisols and 36 pedons of LAC Ultisols were used.

The acric soil material is also suggested to be defined as a mineral soil material that has an ECEC as determined by the sum of bases (extracted with 1N NH_4OAc and KCl extractable aluminum) of <1.5 meq per 100 g clay and a delta pH ($pH_{KCl} - pH_{H_2O}$) of -0.2 or more positive within 1.5 m from the soil surface.

4.3. Testing Criteria of Lower Categories of Oxisols

The ICOMOX's key to the suborder was tested with the flow-diagram key in Figure 10 which was based on the most recent approximation as described in ICOMOX CL No. 10 (1983).

Here, substantial changes were made as shown in Table 15a and 15b.

4.3.1. Testing the ICOMOX's key to the Aquox

Item CA of the proposed key to the suborders of Oxisols defines the Aquox as "The Oxisols that are either saturated with water within 30 cm of the mineral surface for at least 30 days per year in more years or are artificially drained and have one or both of the following characteristics associated with wetness:

a. A histic epipedon, and/or
b. If free of mottles, immediately below any epipedon that has a moist color value of less than 3.5 there is a dominant chroma of 2 or less; or if there are distinct or prominent mottles within 50 cm of the soil surface, the dominant chroma is 3 or less or the hue is 2.5Y or yellower."

The ICOMOX's proposal deleted the plinthite that forms a continuous phase within 30 cm of the mineral surface. It also quantified the required duration of water saturation and introduced the color criterion of 2.5Y or yellower.

The ICOMOX key to the Aquox was tested against the data of 8 available pedons in Sumatra using the flow-diagram key to the great groups in Figure 11. Pedon OX-40, an Umbraquox was excluded while Pedon ULT-36, a Paleaquult was accommodated in the order Oxisols.

Figure 10. Flow-diagram key to test the ICOMOX's proposed suborders of Oxisols.

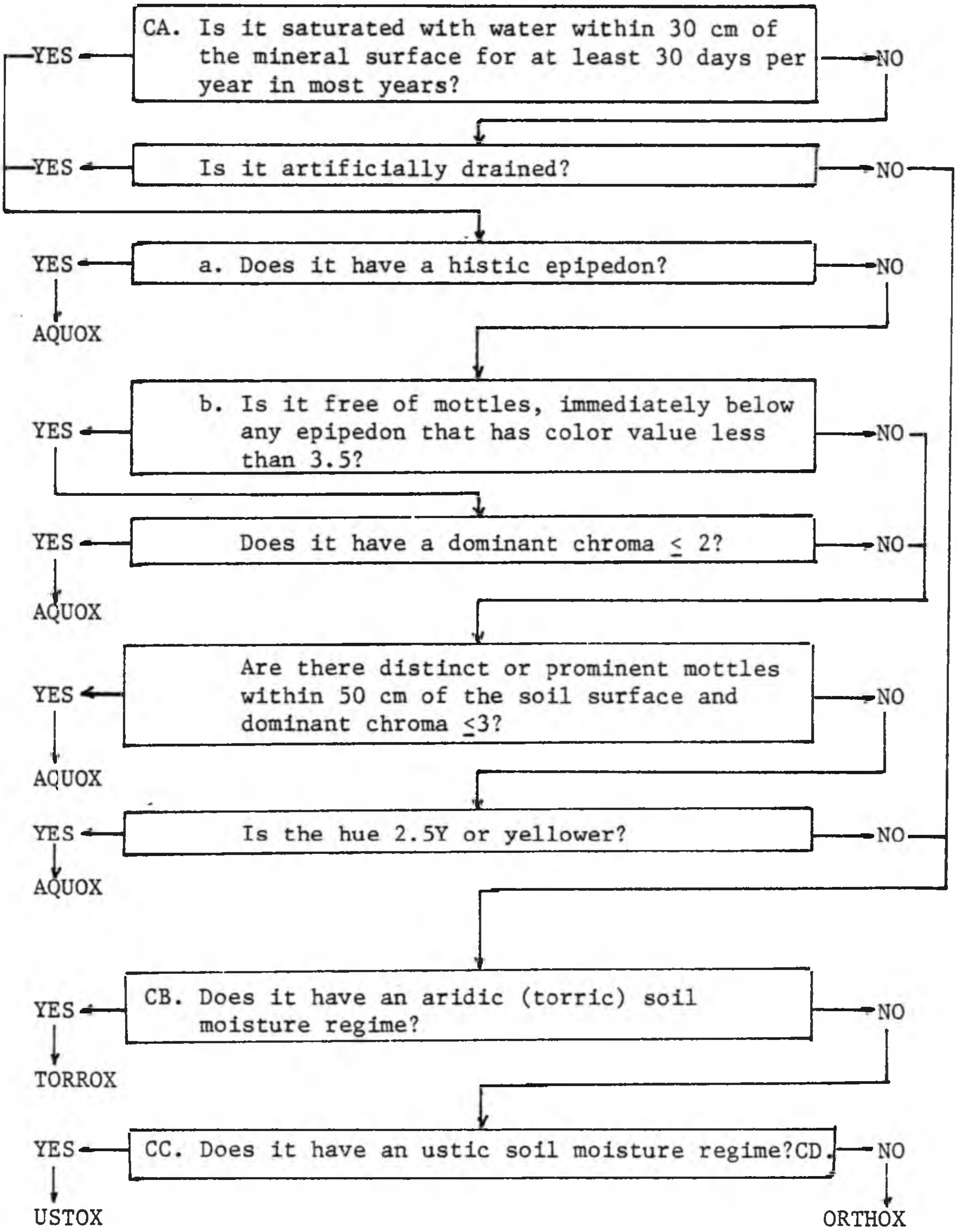


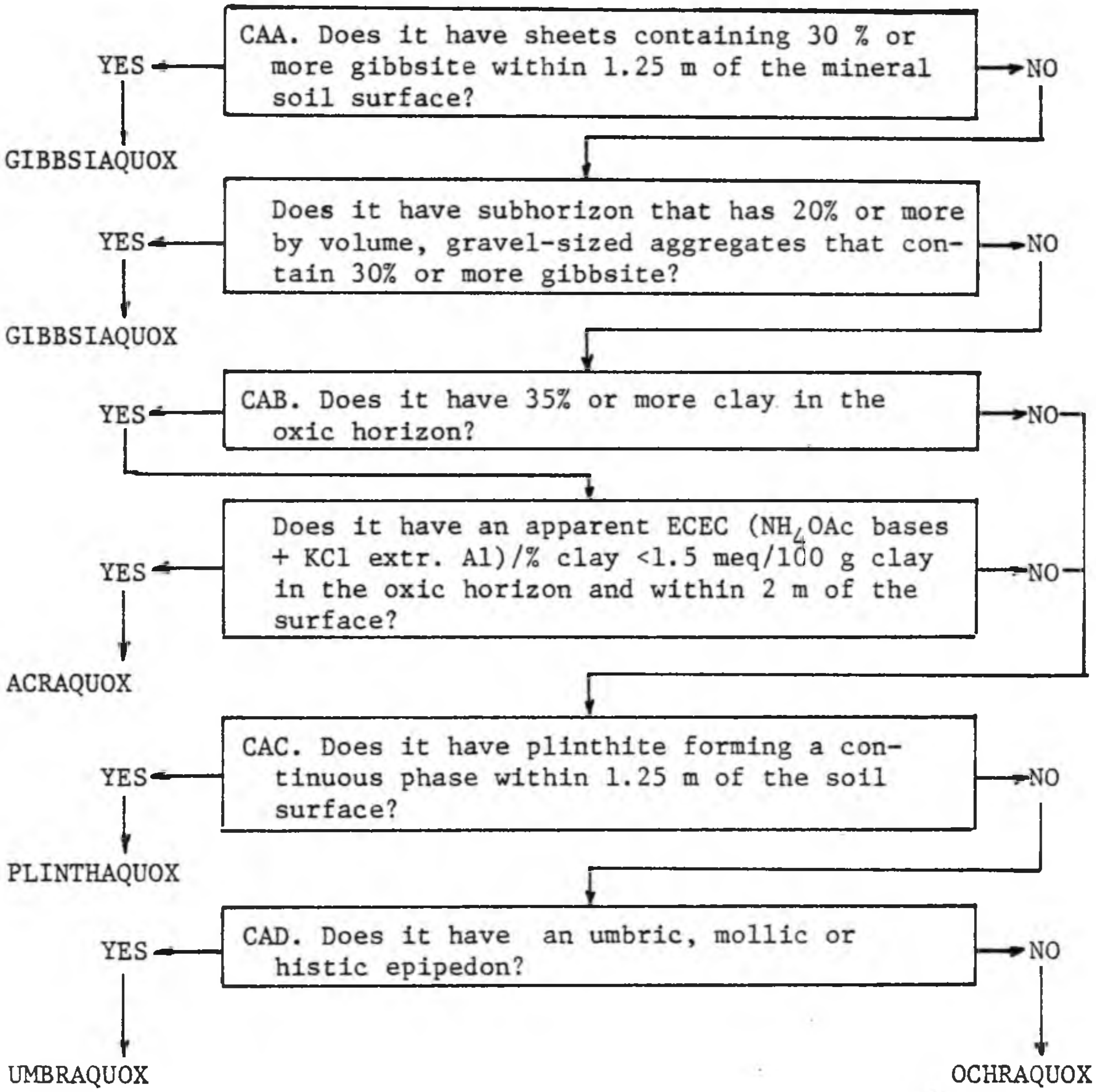
Table 15a. Distribution and placement of the great groups in the key to the suborders of Oxisols in Soil Taxonomy.

	SUBORDERS				
GREAT GROUPS	AQUOX	TORROX	HUMOX	USTOX	ORTHOX
Sombr		X	X	X	X
Gibbsi	X		X		X
Plinth	X				
Ochr	X				
Acr		X	X	X	X
Eutr		X		X	X
Umbr	X				X
Hapl		X	X	X	X

Table 15b. Proposed distribution and placement of the great groups in the key to the suborders of Oxisols (ICOMOX CL No. 9. 1982).

Gibbs	X			X	X
Acr	X	X		X	X
Plinth	X				
Umbr	X				
Ochr	X				
Eutr				X	X
Kur		X		X	X
Hapl		X		X	X

Figure 11. Flow-diagram key to test the ICOMOX's proposed great groups of Aquox.



Pedon OX-42 shifted from the Orthox to the Aquox. The details and rationale follow as they were keyed into the lower categories.

4.3.1.1. Test of the Umbraquox - The properties of Pedon OX-14 in Sumatra agree well with the ICOMOX's key to the Aquox. However, Pedon OX-40, an Umbraquox was excluded from the order Oxisols because the upper boundary was not diffuse as required in Item 6 of the ICOMOX's definition of the oxic horizon. It was placed instead in the "kandi" great group of Ultisols. The change in classification may be viewed in terms of the low clay content of <40 percent in the surface 18 cm, which is favorable for tillage operation and ease of root proliferation while the higher clay content in the subsurface horizon increases its water and nutrient retention capacity. These management properties are more important then the oxic characteristics.

4.3.1.2. The Ochraquox - Item CAE (see Figure 11) of the key to the great groups of Aquox was tested with Pedon OX-22 of the Kuamang series in Singkut, Sumatra (Table 1, Appendix IV). It illustrated the common and distinct mottles and the dominant chroma of 3 or less that define the suborder Aquox. This was confirmed by the properties of the Alai and Kersik series in Sumatra. Pedon OX-22 of the Kuamang series, supported by the data of Pedon OX-3 of the Babeko series in Singkut, Sumatra in the same table illustrated the chroma greater than 2 in some horizons below the epipedon that diagnose the aeric subgroup.

Pedon OX-42 of the Rukani series in Alai Hilir, Sumatra showed the change in classification from the Orthox to the Aquox. Its position in a valley bottom and its imperfectly drained condition, plus the distinct mottles within 50 cm of the soil surface and a hue of 2.5Y in the oxic horizon strongly favored its placement in the Aquox. The chroma greater than 2 in the major part of the horizon also illustrated properties that define an Aeric subgroup.

Item C.2 of the key definition of the order Oxisols, placed pedon ULT-34 of the Grady series in Georgia, U.S.A. from the Ultisols to the Oxisols. Item CA.b (see Figure 10) of the key to the suborders placed it from the Aquults to the Aquox and Item CAE placed it in the great groups of Ochraquox owing to its ochric epipedon. There were not enough data, however, to support this new placement. It is possible that it is in the border line between the Ultisols and the Oxisols.

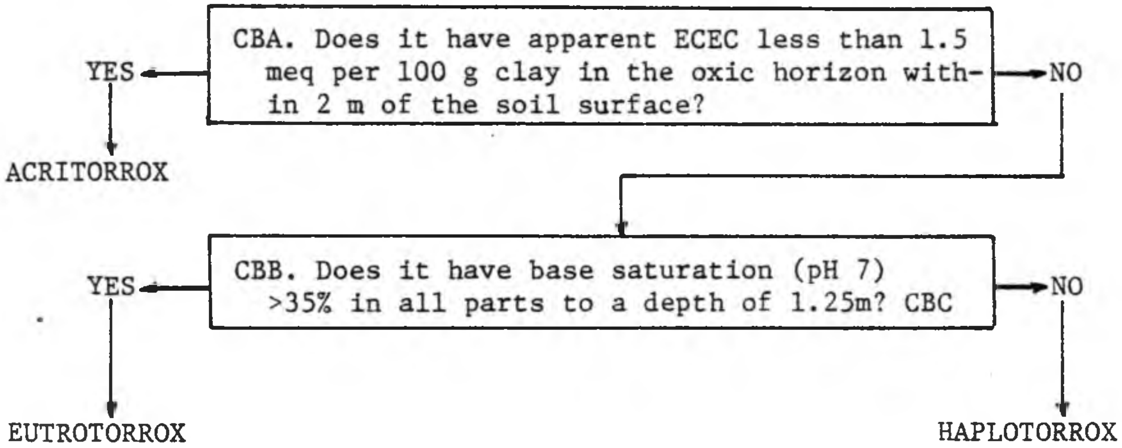
4.3.2. Testing the ICMOX's key to the Torrox

Item CB (see Figure 10) of the key to the suborders introduced three great groups of Torrox (Figure 12). Pedons OX-31 and OX-32 of the Molokai series (Table 2, Appendix IV) and Pedon OX-33 (Yaibuathes, 1966) were reported to have torric soil moisture regime and isohyperthermic temperature regimes. They illustrated the provisions of Item CB for the suborder Torrox.

4.3.2.1. The Eutrotorrox - Item CBB (see Figure 12) of the key to the great groups of Torrox was illustrated by Pedons OX-31 and OX-32 with base saturation ranging from 41 to 49 percent. The delta pH was more negative than -0.2 and the ECEC was greater than 1.5 meq per 100 g clay in all horizons.

Pedon OX-33, however, had base saturation less than 35 percent in the Ap2 horizon which fell short of the requirement. On this basis, the definition of Eutrotorrox may be modified as, "Other Torrox that

Figure 12. Flow-diagram to test the ICOMOX's key to the great groups of Torrox.



have >35 percent base saturation at pH 7 in the major part of the oxic orizon."

In Hawaii, the Torrox show no distinct differentiating properties to permit separation at the great group or subgroup level. Hence, they are Typic Torrox (Soil Survey Staff, 1972). With the ICOMOX proposal, their placement in the Eutrotorrox seem to be an improvement because enrichment of bases is appropriately reflected in the "Eutr" taxon. This was illustrated with the Molokai series, which is considered one of the best soils in the Hawaiian Islands for sugarcane under irrigation, mainly because it is well supplied with bases and it receive much solar radiation (Cline, et al., 1955).

Such placement, however, is not without question because in Soil Taxonomy, p 91, it says that the full definition of a great group as a subdivision of the suborder is usually followed by description of a soil that represents the central concept of the great group. The soil that represents the central concept is used as reference to determine the variants which reflects a soil forming process other than those responsible for the soils belonging to the central concept. These variants are keyed out first, leaving the soil representing the central concept last in the key which is the "Hapl" great group.

In this respect, the Torrox is described as the Oxisols having a relatively high base saturation (Soil Taxonomy, p 33). Concsequently, the Haplotorrox must have a high base saturation and, therefore, those with lower base saturation are the Dystorrox. In other words, the "Hapl" great groups of Torrox become the counterpart of the "Eutr" great groups in the other suborders.

In order to parallel the class limit of the "Eutr" great groups in the other parts of the system, the Haplotorrox may be defined as, "Other Torrox that have more tha 35 percent base saturation at pH 7 in the major parts to a depth of 1.5 m." Or in the key, the Dystorrox will be defined as, "Torrox that have less than 35 percent base saturation at pH 7 in the major parts to a depth of 1.5 m." And, therefore, the Haplotorrox will also be defined as, "Other Torrox". "Acric" great group of Torrox is proposed, but this has yet to be found before it is included in the key.

4.3.3. Illustration for Suggested Retention of the Humox Suborder

One of the major changes in the ICOMOX proposal is the deletion of the suborder Humox. Apparently, this is a debatable proposition. On one side, its deletion may be favorable assuming that clearing the forest and putting it into cultivation would easily lead to the rapid decline in organic carbon content and eventually result to a possible change in classification within a short time. This is in accord with Soil Taxonomy as provided on page 8, which reads, "the differentiae should keep an uncultivated soil and its cultivated or otherwise non-modified equivalents in the same taxon in so far as possible."

Furthermore, the definition of the "Hum" taxon in Soil Taxonomy is being questioned. For instance, the organic carbon-temperature criteria are constraints in Brazil (Bennema and Camargo, 1979) and in Australia (Isbell, 1979) because some soils high in organic carbon content are also found outside regions having thermic or cooler soil temperature regimes.

On the other side, the retention of suborder Humox may be reasonable because the Humox could be geographically delineated, which is one of the purposes of the taxa at the suborder level. This was demonstrated by Ikawa (1979) with the Humox in Hawaii, Leamy _et al_., (1979) in the South Pacific, and Eswaran (personal communication) in the high plateaus of Zaire. According to Eswaran, the properties of the Humox also reflect a process which is another function of the suborder category.

A test of the Humox with Pedons OX-27, OX-37, OX-18, OX-28, OX-25, OX-31, OX-41, OX-24, OX-17, and OX-45 representing different soil moisture regimes showed that the CEC increased with increasing amount of organic carbon content. This seemed to suggest that the organic carbon content may be masking the low CEC of the clay fraction (Figure 13). Apparently, this makes the organic matter-rich Oxisols better than the organic matter-poor Oxisols.

The Humox are also presumed to occur in cooler places, where humus has more chances to accumulate. Pedons OX-27 and OX-15 in Hawaii, OX-62 in Brazil, OX-46 in the South Pacific; selected Orthox such as pedons OX-37, OX-18, OX-36, OX-25, OX-28 in Hawaii; and selected Ustox such as OX-26 in Hawaii illustrated the increasing organic carbon content as the soil temperature regime decrease (Figure 14). Apparently they indicated that Humox are more confined in the cooler climates where moisture regime is udic.

The properties of the Halii series (Gibbsihumox) and the Mahana series (Acrohumox) in Hawaii, Pedon OX-7, an Acrohumox in Parana, Brazil, and Pedon OX-18 of the Farmhill series (Acrohumox, tentative)

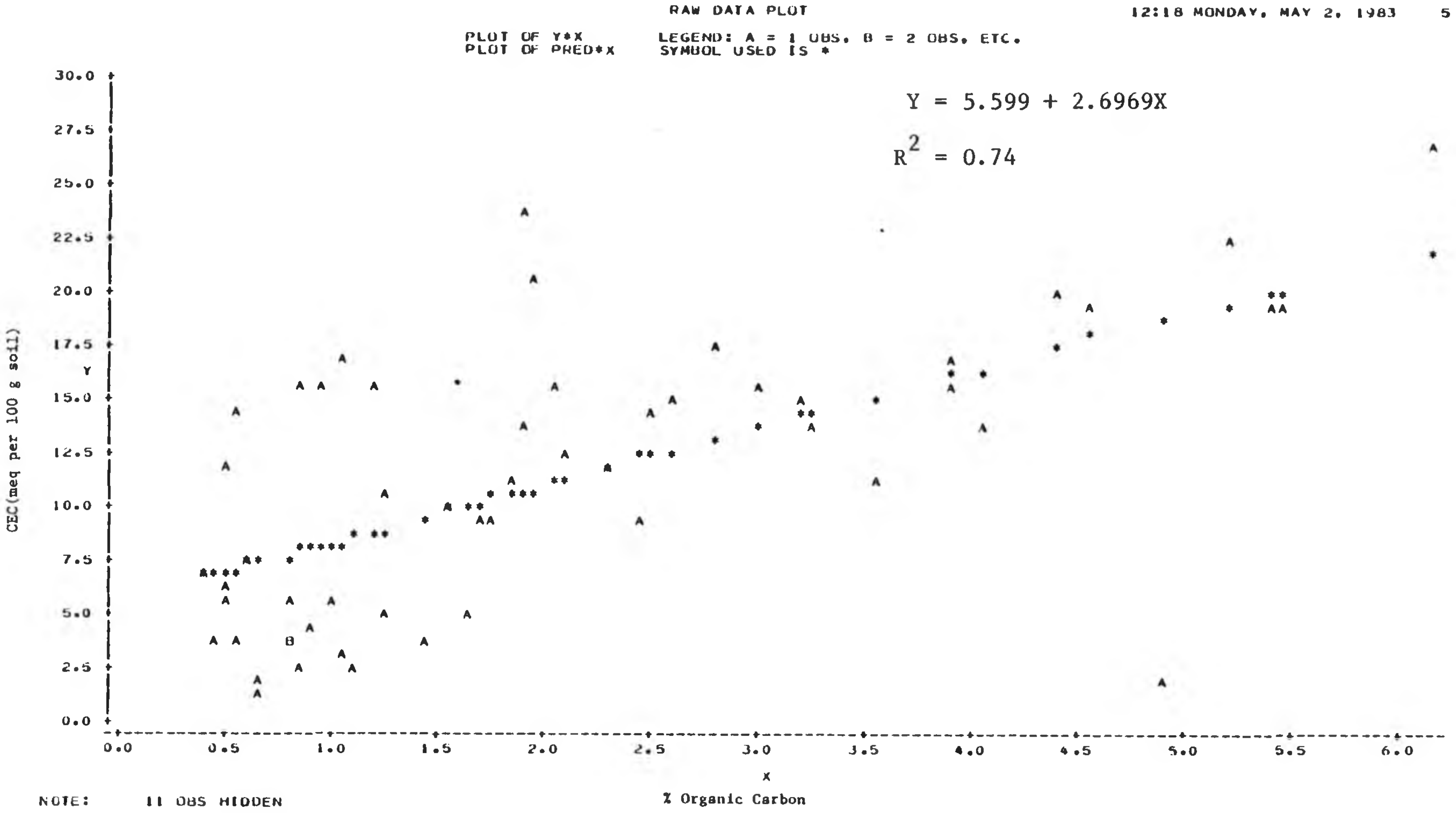


Figure 13. Relationship between organic carbon content and the cation exchange capacity of some pedons of Oxisols.

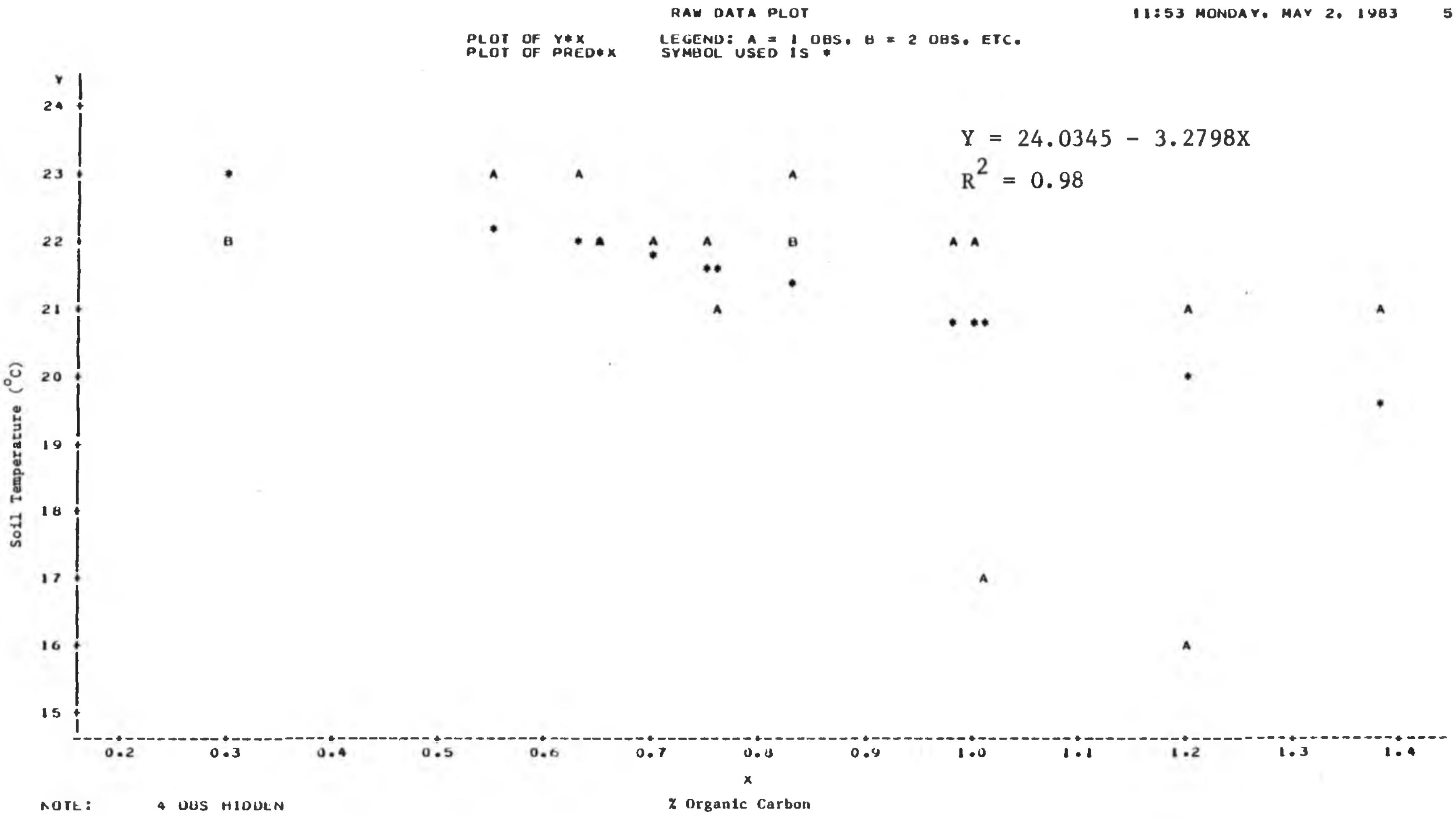


Figure 14. Relationship of percent organic carbon content and soil temperature in selected pedons of Oxisols.

in South Africa illustrated the mollic or umbric criteria.

These evidences supported the inclusion of the "Hum" taxon at the suborder level. It may be defined as "Other Oxisols that have a mollic or umbric epipedon." There were, however, pedons having umbric epipedon such as the Pedons SOR and NAK of the BSP whose performance were not better than the Orthox. To exclude them from the Humox, the "Hum" taxon should be further defined to have an organic carbon content ≤ 16 kg/m^2 to a depth of 1 m.

The ochric epipedon having 1.0 percent organic carbon content to a depth of 75 cm was illustrated by Pedon OX-46 of a Haplohumox in the New Hebrides and Pedon OX-16 of the Pooku series (Acrohumox) in Hawaii. This could be another possible criterion for Humox. Here the ochric epipedon and ≥ 16 kg/m^2 of organic carbon content to a depth of 1 m will accommodate the cleared and cultivated Humox.

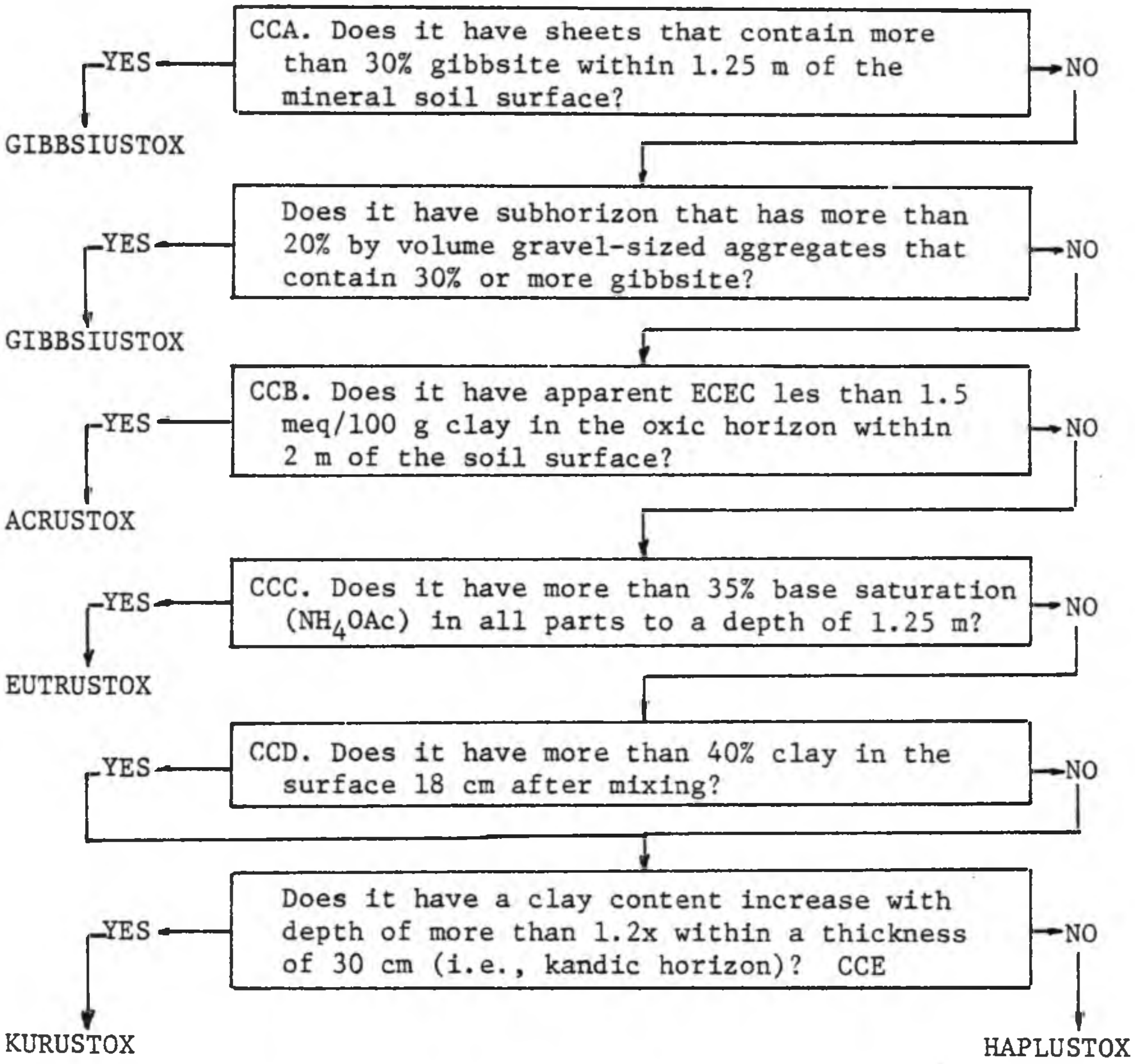
Pedon OX-34, however, of the Nipe series in Puerto Rico, met these criteria but the significance of the organic carbon content >1 percent to a depth of 75 cm was not demonstrated in the performance of this soil compared to the other soils currently classified as Acrorthox in Puerto Rico (Eswaran, personal communication). Further testing of this criterion is, therefore, needed.

4.3.4. Testing the ICOMOX'S Key to the Ustox

Item CC (see Figure 14) of the key to the suborders of Oxisols keys out the Ustox with an ustic soil moisture regime.

Ten representative pedons of Oxisols in Hawaii, Fiji, and in Thailand and several others from other orders were used to test the ICOMOX'S key definition of the Ustox as outlined in Figure 15.

Figure 15. Flow-diagram key to test the proposed ICOMOX's great groups of Ustox.



4.3.4.1. The Eutrustox - Item CCC (see Figure 15) of the ICOMOX'S key to the great group of Ustox was illustrated by Pedons OX-59 of the Wahiawa series and OX-16 of the JAIBA soil with base saturation by NH_4OAc >35 percent in all parts to a depth of 1.25 m. Pedon OX-10 of the COTO series illustrated certain limitations of the provision of Item CCC. The percentage base saturation by NH_4OAc was not more than 35 percent in all parts to a depth of 1.25 m. This was confirmed by a duplicate pedon of COTO series in SSIR No. 12 (1967) which also showed less than 35 percent base saturation in the B21 and B22 horizons. The similar response of COTO to a given management as those of pedons OX-59 and OX-16 (BSP Tech. Report, 1980) suggested its placement in the same taxa with the latter 2 pedons. On that basis, the "Eutr" great groups may be defined with a limit of ≥35 percent base saturation by NH_4OAc in the major part of the oxic horizon. This corroborated the suggestion made earlier for the "Eutr" great groups of Torrox.

4.3.4.2. The Kurustox - Item CCD of the ICOMOX'S key to the great group of Ustox was illustrated by the Ban Chong series in Amphoe Kabin Buri, Thailand with >40 percent clay in the upper 18 cm, after mixing and a clay content increase of an argillic horizon. Its placement from Ultisols to Oxisols may be viewed in terms of its infertile, droughty and unsuitability to paddy rice. Its droughtiness and unsuitability to paddy rice demonstrated its inability to store water. Here, increased water retention is supposed to be one of the benefits associated with the argillic horizon. Hence, the oxic characteristics take precedence over the clay content increase of the horizon. Such clay increase, however, is recognized at the "Kur" great groups.

4.3.4.3. The Haplustox - Item CCE (see Figure 15) of the ICOMOX'S key to the great groups of Ustox was tested with Pedon ULT-62 of the Pak Chong series in Thailand. It illustrated the change in placement from Ultisols to Oxisols by virtue of a clay content that is more than 40 percent in the upper 18 cm, after mixing (Item C.2) and an oxic horizon, the upper boundary of which is within 1 m of the soil surface. Such change in classification may be supported by its droughtiness during periods of insufficient rainfall and unsuitability for paddy cultivation because it is too permeable to impound water (Scholten and Bonnyawat, 1972). These important features appeared less related to the clay accumulation of the argillic horizon than the oxic characteristics. It follows, therefore, that this property is better reflected in the new name Haplustox than the current classification as Paleudults.

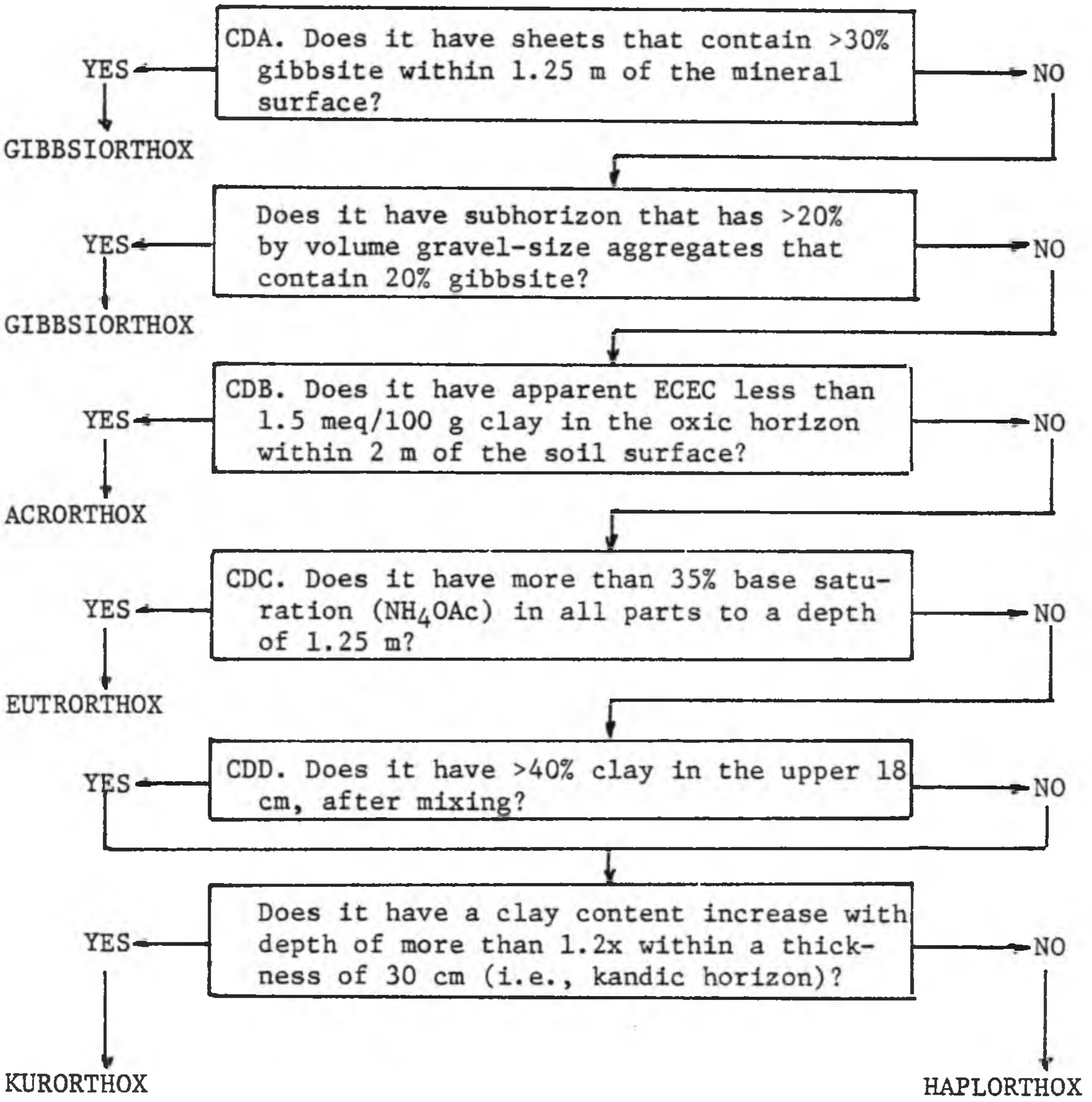
4.3.5. Testing the ICOMOX'S Key to the Orthox

Item CD (see Figure 10) of the ICOMOX'S key to suborders Oxisols keys out the Orthox. It was tested against the data of thirty two pedons in Malaysia, Thailand, Puerto Rico, Indonesia and in the Ivory Coast.

4.3.5.1. The Gibbsiorthox - Item CDA (see Figure 16) of the great groups of Orthox was tested against the Kapaa, Pooku, Halii series in Hawaii and pedon OX-52 in Western Samoa.

In the South Pacific Region, Latham mentioned that Soil Taxonomy do not accommodate soils having gibbsite as high as 40 percent in the "Gibbsi" great groups. This was corroborated by Leslie and Blakemore (1979) in Banuato Santo, in the Solomon Islands; Quantin in the New

Figure 16. Flow-diagram key to test the ICOMOX's proposed great groups of Orthox.



CDA. Does it have sheets that contain >30% gibbsite within 1.25 m of the mineral surface?

Does it have subhorizon that has >20% by volume gravel-size aggregates that contain 20% gibbsite?

CDB. Does it have apparent ECEC less than 1.5 meq/100 g clay in the oxic horizon within 2 m of the soil surface?

CDC. Does it have more than 35% base saturation (NH_4OAc) in all parts to a depth of 1.25 m?

CDD. Does it have >40% clay in the upper 18 cm, after mixing?

Does it have a clay content increase with depth of more than 1.2x within a thickness of 30 cm (i.e., kandic horizon)?

Hebrides; and Tercinier in Tahiti as cited by Latham (1981).

The important attribute of the "Gibbsi" taxon seem to be the sheets or gravel-size aggregates of gibbsite that appear to inhibit root proliferation as indicated by root mats above the gibbsite sheets in the Kapaa and the Pooku series (Table 16).

Table 17 shows the P requirement of some Oxisols in relation to their mineralogies. The Kapaa series (a "Gibbsi" great group) which is predominantly gibbsite and goethite sorbed more P than the non-"gibbsi" soils like the Wahiawa and Molokai series. This indicated a different management property for the "Gibbsi" taxa.

In another case, Younge and Plucknett (1966) demonstrated a heavy application of P to increase crop yields of the bauxitic Kapaa soils in Kauai. Foote et al. (1968) also found that residual fertilizer phosphate efficiencies were greater for strip soil than for the surface soil in the Kapaa series. These evidently showed that bauxitic materials may be management limitations in the "Gibbsi" taxon.

Table 18 shows, however, that there is no root matting in the pedons that have more than 30 percent gibbsite in the whole soil suggesting that the high gibbsite content may not be a management limitation unless they are in sheets or in gravel-size aggregates. This seems to support Item CDA (see Figure 16) in excluding these soils in the "Gibbsi" great group. Nevertheless, Soil Taxonomy considers soils having more than 40 percent gibbsite in the whole soil as gibbsitic in the mineralogy class. It might be mentioned that ICOMOX proposes to delete the gibbsitic mineralogy class on the presumption that it is covered by the "Gibbsi" great groups (ICOMOX CL No. 10, 1983). Table 16,

Table 16. Some diagnostic attributes of selected pedons related to Gibbsi characteristics.

Depth	Horizon	Mineralogical Anal. KK	GI	GE	MT	Org. Carbon	Base Sat.	CEC	ECEC	Soil Color	pH	Root Distribution	Description
-cm-		--pct of whole soil--				----pct-----		-meq/100g clay-					
Kapaa series, Typic Gibbsiorthox,clayey,oxidic,isohyperthermic. Kauai,Hawaii (SSIR No.29,pp 164-165).													
0-30	Ap	10	25	40	5	3.92	11	21.2	3.1	10YR4/3	-0.5	M	-
30-40	B21	0	30	35	10	1.46	14	4.2	0.6	5YR4/6	+0.2	f	5% swgi GI
40-63	B22	0	30	35	10	1.09	31	3.4	1.0	5YR4/8	+0.2	vf	20% swgi GI
63-90	B23	0	35	30	10	0.64	26	2.4	0.6	5YR4/6	-0.1	vf	40% swm sbw
90-123	B24	0	10	30	15	0.46	32	4.6	1.6	5YR4/8	+0.1	vf	60% swm sbw
123-150	B25	20	10	30	20	0.48	24	7.6	1.7	5YR4/4	-0.6	n	-
Pooku series, Typic Gibbsiorthox,clayey,oxidic,isohyperthermic. Kauai,Hawaii (SSIR No.29, pp168-169).													
0-38	Ap1	5	40	40	15	3.88	9	18.9	2.1	10YR4/4	-1.0	m	-
38-48	Ap2	2	35	50	2	2.43	2	11.4	0.4	10YR4/4	-0.3	c	-
48-75	B21	-	25	40	15	1.58	12	5.8	0.8	5YR3/4	+0.1	-	ncps
75-100	B22	-	35	40	10	1.10	t	3.5	-	5YR3/4	+0.5	c	M on dis
100-155	C1	-	45	40	10	0.66	26	2.9	0.9	5YR3/3	+0.6	f	tp of HE GI
155-225	C2	-	45	30	15	0.16	20	1.1	0.4	5YR2/3	+0.4	-	ts of HE GI
Halii series, Typic Gibbsihumox,cleyey,ferritic,isothermic. Kauai, Hawai (Ikawa, 1979).													
0-33	Ap					2.87	24	36.1	8.8	10YR3/3	-0.4	n	-
33-58	B21					1.91	12	24.3	3.1	10YR3/4	-0.2	n	10-20% sap
58-76	B22					1.31	6	14.6	0.9	7.5YR4/4	+0.1	n	50% sap
76-112	C1					0.99	6	13.5	0.9	5YR3/4	+0.2	n	80-90% sap
OX-52,Typic Gibbsiorthox,clayey,oxidic,isohyperthermic.Afiamalu, W.Samoa (Proc 2nd ISCW, 1979, p 188).													
0-3	A					20.6	16	59.7	15.0	5YR3/3	-	-	-
3-30	B					6.0	4	-	-	7.5YR4/4	-	-	-
51-61	C		36.0			1.9	10	7.7	0.7	2.5YR4/6	-	-	-

Mineralogy: KK=kaolinite, GI-gibbsite, GE-goethite, MT=magnetite, HE=hemathite. Root Distribution: M=root matting, m=many, c=common, a=abundant, ve=very few, f=few, n=none. Description: swgi=strongly weathered gravel impregnated with, swm=strongly weathered material, sbw=streaks of black and white, ncps=nearly continuous pressure surface, dis=discontinous iron seam, tp=thin plates,ts=thin sheets, c=common, sap=saprolite.

Table 17. P sorption capacity of selected Oxisols.

Soil Series	Present Classification	Important Secondary Minerals	Parent Material	P-sorbed at 0.2ppm P in supernatant (ppm)
Molokai	Torrox	1:1 clays	Basalt	30
Wahiawa	Eutrustox	1:1 clays	Basalt	390
Kapaa	Gibbsiorthox	Gibbsite Goethite	Basalt	660

Source: Fox *et al*. (1968).

Table 18. Characteristics of pedons that are not accommodated by Item CDA[a] of the proposed key to Orthox great groups.

Depth	Horizon	Clay Content (<.002mm)	CEC	ECEC	Root Distribution	Comments
-cm-		(%)	-meq/100g clay-			
OX-49, Leptic Acrorthox, clayey, gibbsitic, isohyperthermic. Kolombangara, Solomon Islands (Proc 2nd ISCW Part I, 1979, pp 181-182).						
0-15	A1	35.8	18.7	1.7	s	50-70% GI
15-61	A1g	-	-	-	vf	
61-71	AC	45.3	3.8	0.1	n	
71-+	AC	15.0	3.3	0.2		
OX-50, Haplic Acrorthox, clayey, gibbsitic, isohyperthermic, Kolombangara, Solomon Islands (Proc 2nd ISWC Part 1, 1979, pp 183-184).						
0-10	A11	52.8	44.5	8.7	m	40% GI and
10-28	A12	-	-	-	f	35% KK
28-81	B	54.5	7.2	0.1	vf	
81-127	-	-	-	-	n	
OX-55, Tropeptic Eutrorthox, clayey, oxidic, isohyperthermic. Bua Prov., Vanua Levu, Fiji (Proc 2nd ISCW Part I, 1979, pp 193).						
0-8	A	53.3	40.9	23.6	c	25-40% GI
8-23	B	63.8	14.9	5.8	f	15-30% KK
30-45	C	75.0	7.2	2.8	f	

a - CDA: Orthox that have within 1.25 m of the mineral surface sheets that contain 30 percent or more gibbsite or a subhorizon that has 20% or more by volume gravel-size aggregates that contain 30 percent or more gibbsite.

Root Distribution: m=many, c=common, s=some, f=few, n=none.
Commonts: GI=gibbsite, KK=kaolinite.

however, shows that some "Gibbsi" great groups have oxidic rather than gibbsitic mineralogy. These soils have 25 to 35 percent gibbsite and 30 to 35 percent goethite. This meant, therefore, that not all "Gibbsi" great groups have gibbsitic mineralogy.

4.3.5.2. The Acrorthox - Item CDB (see Figure 16) of the key to the great groups defines the Acrorthox as the other Orthox that have apparent ECEC of less than 1.5 meq per 100 g clay in the oxic horizon within 2 m of the soil surface. This was illustrated by Pedon OX-47 in the Solomon Islands which is presently classified as Acrorthox (Table 2, Appendix IV). The properties conformed well with the definition.

There were also some pedons presently classified as Haplorthox that were placed in the great group of Acrorthox. This was illustrated by the Segamat series in Malaysia. The ECEC of less than 1.5 meq per 100 g clay within 2 m of the soil surface placed it in the Acrorthox. The hue of 2.5YR in all horizons also illustrated the need for a Rhodic subgroup in the great group Acrorthox.

Another important change in the proposed key to the suborder Orthox is the deletion of the great group Umbriorthox, resulting to their placement in the Acrorthox and to the Haplorthox. This was illustrated by the Makapili series (Table 4, Appendix IV). The other two pedons of Umbriorthox like the Lawai and Puhi series were placed in the great group Haplorthox on the basis of a udic soil moisture regime and an apparent ECEC greater than 1.5 meq per 100 g clay (Table 4, Appendix IV).

The justification of the separation of the Makapili series from the Lawai and Puhi series was viewed in terms of their generic factors and their management properties (Table 5, Appendix IV). The parent material of both Makapili and the Puhi series is basalt while the Lawai series is collovium weathered from basic igneous rocks. The former two soils were also closer with respect to elevation, MAR and MAT. The Lawai series, on the other hand, receives more rainfall and is 0.2°C cooler than the two pedons. Management wise, the Makapili and Puhi series have similar productivity rating as evaluated by the Modified Storie Rating Index (Land Study Bureau, LXB, Bul. 9, 1967). The Makapili and Puhi series have more properties in common than with the Lawai series, suggesting that Item CDB that defines the Acrorthox seem to be inadequate to separate the soils under consideration. Evidently, the Makapili and Puhi series both have zero or positive delta pH while the Lawai series did not, suggesting that the delta pH may be a useful criterion.

4.3.5.3. <u>The Eutrorthox</u> - Item CDC (see Figure 16) of the key to the great groups defines the Eutrorthox as the Orthox that have more than 35 percent base saturation by NH_4OAc in all parts to a depth of 1.25 m. This was illustrated by Pedon OX-6 of the Latossolo Roxo Eutrofico in Brazil, Pedon OX-4 of the Bayoman series, and Pedon OX-29 of the Matanzas series in Puerto Rico (Table 6, Appendix IV). The subgroup class of the latter 2 pedons, however, changed from Tropeptic to Rhodic taxa.

The change from Tropeptic to Rhodic may not matter so much. It depends on how the two taxa are defined. The initial intent of the Rhodic taxon was to group soils that do not have serious problems of soil structure under cultivation. They are rhodic because they are dark red (Smith, 1979). The structure is also carried in the name Tropeptic (Soil Taxonomy). The advantage of Rhodic is that it is quantitative. Tropeptic is qualitative. Rhod taxon is often associated with abundant iron, but it has been shown that the red color is not always correlated with high iron content (Isbell, 1959, and Paramananthan and Lim, 1979).

4.3.5.4. The Kurorthox - Item CDD (see Figure 16) of the key to the great groups of Orthox defines the Eutrorthox as the Orthox that have more than 40 percent clay in the surface 18 cm, after mixing, and a clay content increase with depth of more than 1.5 m within a thickness of 30 cm (i.e., kandic horizon).

It is intended to group together the youthful Oxisols (ICOMLAC CL No. 6, 1980) and permits the clay increase of an argillic or kandic horizon in the order Oxisols. This was illustrated by the pedons in Hitam Ulu, Sumatra and in the Southwest Ivory Coast (Tables 7 and 8, Appendix IV). They were placed from the Haplorthox to the Kurorthox to recognize the clay accumulation at the subsurface horizon that seemed to influence their behaviour and uses.

Pedon ULT-9 of the Terra Roxa Estruturada Distrofico in Brazil illustrated the change in classification from Ultisols to Oxisols. The clay content that was more than 40 percent in the upper 18 cm, after mixing, and the clay content increase with depth of more than 1.2 x within a thickness of 30 cm qualified this pedon for a kandic horizon. This was permitted in the order Oxisols by virtue of Item C.2 of the key to the order category. Its placement in the Oxisols was supported by its properties that were influenced by the high specific surface of the Fe-oxides (Proc. 1st ISCW, 1978) which was appropriately reflected in the name "OX."

This was further illustrated by Pedon ULT-23 of the CAM soil of the Benchmark Soils Project in Cameroon. Currently, it is a Typic Paleudult, but it became a Typic Kurorthox by virtue of Item CDD. The new placement may be viewed in terms of its very low weatherable mineral content and the delta pH that is more positive than -0.2 in some horizons. These are features of soils that have undergone extreme weathering and that the clay content increase is less important than the oxic characteristics.

The provisions of Item CDD that defines the "Kur" great groups are close to those of the kandic horizon, viz, the CEC ≤16 meq and ECEC ≤12 meq per 100 g clay, and clay increase of 1.2 x the overlying coarser textured horizon. They only differ in clay content where the "Kandi" great groups do not have >40 percent clay in the upper 18 cm, after mixing. Therefore, it seems appropriate that the "Kur" should be the "Kandic" great groups of Oxisols, in order to parallel the LAC taxa of Ultisols and Alfisols.

4.3.5.5. The Haplorthox - Item CDE of the ICOMOX key to the Orthox great groups that defines the Haplorthox was illustrated by Pedon ULT-69 in the Philippines with a clay content >40 percent and an oxic horizon.

4.4. Suggested Amendments

Table 19 summarizes the key to the suborders of Oxisols as defined in Soil Taxonomy, the proposed revision by ICOMOX and the suggested amendments made in this study. Table 20 also shows the key to

Table 19. Proposed ICOMOX revision of the key to suborders of the order Oxisols and suggested amendments.

IN SOIL TAXONOMY	ICOMOX PROPOSAL	SUGGESTED AMENDMENTS
CA. Oxisols that have one or both of the following characteristics: 1.Plinthite that forms a continuous phase within 30cm of the mineral surface of the soil and the soil is saturated with water within this depth at some time during the year; or 2.Either are saturated with water at some time during the year or are artificially drained, have an oxic horizon, and also have one or both of the following characteristics associated with wetness: a.A histic epipedon; or b.If free of mottles immediately below any epipedon that has moist color value of less than 3.5 there is dominant chroma of 2 or less; or if there are distinct or permanent mottles within 50 cm of the soil	CA. Oxisols that are either saturated with water within 30 cm of the mineral surface for at least 30 days per year in most years or are artificially drained and have one or both of the following characteristics associated with wetness: a.A histic epipedon, and/or; b.If free of mottles, immediately below any epipedon that has a moist color value of less than 3.5 there is a dominant chroma of 2 or less; or if there are distinct or prominent mottles within 50 cm of the soil surface, the dominant chroma is 3 or less or the hue is 2.5Y or yellower. . . . . AQUOX	

Table 19 (Continued)

IN SOIL TAXONOMY	ICOMOX PROPOSAL	SUGGESTED AMENDMENTS
surface, the dominant chroma is 3 or less. . . . . AQUOX		
CB. Other Oxisols that have a torric moisture regime. . . . . TORROX	CB. Other Oxisols that have an aridic (Torric) soil moisture regime. . . . . TORROX	
CC. Other Oxisols that: 1. Have 16 kg or more organic carbon per square meter to a depth of 1 m, exclusive of organic surface litter; 2. Have weighted average base saturation in the oxic horizon (by NH_4OAc) of >35 percent; and 3. Have isothermic, thermic, or cooler temperature regime. . . . . . . .HUMOX		CC. Other Oxisols that: Have a mollic or umbric epipedon and an organic carbon content of 16 kg or more per sq m to a depth of 1 m. . . . . HUMOX
CD. Other Oxisols that have an ustic soil moisture regime and an isothermic, thermic,	CC. Other Oxisols that have ustic soil moisture regime. . . . . USTOX	

Table 19 (Continued)

IN SOIL TAXONOMY	ICOMOX PROPOSAL	SUGGESTED AMENDMENTS
or warmer temperature regime. .... USTOX		
CE. Other Oxisols. .... ORTHOX	CD. Other Oxisols. .... ORTHOX	

Table 20. Proposed ICOMOX revisions of the key to the great groups and the suggested amendments.

IN SOIL TAXONOMY	ICOMOX PROPOSAL	SUGGESTED AMENDMENTS
KEY TO AQUOX GREAT GROUPS		
CAA. Aquox that either have cemented sheets containing 30 percent or more gibbsite or have 20 percent or more by volume gravel-size aggregates containing 30 percent or more gibbsite within 1 m of the mineral soil surface but that do not have plinthite that forms a continuous phase within 30 cm of the soil surface. ....Gibbsiaquox	CAA. Aquox that have within 1.25 m of the mineral soil surface sheets containing 30 percent or more gibbsite or a subhorizon that has 20 percent or more by volume, gravel-size aggregates that contain 30 percent or more gibbsite. ......Gibbsiaquox	CAA. Aquox that have acric soil materials within 1.5 m of the soil surface. .... Acraquox
CAB. Other Aquox that have plinthite that forms a continuous phase within 1.25 m of the soil surface. .... Plinthaquox	CAB. Other Aquox that have 35% or more clay in the oxic horizon and an apparent effective cation exchange capacity (NH$_4$-OAc bases + KCl extr. Al)/% of less than 1.5 meq/100g clay in the oxic horizon and within 2 m of the surface. .... Acraquox	CAB. .... Gibbsiaquox
CAC. Other Aquox that have an ochric epipedon. .... Ochraquox	CAC. Other Aquox that have plinthite forming a continuous phase within 1.25 m of the soil surface. ..... Plinthaquox	CAC. .... Plinthaquox

Table 20. (Continued)

IN SOIL TAXONOMY	ICOMOX PROPOSAL	SUGGESTED AMENDMENTS
CAD. Other Aquox. .... Umbraquox	CAD. Other Aquox that have umbric, mollic or histic epipedon. .... Umbraquox	CAD. .... Umbraquox
	CAE. Other Aquox. .... Ochraquox	CAE. .... Ochraquox
KEY TO TORROX GREAT GROUPS		
CBA. Torrox are the Oxisols that have a torric moisture regime. "The soils we know in this suborder are so similar that no subdivisions seem justified at the great group or subgroup levels. All are considered to be typic soils of the suborder."	CBA. Torrox that have an apparent effective cation exchange capacity of less than 1.5 meq/100 g clay in the oxic horizon within 2 m of the soil surface. .... Akritorrox	CBA. Torrox that have base saturation (by NH_4OAc at pH 7) ≤ 35 percent in the major part of the oxic horizon within a depth of 1.5 m. ....Dystorrox
	CBB. Other Torrox that have more than 35% base saturated (pH 7) in all parts to a depth of 1.25 m. ...... Eutrotorrox	CBB. Other Torrox .... Haplortorrox
	CBC. Other Torrox. ...... Haplotorrox	

Table 20 (Continued)

IN SOIL TAXONOMY	ICOMOX PROPOSAL	SUGGESTED AMENDMENTS
KEY TO HUMOX GREAT GROUPS		
CCA. Humox that have sombric horizon. .... Sombrihumox	CCA. "Humox deleted"	CCA. Humox that have an acric soil materials within 1.5 m of the soil surface. .... Acrohumox
CCB. Other humox that have, within 1 m of the soil surface, either cemented sheets that have 30 percent or more gibbsite or a subhorizon that has 20 percent or more by volume gravel-size aggregates that contain 30 percent or more gibbsite. .... Gibbsihumox		CCB. Other Humox that have within 1.25 m of the mineral surface, sheet containing 30 percent or more gibbsite or 20 percent or more by volume, gravel-sized aggregates that contain 30 percent or more gibbsite. .... Gibbsihumox
CCC. Other Humox that have in all subhorizons of the oxic horizon a cation-retention capacity (from NH_4Cl) of >1.5 meq per 100 g clay or that have >1.5 meq of extractable bases plus extractable aluminum per 100 g clay.		CCC. Other Humox that have >35 percent base saturation (NH_4OAc pH 7) in the major part of the oxic horizon within a depth of 1.25 m. .... Eutrohumox
		CCD. Other Humox that have kandic horizon. .... Kandihumox

Table 20 (Continued)

IN SOIL TAXONOMY	ICOMOX PROPOSAL	SUGGESTED AMENDMENTS
CCD. Other Humox. ..... <u>Acrohumox</u>		CCE. Other Humox. ...... <u>Haplohumox</u>
<u>KEY TO USTOX GREAT GROUPS</u>		
CDA. Ustox that have a sombric horizon. ... <u>Sombriustox</u>	CCA. Ustox that have within 1.25 m of the mineral surface sheets that contain 30 percent or more gibbsite or a subhorizon that has 20 percent or more by vol. gravel-size aggregates that contain 30 percent or more gibbsite. .... <u>Gibbsiustox</u>	CDA. Ustox that have acric soil materials within 1.5 m of the soil surface. .... <u>Acrustox</u>
CDB. Other Ustox that have a cation-retention capacity (from NH_4OCl) of 1.5 meq or less per 100 g clay in some subhorizon of the oxic horizon (or have 1.5 meq or less of extractable bases plus extractable aluminum per 100 g clay). ...... <u>Acrustox</u>	CCB. Other Ustox that have an apparent effective cation exchange capacity of less than 1.5 meq/100 g clay in the oxic horizon within 2 m of the soil surface. .... Akrustox	CDB. . . . . <u>Gibbsiustox</u> CDC. Other Ustox that have >35 percent base saturation (NH_4OAc, pH 7) in the major part of the oxic horizon. .... <u>Eutrustox</u>
CDC. Other Ustox that have base saturation of 50 percent or more (by NH_4OAc) in the major part of the oxic horizon if the particle size class is clayey or 35 percent or more if the particle-size class is loamy. .... <u>Eutrustox</u>	CCC. Other Ustox that are more than 35% base saturated (NH_4OAc) in all parts to a depth of 1.25 m. .... <u>Eutrustox</u>	CDD. Other Ustox that have a clay increase of a kandic horizon. ... <u>Kandiustox</u>

Table 20 (Continued)

IN SOIL TAXONOMY	ICOMOX PROPOSAL	SUGGESTED AMENDMENTS
CDD. Other Ustox. .... Haplustox	CCD. Other Ustox that have more than 40% clay in the surface 18 cm after mixing, and a clay content increase with depth of more than 1.2x within a thickness of 30 cm (i.e., kandic horizon). ...... Kurustox	CDE. Other Ustox. ...... Haplustox
	CCE. Other Ustox. ..... Haplustox	
KEY TO ORTHOX GREAT GROUPS		
CEA. Orthox that have sombric horizon. ..... Sombriorthox	CDA. Orthox that have within 1.25 m of the mineral surface sheets that contain 30 percent or more gibbsite or a subhorizon that has 20 percent or more by vol. gravel-size aggregates that contain 30 percent or more gibbsite. ..... Gibbsiorthox	CEA. Orthox that have acric soil materials within 1.5 m of the soil surface. ...... Acrorthox
CEB. Other Orthox that have within 1.25 m of the soil surface sheets that contain 30 percent or more gibbsite or a subhorizon that has 20 percent or more by vol. gravel-size aggregates that contain 30 percent or more gibbsite. ..... Gibbsiorthox	CDB. Other Orthox that have an apparent effective cation exchange capacity of less than 1.5 meq/100 g clay in the oxic horizon within 2 m of the soil surface. .... Akrorthox	CEB. . . . . Gibbsiorthox

Table 20 (Continued)

IN SOIL TAXONOMY	ICOMOX PROPOSAL	SUGGESTED AMENDMENTS
CEC. Other Orthox that 1. Have in some subhorizon of the oxic horizon a cation-retention capacity of 1.5 meq or less (from NH_4Cl) per 100 g clay (or 1.5 meq or less extractable bases plus extractable aluminum per 100 g clay); and 2. Do not have discernible structure in the oxic horizon or have only weak blocky or prismatic peds. ...... Acrorthox	CDC. Other Orthox that are more than 35% base saturated (NH_4OAc) in all parts to a depth of 1.25 m. ...... Eutrorthox	CEC. Other Orthox that have ≥ 35 percent base saturation (NH_4OAc, pH 7) in all subhorizons of the oxic horizon within a depth of 1.5 m. ..... Eutrorthox
	CDD. Other Orthox that have more than 40% clay in the surface 18 cm, after mixing, and a clay content increase with depth of more than 1.2 x within a thickness of 30 cm (i.e., kandic horizon). .... Kurorthox	CED. Other Orthox that have the clay increase of a kandic horizon. ....Kandiorthox
CED. Other Orthox that do not have an anthropic epipedon and have base saturation of 35 percent or more (by NH_4OAc) in the epipedon and in all subhorizons of the oxic horizon to a depth of at least 1.25 m. ...... Eutrorthox	CDE. Other Orthox. ...... Haplorthox	CEE. Other Orthox. ..... Haplorthox

the great groups of Oxisols in Soil Taxonomy, the corresponding proposed revision by ICOMOX and the suggested amendments.

V. RESULTS AND DISCUSSION - LAC ALFISOLS AND ULTISOLS

The proposal that was tested is found in the review draft prepared by the SCS, dated June 1, 1983, based on the final report of ICOMLAC. The proposed definition of the kandic horizon was first tested, followed by the proposed key to the "Kandi" great groups. The test for the criteria of the kandic horizon was done as illustrated in Figure 17.

5.1. Testing the Criteria of the Kandic Horizon

5.1.1. The Charge Properties

The opening statement of the ICOMLAC's definition reads, "The Kandic horizon is a subsurface horizon which has a CEC $\leq$16 meq per 100 g clay (by NH_4OAc) or have ECEC $\leq$12 (sum of bases plus KCl extractable Al) in the fine earth fraction at a depth of 50 cm below the top of the horizon or immediately above a lithic, paralithic, or petroferric contact that is shallower."

Out of the 65 test pedons of LAC Ultisols, 13 have CEC >16 meq per 100 g clay but have ECEC <12 meq per 100 g clay; 17 pedons have ECEC >12 but have CEC $\leq$16 meq per 100 g clay; and 35 pedons have both CEC <16 meq and ECEC <12 meq per 100 g clay. The 4 pedons of LAC Alfisols have CEC $\geq$16 meq per 100 g clay, but they all have ECEC $\leq$12 meq per 100 g clay. The 2 LAC Mollisols have ECEC >12 meq but they both have CEC $\leq$16 meq per 100 g clay (Table 21). The LAC Inceptisols were illustrated by the Uwala series, which had CEC <16 meq and ECEC <12 meq per 100 g clay (Table 22).

The result showed that all the test pedons met the charge characteristics of a Kandic horizon.

Figure 17. Flow-diagram key to test the definition of the Kandic horizon.

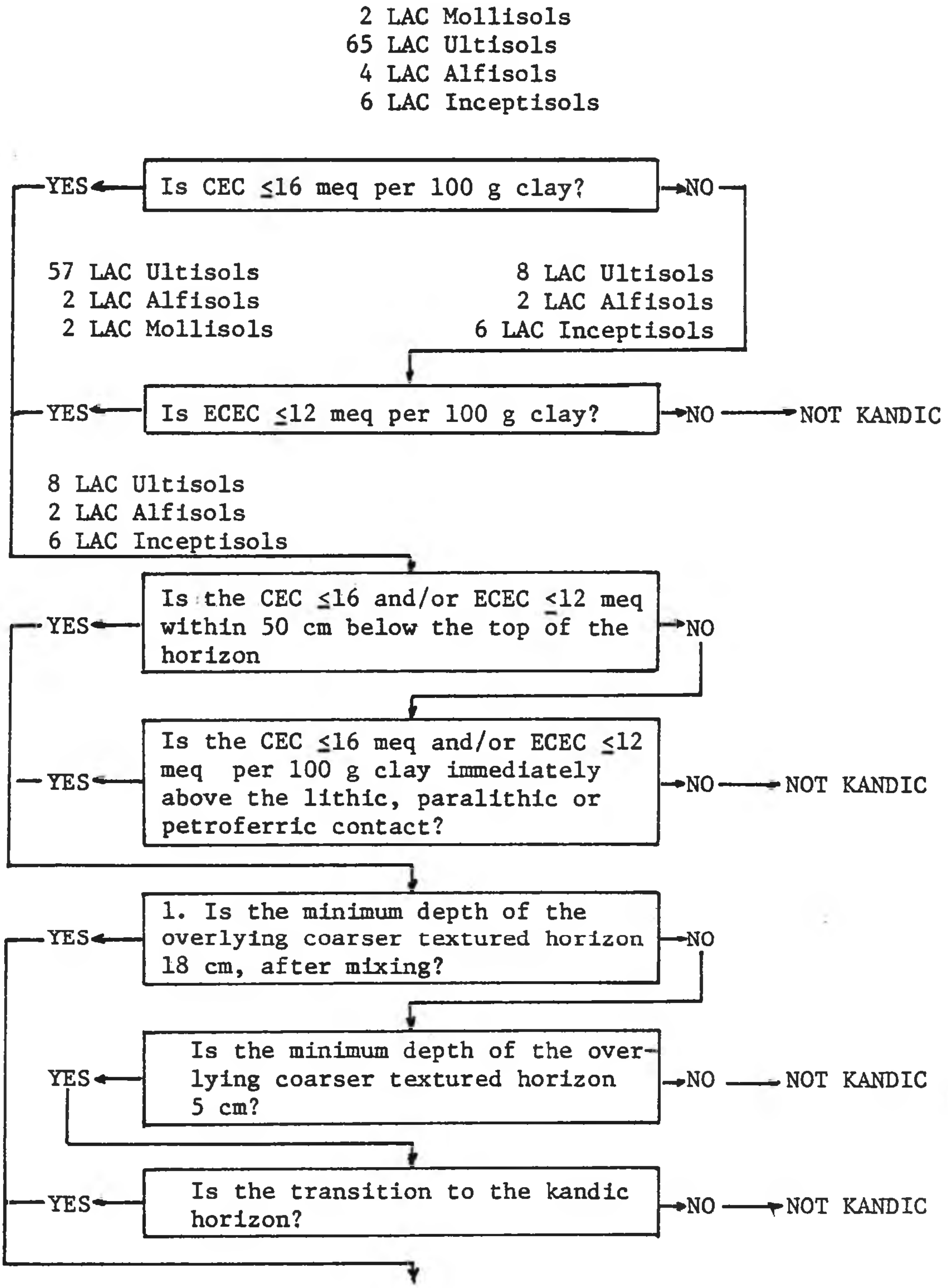


Figure 17 (Continued)

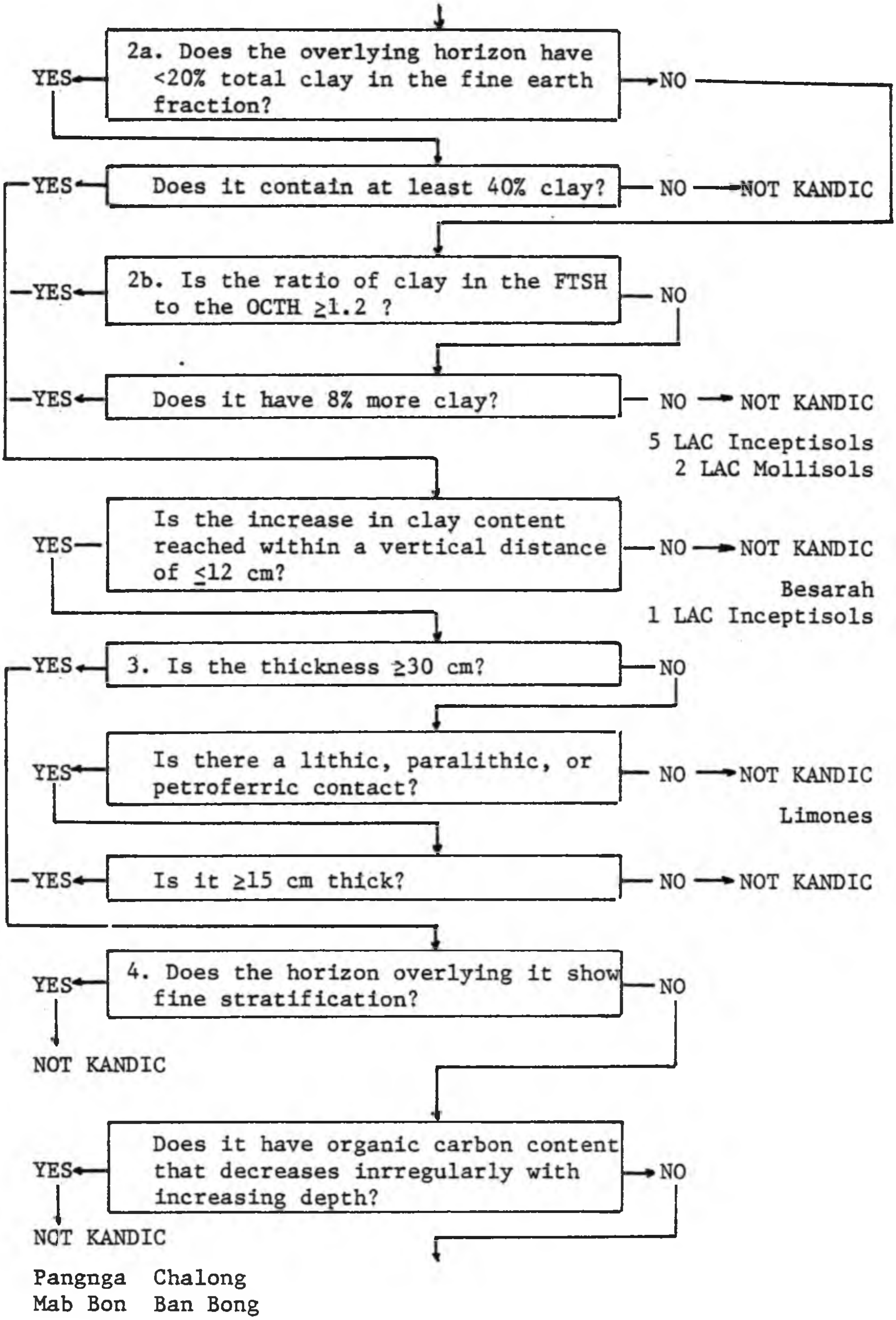
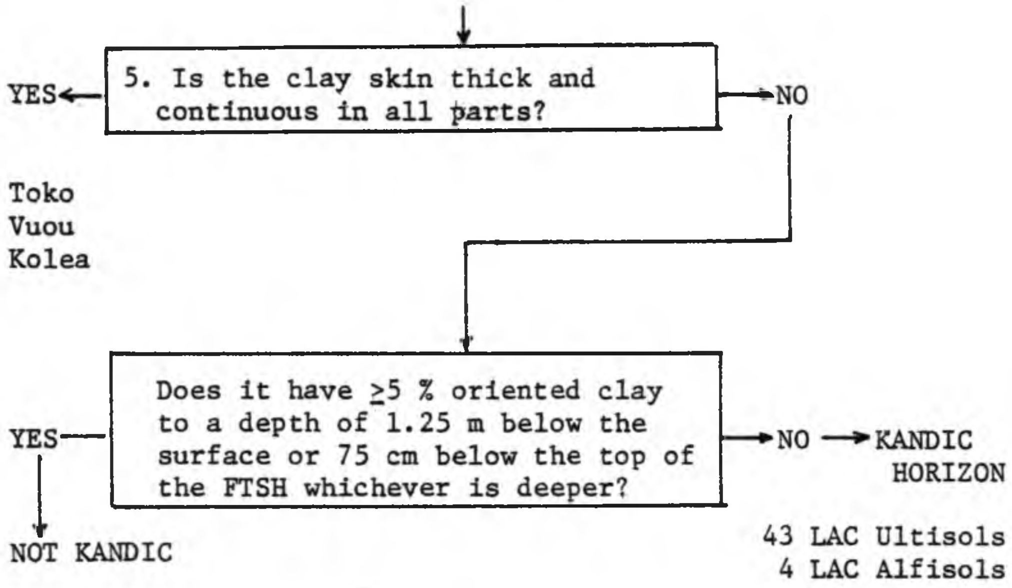


Figure 17 (Continued)



5. Is the clay skin thick and continuous in all parts?

Does it have ≥5 % oriented clay to a depth of 1.25 m below the surface or 75 cm below the top of the FTSH whichever is deeper?

Table 21 . Key attributes of selected pedons of LAC Mollisols. Source: SSIR No. 29, pages 104 and 108.

Depth -cm-	Horizon	Organic Carbon (%)	CEC	ECEC	15-Bar Water (%)	Base Saturation (%)	Soil Color	
			(meq/100g clay)				Moist	Dry
Makawali series, Oxic Haplustoll, fine kaolinitic, isohyperthermic.								
0-18	Ap1	2.44	18.9	27.0	24.4	100+	10YR3/2	10R3/6
18-30	Ap2	1.35	12.3	16.6	24.1	100+	10R3/3	10R3/4
30-60	B21	0.59	15.8	13.7	22.7	87	10R3/4	10R4/6
60-90	B22	0.37	15.9	15.6	23.9	98	10R3/4	10R3/6
90-150	B23	0.53	19.0	16.5	24.8	86	10R3/3	10R3/6
Paia series, Oxic Haplustoll, fine kaolinitic, isohyperthermic.								
0-28	Ap1	1.85	32.6	40.5	27.3	100+	5YR3/2	5YR3/3
28-48	Ap2	1.62	27.9	31.5	28.3	100+	5YR3/2	5YR3/3
48-75	B1	0.70	19.8	19.3	26.6	100+	5YR3/3	5YR3/4
75-103	B21	0.21	15.8	12.2	25.3	97	5YR3/2	5YR3/3
103-133	B22	0.12	14.3	14.5	24.9	100+	5YR3/3	5YR3/4
133-150	B23	0.28	14.2	14.2	25.4	99	5YR3/3	5YR3/4

Table 22. Key attributes of the Uwala series, a LAC Inceptisols. Source: SSIR No. 29, 1979, page 92.

Depth (cm)	Horizon	Organic Carbon (%)	CEC (meq/100g clay)	ECEC (meq/100g clay)	15-Bar Water (%)	Base Saturation (%)
0-18	Ap1	1.70	20.9	9.5	22.7	39
18-38	Ap2	0.90	17.0	9.8	25.2	57
38-75	B2	0.61	16.4	10.9	29.2	65
75-110	B3	0.45	15.5	11.0	32.1	67
110-150	C	0.70	16.2	10.8	29.0	61

5.1.2. The thickness of the surface horizon

Item 1 of the summary of properties of the kandic horizon reads, "The kandic horizon has a coarser textured surface horizon. The minimum thickness of the surface horizon is 18 cm, after mixing or 5 cm if the transition to the kandic horizon is abrupt."

This provision is intended to exclude soils with very thin coarser textured surface horizons because they can easily be altered by cultivation practices which result in a sudden change in classification (Moormann, personal communication).

Pedon ULT-29 of the Daobli series in Southwest Ivory Coast illustrated the significance of this provision. The A horizon is 5 cm thick and has 41.0 percent clay that decreases to 21 percent in the B11 horizon within 19 cm from the surface (Figure 18). Without mixing the surface 18 cm, the overlying coarser textured horizon (OCTH) would be 41.0 percent and the required clay content increase for recognition of an argillic horizon is 49.0 percent (Point B). This point is reached within a vertical distance of more than 65 cm which is too deep. But if the upper 18 cm is mixed, as in plowing, the clay content of the OCTH is 26.8 percent and the required increase in clay content for the kandic horizon is 32.1 percent (Point A). This point is reached within a vertical distance less than 12 cm and so the subsurface layer can qualify as a kandic horizon. It means, that without mixing the surface 18 cm, the soil becomes an Oxisol, but when mixed, it could be placed in the "Kandi" great groups of Ultisols.

5.1.3. The rate and amount of clay increase

Item 2 reads, "The Kandic horizon has more total clay than the overlying horizon and the increased clay content is reached within a vertical distance of 12 cm or less.

2.1. If the horizon, overlying the kandic horizon has less than 20 percent total clay in the fine-earth fraction, the kandic horizon must contain at least 4 percent more clay.

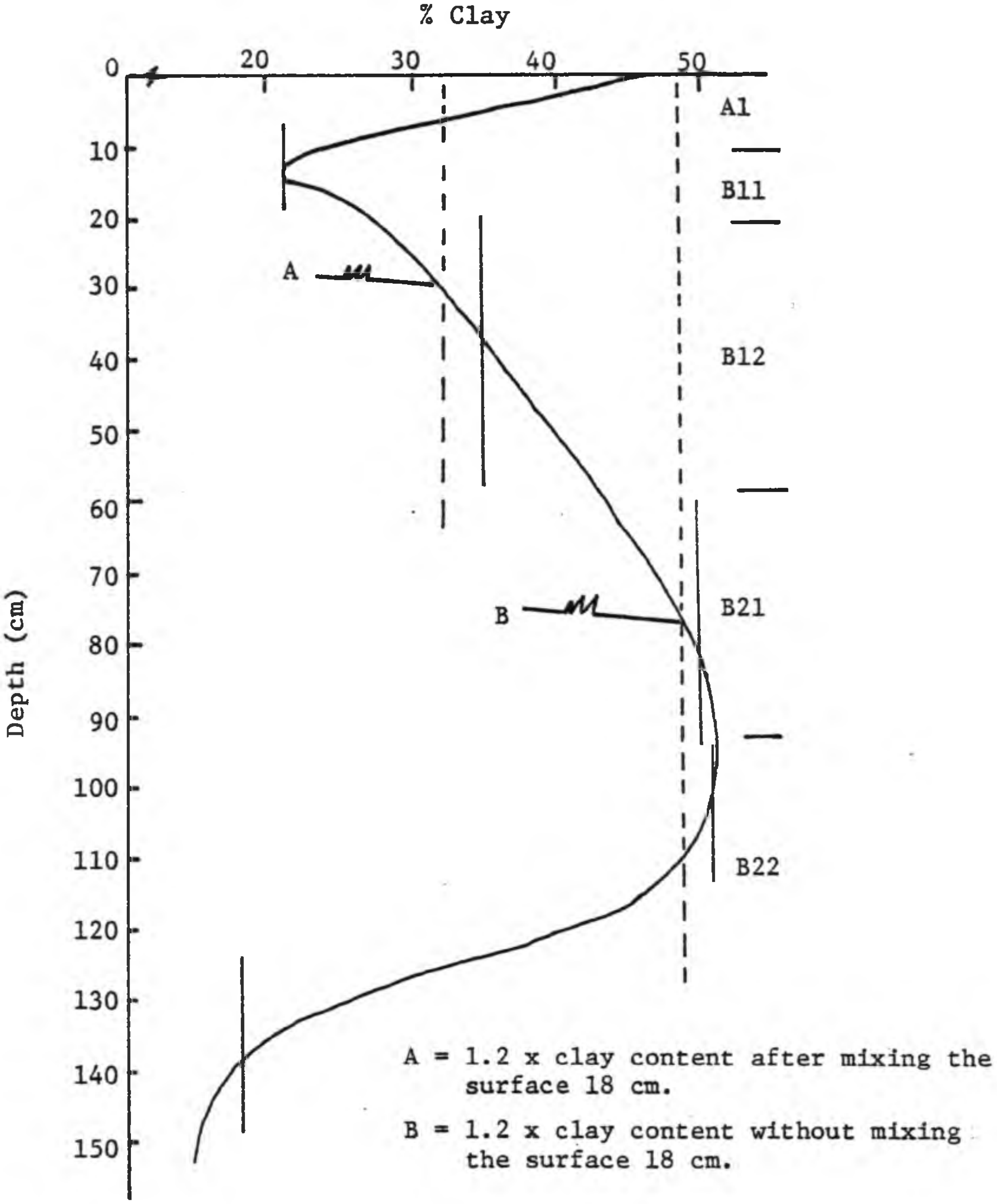


Figure 18. Clay content of the Daobli series in the Southwest Ivory coast showing the depth of the required clay increase of a kandic horizon.

2.b. If the horizon, overlying the kandic horizon has more than 20 percent total clay in the fine-earth fraction, the ratio of clay in the kandic horizon to that in the overlying horizon must be 1.2 or more, or the kandic horizon must contain at least 8 percent more clay."

Pedon EPT-10 (SV 2/4), a Tropaquept in Lampung, Sumatra illustrated the significance of the above provision by excluding the LAC Inceptisols from the LAC Ultisols and Alfisols. It had 27 percent clay in the OCTH and it met the required clay content increase but the vertical distance was more than 12 cm. Hence, it did not meet the requirement of a kandic horizon. The other 5 LAC Inceptisols also did not meet the required clay content increase (Table 1, Appendix V). The LAC Mollisosl, on the other hand, were separated from the LAC Alfisols by keying out first the former with a mollic epipedon (Table 21).

Pedon ULT-64 of the Pak Chong series in Thailand illustrated the change in classification from Ultisols to Oxisols on account of the provision of Item 2 where the vertical distance is >12 cm (79 cm). The clay content that was >40 percent in the surface 18 cm, after mixing, and the oxic characteristics placed Pedon ULT-64 in the Oxisols.

The Kabin Buri (Haplustults) in Thailand and the Drasa series (Haplustults) in Fiji (Table 23) illustrated a different case. Like the Pak Chong series, they met the required clay content increase and a vertical distance to the overlying horizon that was more than 12 cm but not greater than 30 cm, thus an argillic horizon was present. While the clay content was >40 percent in the upper 18 cm, after mixing, they could not be placed in the Oxisols because Item C.2 of the ICOMOX'S key definition to the order Oxisols does not accommodate argillic horizons that have CEC ≤16 meq or ECEC ≤12 meq per 100 g clay. It could not be placed in the LAC Ultisols because the clay content was >40 percent

Table 23. Calculated data of LAC Ultisols used to test the definition of the Kandic horizon.

Soil Series or pedon	Present Classification	Thickness of kandic horizon (cm)	Clay Content		Required clay increase (%)	Amount of clay increase (%)	Vert. dist. bet. OCTH & FTSH (cm)	Depth of upper bdry. of the kandic hor. (cm)
			OCTH (%)	FTSH (%)				
U.S.A.								
1. Faceville	Paleudults	139	6.0	19.1	10.0	13.1	2.5	21
2. Grady	Paleaquults	98	40.9	52.7	49.0	11.8	2.5	20
3. Cecil	Hapludults	99	13.9	33.2	17.9	19.3	6	23
4. Dunmore	Paleudults	105	18.1	58.2	22.1	40.1	2.5	21
5. Marlboro	Paleudults	108	3.6	21.2	7.6	17.6	2.5	19
PUERTO RICO								
6. Jagueyes	Tropudults	142	20.1	32.0	24.1	11.9	6	39
7. Limones	Tropohumults	18	48.5	59.0	24.1	10.5	5	23
THAILAND								
8. Pak Chong	Paleustults	122	83.9	93.7	91.9	9.8	79	59
9. Banchong	Paleustults	123	56.6	67.4	64.6	10.8	2.5	20
10. Kabin Buri	Haplustults	110	48.3	63.2	56.3	14.9	13	31
11. Mab Bon	Paleustults	177	18.4	29.9	22.4	11.5	5	23
12. Chalong	Plinthustults	160	15.5	21.4	19.4	5.5	2.5	20
13. Warin	Paleustults	178	6.9	13.9	10.9	7.0	6	32
14. Yasothon	Rhodustults	132	5.4	15.8	9.4	10.4	12	68
15. Phangnga	Paleudults	160	23.0	37.1	27.4	14.1	2.5	20
16. Kho Hong	Paleudults	130	12.2	17.5	16.2	5.3	6	29

OCTH= overlying coarser textured horizon, FTSH= textured subsurface horizon.

Table 23 (Continued)

Soil Series or pedon	Present Classification	Thickness of kandic horizon (cm)	Clay Content OCTH (%)	Clay Content FTSH (%)	Required clay increase (%)	Amount of clay increase (%)	Vert. dist. bet. OCTH & FTSH (cm)	Depth of upper bdry. of the kandic hor. (cm)
17. Khlong Chak	Paleudults	190	28.7	53.0	34.4	24.3	2.5	20
18. Songkhla	Paleaquults	143	12.4	31.0	14.4	18.6	6	43
19. Khorat	Haplustults	117	5.5	17.6	9.3	12.1	6	61
BRAZIL								
20. BR3	Haplustults	122	14.2	24.0	18.2	9.8	12	46
21. BR4	Palehumults	257	23.8	42.0	28.6	18.2	12	33
22. BR8	Palehumults	31	48.7	59.0	56.7	10.3	2.5	25
23. BR20	Fragiudults	81	9.7	18.1	13.7	8.4	12	76
24. BR23	Paleudults	230	30.9	46.5	37.1	15.6	6	46
25. BR27	Paleudults	214	19.8	44.0	23.8	24.2	2.5	46
26. BR30	Paleudults	179	8.8	32.6	12.8	23.8	6	41
MALAYSIA								
27. Lanchang	Paleudults	218	37.8	58.2	45.4	20.4	2.5	19
28. Kening	Paleudults	231	28.5	36.9	34.2	8.4	2.5	19
29. Bungor	Paleudults	205	18.1	30.7	22.1	12.6	2.5	13
HAWAII								
30. Haiku taxadjunct	Tropohumults	141	62.5	96.0	70.5	33.5	2.5	34
31. Pauwela	Tropohumults	47	60.3	88.3	68.3	28.0	12	36
SUMATRA								
32. Sijau	Paleudults	130	53.1	62.0	61.1	8.8	6	24
33. Sijau	Tropudults	128	73.3	87.5	81.3	14.6	6	22
34. Dalek	Tropudults	91	22.3	27.0	30.3	4.7	2.5	19
35. MU-7	Tropaquults	61	25.0	33.0	30.0	8.0	6	26

Table 23 (Continued)

Soil Series or pedon	Present Classification	Thickness of kandic horizon (cm)	Clay Content OCTH (%)	Clay Content FTSH (%)	Required clay increase (%)	Amount of clay increase (%)	Vert. dist. bet. OCTH & FTSH (cm)	Depth of upper bdry. of the kandic hor. (cm)
36. MU-11	Tropudults	100	38.6	49.0	46.3	10.0	2.5	17
37. MU-13	Tropudults	90	30.4	39.0	36.5	8.6	2.5	14
BNAGLADESH								
38. Tejgaon	Paleudults	39	35.1	49.0	42.1	13.9	15	48
IVORY COAST								
39. Bedoule	Paleudults	136	26.0	36.5	31.2	10.5	8	23
40. Daobli	Paleudults	196	21.3	50.1	32.8	28.8	6	44
41. Gloaumo	Paleudults	140	9.2	15.7	13.2	6.5	8	27
42. Guire	Paleudults	200	6.5	34.8	10.5	28.3	12	40
43. Kolea	Paleudults	207	21.8	58.4	26.1	36.6	12	43
44. Malan	Plinthudults	42	44.5	56.3	53.4	11.8	6	36
45. Neira	Paleudults	182	41.8	51.0	49.8	9.2	6	33
46. Niagui	Paleudults	98	9.4	13.9	12.4	4.5	2.5	37
47. Nonoua	Paleudults	234	34.3	63.7	41.3	29.3	2.5	13
48. Saoa	Paleudults	197	14.4	29.5	17.2	15.1	6	43
49. Tabou	Plinthudults	124	23.9	32.0	28.7	8.1	6	34
FIJI								
50. Koronivia	Tropodults	59.5	37.0	69.0	44.5	32.0	2.5	40
51. Mokambo	Haplustults	156.0	27.0	36.0	32.4	9.0	11	24
52. Drasa	Haplustults	75	44.2	54.0	53.1	9.9	17	50

Sources: U.S.A. = SSIR Nos. 15 (1967) and 16 (1967); Puerto Rico= SSIR No. 12 (1967); Thailand= Proc. 2nd ISCW, Part II (1979); Brazil= Proc. 1st ISCW (1978); Malaysia= Proc. 2nd ISCW, Part II (1979); Hawaii= SSIR No. 29 (1976); Sumatra= Williams and Harding (1979) and SRL (1975); Ivory Coast= Soil Survey of the Southwest Region, Ivory Coast (1978); Fiji= Morrison and Leslie (1981).

(Item C.1). They could not be placed in the LAC Inceptisols because they have argillic horizon or in the LAC Mollisols because they have no mollic epipedon.

A question then arises, relative to the intent of Item C.2 of the ICOMOX'S key definition of the order Oxisols, wherein the advanced stage of weathering in fine textured soils (>40 percent clay) as evidneced by the low activity of the clay is more important than the evidence of clay movement in the kandic or argillic horizon. Here, the oxic horizon takes precedence over the argillic and therefore, it should be placed in the Oxisols. Several alternatives, however, are suggested. One is to modify the provision of Item 2, such that the rate of clay increase may be the same as that of the argillic horizon, which is ≤30 cm. In this respect, the kandic horizon may be recognized with >40 percent clay in the upper 18 cm. By this modification, the Kabin Buri series qualify for a kandic horizon. Having a kandic horizon and with clay contents >40 percent, it can be accommodated in the order Oxisols. Here, the intent is to bring the argillic horizons with LAC into the kandic horizon. Another alternative is to define Item C.2 of the Oxisols criteria, as "Have 40 percent or more clay in the upper 18 cm of the soil, after mixing, and an oxic horizon that met the clay content increase of a kandic or argillic horizon."

In Table 23, column 7, the amount of clay content increase in the pedons having less than 20 percent clay in the overlying coarser textured horizon(s) ranged from 4.5 to 30.1 percent, while those having more than 20 percent ranged from 8.0 to 36.6 percent. The data seemed to indicate that the absolute value of clay increase of 4 percent in the kandic horizon for soils having less than 20 percent clay in the overlying coarser textured horizons or 8 percent more clay in the kandic for soils more than 20 percent clay were appropriate. The rationale for these limits is that the increase in absolute amount of clay of less than 4 percent is not consistently observable in the field for the coarser textured soils. In the same manner, the absolute increase of 8 percent more clay is about the minimum that could be consistently observed in the field for the finer textured soils (Smith, as interviewed by Leamy, 1978).[2/]

5.1.4. The thickness of the horizon

Item 3 requires that, "The kandic horizon should have a thickness of at least 30 cm, or at least 15 cm if a lithic, paralithic, or petroferric contact occur within 50 cm of the mineral soil surface."

The Limones series in Puerto Rico was the only soil that did not meet the thickness criterion. It had 45.5 percent clay content in the surface 18 cm, after mixing, and satisfied the required clay increase of 1.2 x (58.5 percent) which was reached within a vertical distance of 5 cm, but it was too thin (<18 cm) to be a kandic horizon. It was placed in the order Oxisols by virtue of Item C.2 of the key definition of the order Oxisols. The new placement may be justified by the thin layer of clay accumulation which may not be sufficient to exert significant influence associated with the kandic or argillic horizon, and therefore, the effect of the oxic material takes precedence.

5.5.5. The stratification and organic matter distribution

Item 4 reads, "The layers or horizons, overlying the kandic horizon do not show fine stratification, and the organic carbon content do not decrease irregularly with increasing depth."

[2/] Leamy, M. (1978). Conversations in Taxonomy, New Zealand Soil News. Vol. 26, No. 6, 1978.

Several pedons of Ultisols having low activity clays did not satisfy the requirement such as Pedons ULT-25 of the Chalong, ULT-51 of the Mab Bon and ULT-66 of the Phangnga series in Thailand (Table 1, Appendix VII). They illustrated a carbon content that decreases irregularly with increasing depth. By the ICOMLAC definition, these soils did not qualify for a kandic horizon nor did they qualify for an oxic horizon because of the abrupt upper textural boundary. Neither could they qualify for the LAC Inceptisols because of the presence of an argillic horizon. Perhaps they may be placed in the kandic subgroups of Ultisols, These will be the Ultisols that have low activity clay that do not meet the definition of a kandic horizon. It is reported that Ultisols in Thailand occur in all landforms and on a wide range of parent materials. It is possible that these pedons occur between the landforms in organic matter and in fans of old alluvium or collovium that may result to the organic carbon content that decrease irregularly with depth (Proc. 2nd ISCW, Part II, 1979). This kind of soil-landscape relationship seem to favor their placement at the subgroup level.

5.1.6. The clay skins

> Item 5 requires that, "A kandic horizon lacks clay skins that are thick and continuous in all parts, and the cross section should have $\leq$5 percent oriented clay to a depth of 125 cm below the mineral soil surface or 75 cm below the top of the kandic horizon whichever is deeper."

Three test pedons in the Southwest Ivory Coast did not meet the criterion. Pedon ULT-47 of the Kolea series, illustrated this with thick and continuous clay skins but has an argillic horizon that has CEC by NH_4OAc $\leq$16 meq per 100 g clay. Since the clay content is <40 percent in the surface 18 cm, after mixing, the clay content increase in the argillic horizon takes precedence over the advanced weathering condition, as evidenced by the low activity of the clay and, therefore, it may be placed in the "Kandi" great groups. This suggest the deletion of Item 5 since the clay skin criterion is too subjective.

5.1.7. Depth of Top of the Kandic Horizon

In place of the clay skin criterion, it is suggested that the depth requirement of the top of the kandic horizon as described by ICOMLAC in the review draft (SCS, 1983) be included in the summary of properties.

"The top of the kandic horizon is normally within one of the following depths:

> a. If the clay content of the surface horizon is 20 percent or more, the upper boundary is at a depth of less than 100 cm from the mineral soil surface.
>
> b. If the clay content of the surface horizon is less than 20 percent and the particle size class (of part or all of the upper 100 cm) is finer than sandy or sandy skeletal, the upper boundary is at a depth of less than 125 cm from the mineral soil surface.
>
> c. If the particle size class of the upper 100 cm is sandy or sandy skeletal, the upper boundary is at a depth between 100 cm and 200 cm from the mineral soil surface in most of the pedon."

All test pedons met the above requirements.

The result of the test for the proposed criteria for the kandic horizon is summarized in Table 24. The 2 LAC Mollisols, 6 LAC Inceptisols and 11 LAC Ultisols that did not meet some of the requirements illustrated the appropriateness of the proposal. However, the LAC Ultisols that did not qualify for a kandic horizon indicated the need for certain modifications as shown in Table 24.

Table 24. Result of test of the ICOMLAC's proposed diagnostic properties of the Kandic horizon.

ITEM NO.	PROPOSED SUMMARY OF PROPERTIES	RESULT OF TEST	REMARKS
Opening Statement	The kandic horizon is a subsurface horizon which has a CEC ≤16 meq per 100 g clay (by NH$_4$OAc) or have ECEC ≤ 12 (sum of bases plus KCl extractable Al) in the fine earth fraction at a depth of 50 cm below the top of the horizon or immediately above a lithick, paralithic, or petroferric contact that is shallower. The kandic horizon has the following properties:	All test pedons met the limits for the charge properties.	
1	A coarser textured surface horizon. The minimum thickness of the surface horizon is 18 cm after mixing or 5 cm if the transition to the kandic horizon is abrupt.	All test pedons met the criterion.	
2	More total clay than the overlying horizon and the increased clay content is reached within a vertical distance at 12 cm or less as follows:	1 LAC Ultisols and 1 LAC Inceptisols did not meet the criterion.	The LAC Ultisols was placed in the Oxisols by Item C.2 of the key definition of the Oxisols; Exclusion of the LAC Inceptisols was faborable.
2a	If the surface horizon has less than 20 percent total clay, the kandic horizon must contain at least 4 percent more clay; or	All test pedons met the criterion.	

Table 24. (Continued)

ITEM NO.	PROPOSED SUMMARY OF PROPERTIES	RESULT OF TEST	REMARKS
2b	If the surface horizon has more than 20 percent total clay, the kandic horizon must have 1.2 times more clay than the overlying horizon or at least 8 percent more clay.	5 LAC Inceptisols and 2 LAC Mollisols did not meet the criterion.	The criterion is useful to exclude the LAC Mollisols and LAC Inceptisols.
3	A thickness of at least 30 cm, or at least 15 cm if a lithic, paralithic or petroferric contact occur within 50 cm of the mineral soil surface.	One (1) test pedon did not meet the criterion.	The excluded pedon was placed in the Oxisols by virtue of Item C.2 of the key definition of the order Oxisols.
4	The layers or horizons overlying the kandic horizon do not show fine stratification and the contents of organic carbon does not decrease irregularly with increasing depth.	Four (4) test pedons did not meet the criterion.	These pedons may be placed in the Kandic subgroups.
5	Lacks clay skins that are thick and continuous in all parts, and the mineral soil surface or 75 cm below the top of the kandic horizon, whichever is deeper.	Three (3) test pedons did not meet the criterion.	The criterion is subjective and a constraint to LAC Ultisols.

5.2. Suggested Addendum to the Key Definition of the order Ultisols

The key definition of the order Ultisols in Soil Taxonomy, p 92 needed a provision to accommodate the LAC Ultisols that were proposed to be identified with the newly introduced kandic horizon.

This was done in Item F.1 of the key to soil orders, by inserting the phrase, "or a kandic horizon," after the words, "Have an argillic....," to read, "Have an argillic or a kandic horizon but not a fragipan and have base saturation (by sum of cations) of <35 percent within the following depths."

5.3. Key Definition to the Great Groups of LAC Ultisols

The proposed keys to suborders, great groups and subgroup that were tested were obtained from the review draft of a proposal for reclassification of Ultisols and Alfisols with low activity clays by the SCS, based on the final report of the ICOMLAC, dated June 1, 1983.

In the key to the suborders of Ultisols, ICOMLAC deleted the Xerults in Soil Taxonomy.

The great groups Tropaquults and Umbraquults of the suborder Aquults in Soil Taxonomy were deleted. Similarly, the Palehumults and Tropohumults of the suborder Humults as well as the Tropudults in the suborder Udults were also deleted.

The ICOMLAC key to the great groups recognizes two LAC Ultisols. One has a deeply developed kandic horizon (Kandi) and the other has a less deeply developed kandic horizon (Kandhapl). The two LAC great groups parallel the present "Pale" and "Hapl" great groups in the various suborders of the Ultisols.

The advantage of segregating the LAC great groups into the more developed and the less developed taxa may be related to the deeper accumulation of the clay in the "Kandi" great groups which may be more suitable for farm ponds than the less developed "Kanhapl" great group (Figure 19).

On the other hand, the "Kanhapl" great group may perform better for septic tank than the "Kandi" great group because there is less clay accumulation with depth that would permit better filtering effect. In terms of crop performance, the less deeply developed textural differentiation of the Kanhapl may have less ability to retain soil moisture and plant nutrients, but this has yet to be supported with data.

Since Soil Taxonomy is not only for agriculture, but for other purposes like engineering, the recognition of the "Kandi" and the "Kanhapl" taxa may be useful.

5.4. Testing the ICOMLAC Key to the LAC Ultisols

The placement of the LAC great groups in the key varied with suborders but in general, the "Kandi" and "Kanhapl" taxa are keyed out after the "Plinth", "Frag", "Alb", and "Sombr" great groups. They were also keyed out before the "Pale", "Rhod", "Hapl", and "Ochr" great groups.

The ICOMLAC's key to the suborders of LAC Ultisols was tested as illustrated in Figure 20. The result of the test in Table 25 shows that some of the "Pale" great groups were placed in the "Kandi" taxon while the other LAC Ultisols were placed in the "Kanhapl taxon" particularly the Trop taxa.

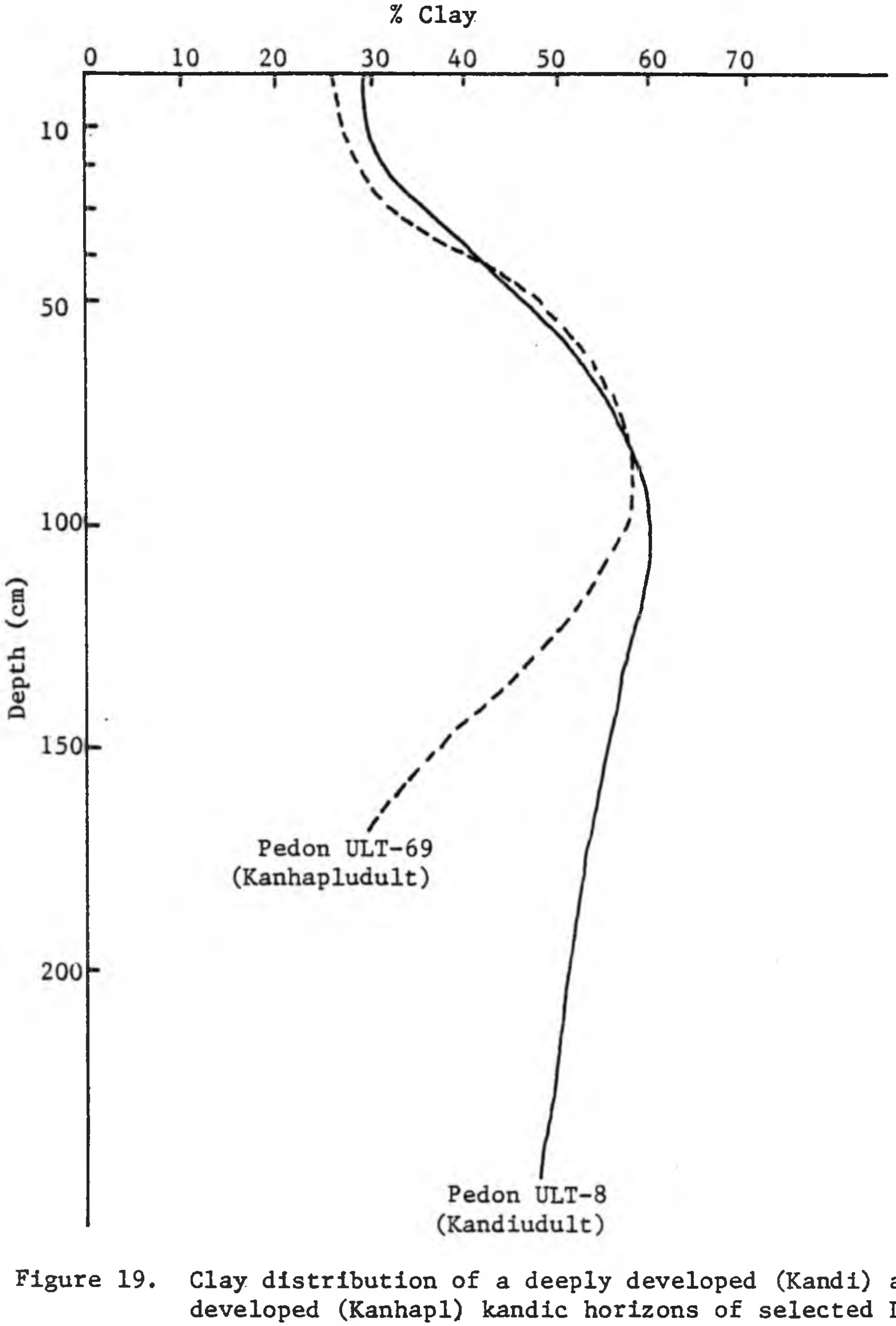


Figure 19. Clay distribution of a deeply developed (Kandi) and a less developed (Kanhapl) kandic horizons of selected LAC Ultisols in Brazil. Source: Proc 1st ISCW (1978) page 226.

Figure 20. Flow-diagram to test the ICOMLAC's key to the suborders of Ultisols.

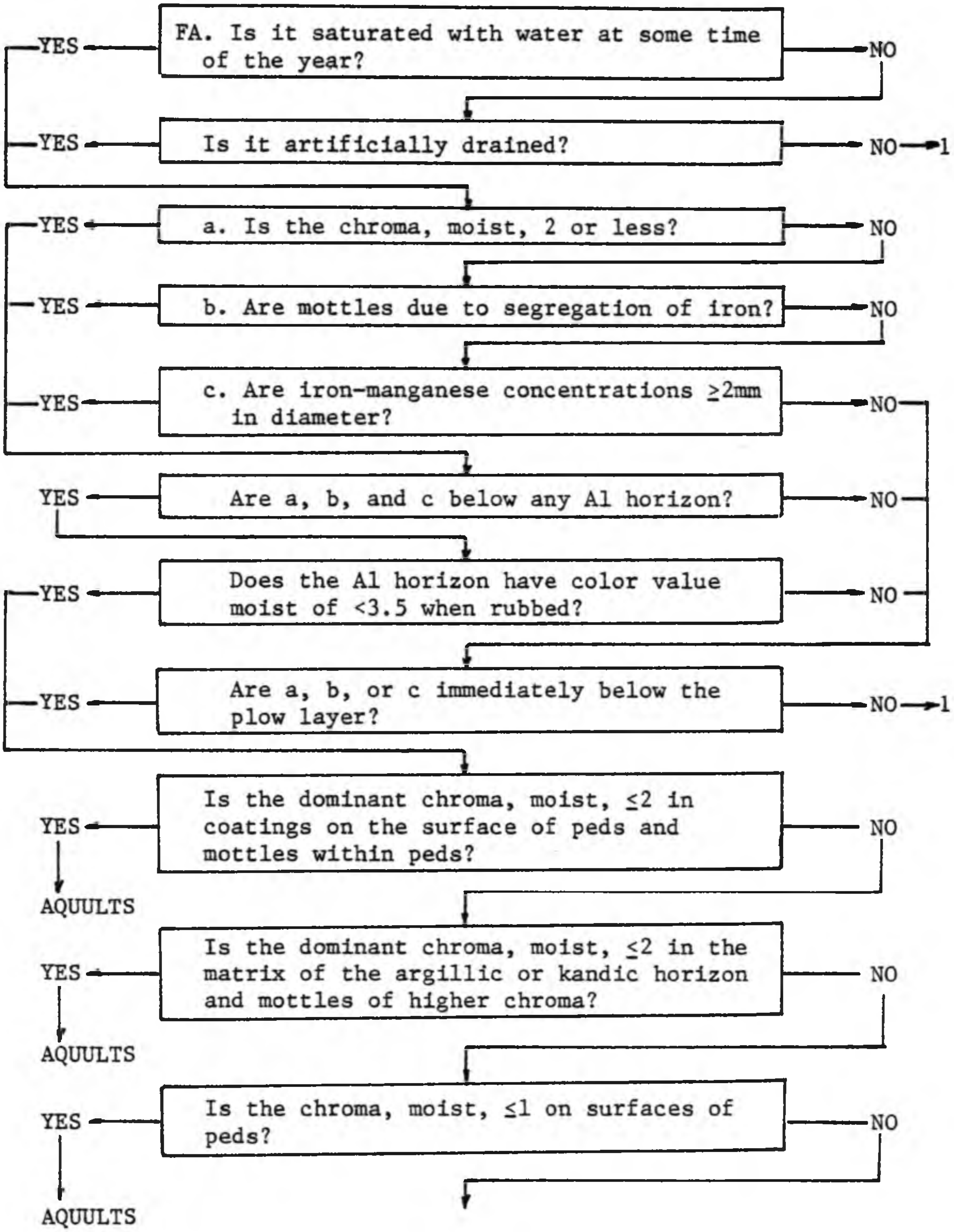


Figure 20. (Continued)

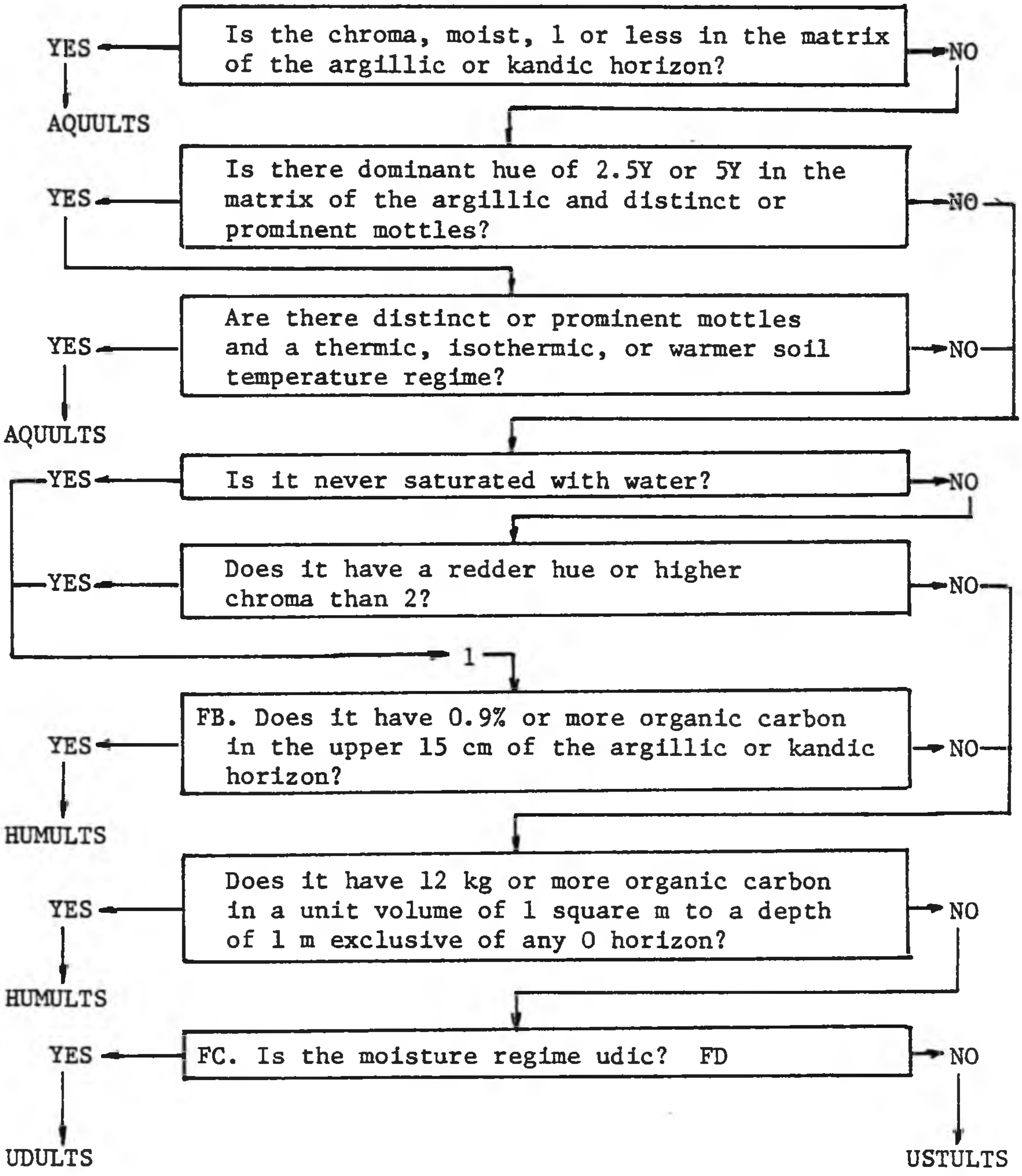


Table 25. Result of tests of the kandi taxa of LAC Ultisols.

Pedon/ Series	Suborder	CLASSIFICATION	
		In Soil Taxonomy	In ICOMLAC proposal
Songkhla	Aquults	Paleaquults	Kandiaquults
MU-7	Aquults	Paleaquults	Kandiaquults
Koronivia	Humults	Tropohumults	Kanhapluhumults
ULT-15	Udults	Paleudults	Kandiudults
ULT-19	Udults	Paleudults	Kandiudults
Saoa	Udults	Paleudults	Kandiudults
Toko	Udults	Paleudults	Kandiudults
Guire	Udults	Paleudults	Kandiudults
Kolea	Udults	Paleudults	Kandiudults
Glouamo	Udults	Paleudults	Kandiudults
ULT-14	Udults	Tropudults	Kanhapludults
MU-11	Udults	Tropudults	Kanhapludults
MU-13	Udults	Torpudults	Kanhapludults
Mab Bon	Ustults	Paleustults	Kandiustults
ULT-8	Ustults	Paleustults	Kandiustults
ULT-4	Ustults	Paleustults	Kandiustults
Mocambo	Ustults	Haplustults	Kanhaplustults

5.4.1. Testing the Kandiaquults and Kanhaplaquults

The ICOMLAC key to the great groups of suborder Aquults was tested in accordance with the flow-diagram in Figure 21.

Pedon ULT-70 of the Songkhla series in Thailand illustrated Item DAD (Figure 20) with a CEC <16 meq per 100 g clay which indicated the predominance of low activity clays; a clay content of <40 percent (12.4%) in the surface 18 cm, after mixing, and a clay content increase of more than 4 percent that was reached at a vertical distance of <12 cm (6 cm) which defines LAC Ultisols.

It also illustrated the chroma, moist, of 2 or less; a color value, moist, of <3.5 in the A1 and; a dominant chroma, moist ≤2 in coatings on the surfaces of peds and mottles within peds that distinguish the Aquults. This was confirmed by the aquic features as shown in the micromorphological description at 100 cm depth in which iron diffuses in the kaolinan or the matrix of the soil material resulting in reddish features (Proc 2nd ISCW, Part II, 1979). It also illustrated a chroma of 12 in some horizons (B21t) that defines an aeric subgroup.

Pedon ULT-55 in Lampung, Sumatra illustrated the concept of the "Kanhapl" great group wherein the CEC is <16 meq and ECEC is <12 meq per 100 g clay and the percentage clay distribution decreases by as much as 20 percent within a depth of 1.5 m from the surface (Table 26).

It also illustrated the color value, moist <3.5 in the Ap horizon that defines an umbric subgroup.

5.4.2. The Kandihumults and Kanhapluhumults

The ICOMLAC's key to the great groups of suborder Humults was

Figure 21. Flow-diagram to test ICOMLAC's key to Aquult great groups.

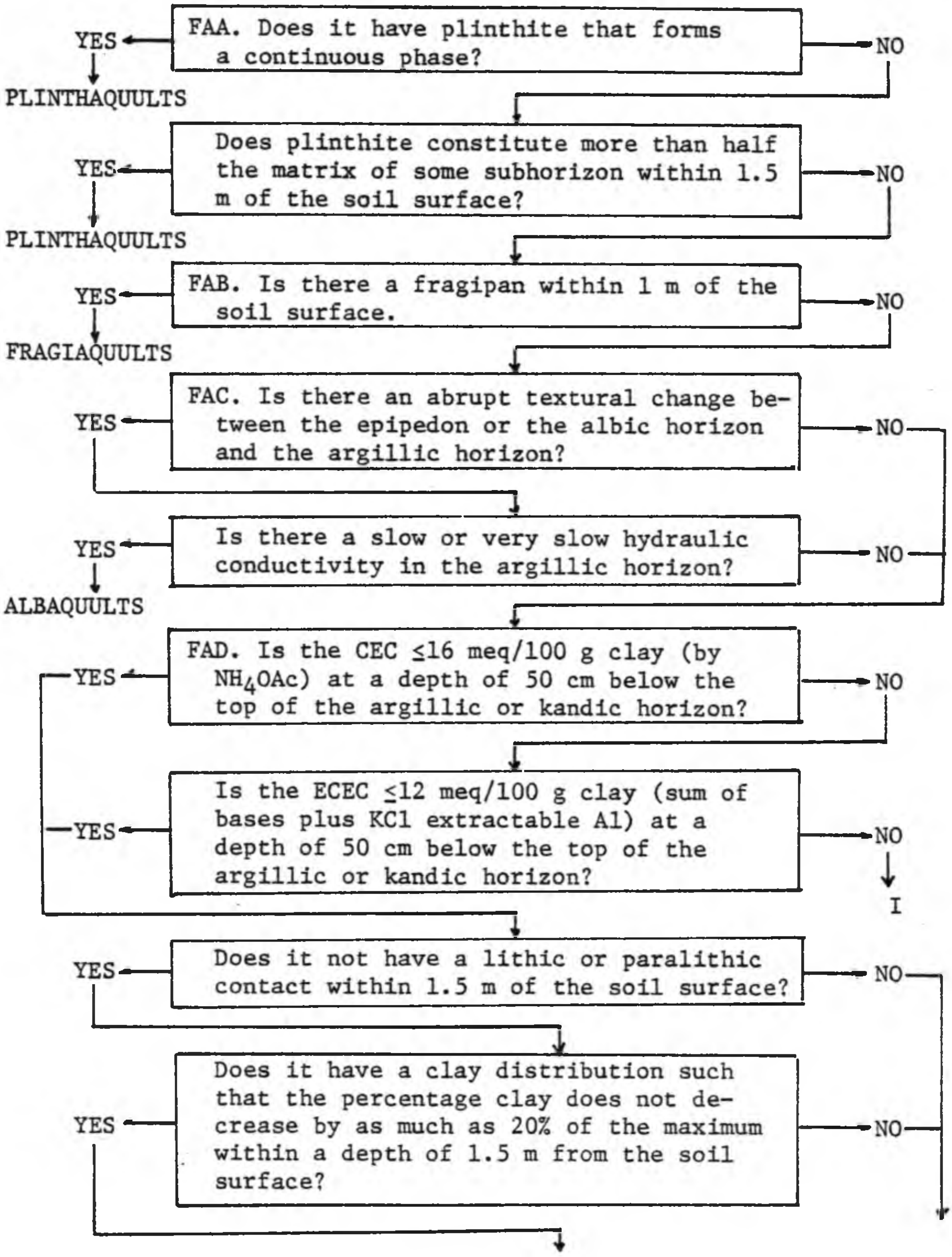
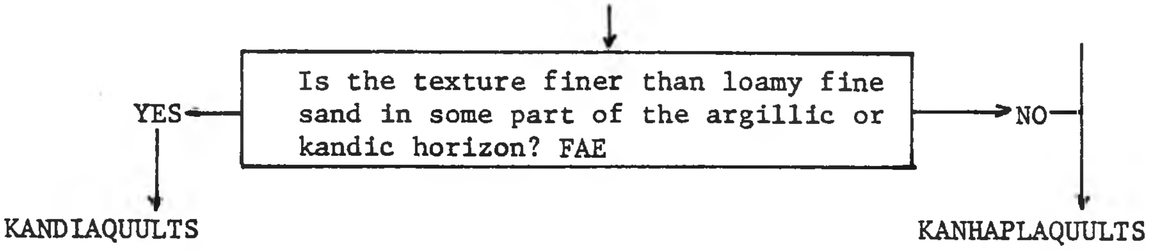


Figure 21 (Continued)



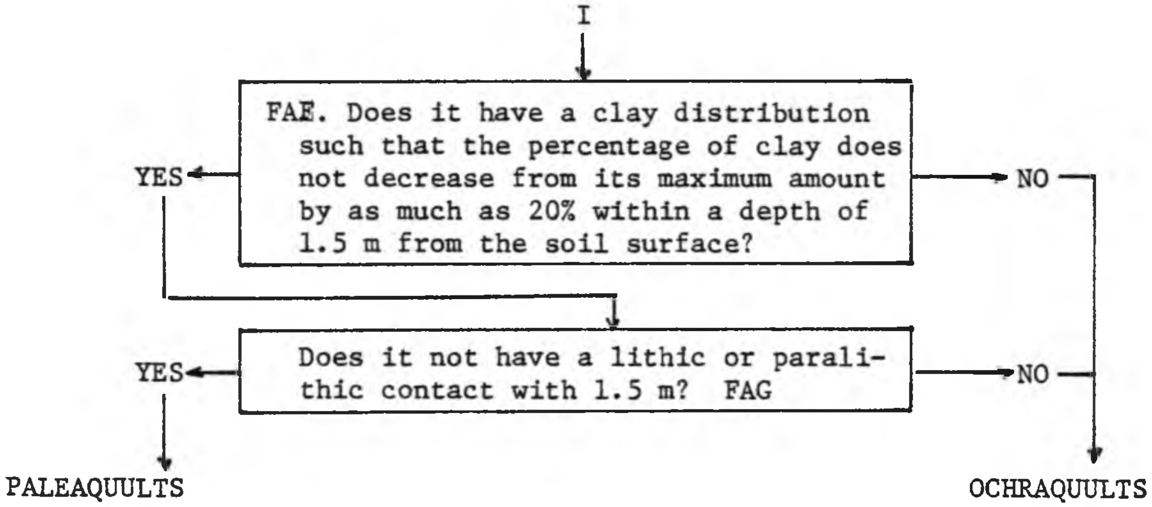


Table 26. Key attributes of Pedon ULT-53 that were used to test the LAC Aquults.

Depth -cm-	Horizon	Organic Carbon (%)	CEC	ECEC	Base Sat. (%)	Clay (<.002mm) (%)	Texture	Soil Color (moist)	Clay Skins	Mottles
			(meq/100g clay)							
0-26	Ap	3.95	69.2	7.2	4	25	scl	10YR3/1	-	-
26-50	B21t	0.50	16.9	0.6	4	33	scl	10YR4/1-4/2	-	-
50-65	B22t	0.40	8.8	0.6	7	52	c	10YR5/6	-	5YR5/8
65-90	C	0.25	7.8	0.4	4	57	c	10YR5/2-5/6	-	2.5YR4/6

tested in accordance with the flow-diagram in Figure 22.

In Soil Taxonomy, the Plinthohumults are keyed after the Palehumults. ICOMLAC deleted the latter and introduced the "KANDI" taxa.

Pedon ULT-48 of the Koronivia series in Fiji illustrated the concept of the great group of Kanhaplohumults in which the clay content was less than 40 percent in the upper 18 cm, after mixing, and a kandic horizon was present. This supported its placement in the order Ultisols. It further demonstrated the 0.9 percent organic carbon content in the upper 18 cm of the kandic horizon that defines the suborder Humox, and finally illustrated the need to amend item FB in the key to suborders in Soil Taxonomy, pp 350-351.

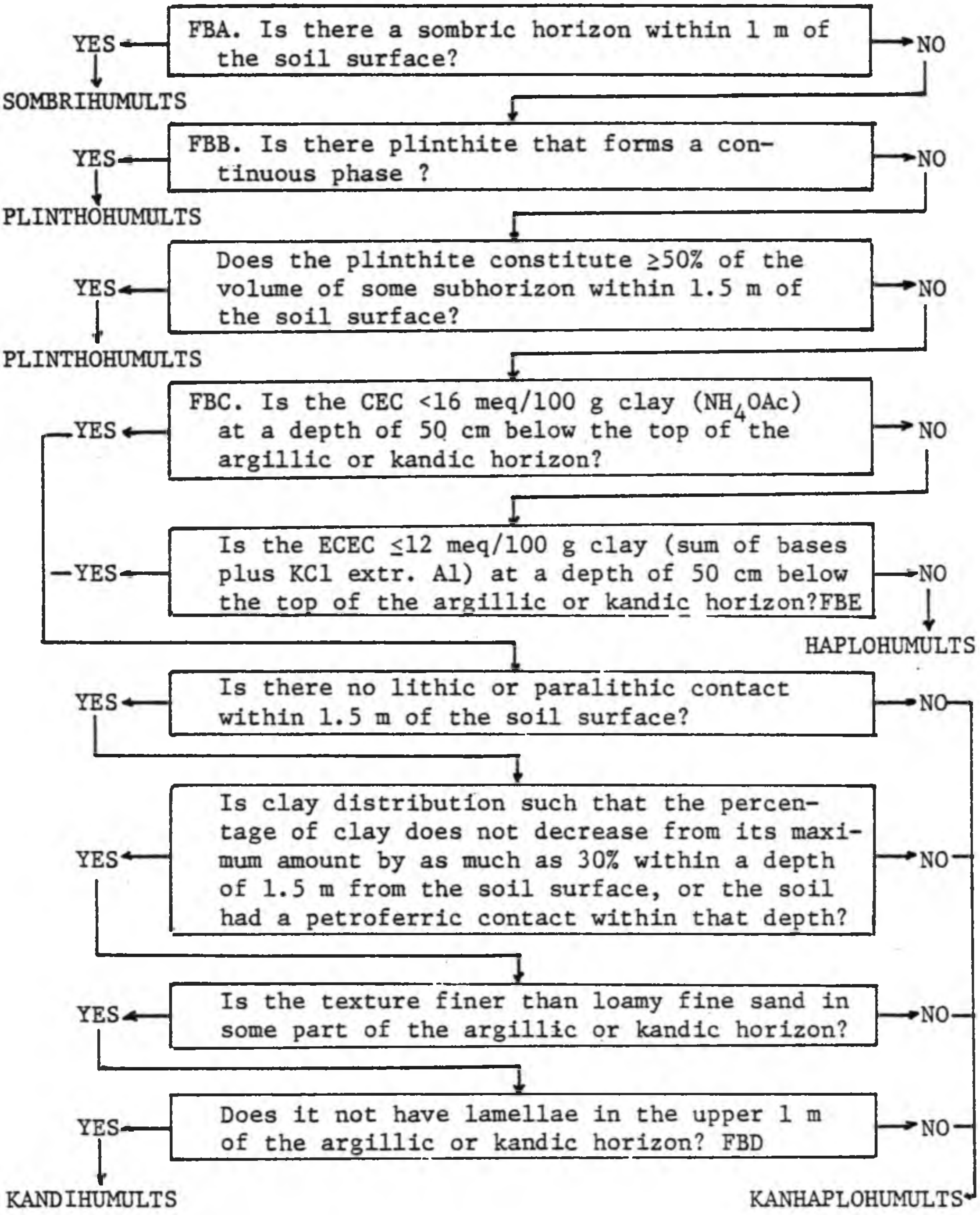
Here, it is suggested that the key definition of Humults be modified by inserting the phrase, "or Kandic", after the word argillic, in order to permit the LAC Humults to be keyed in the suborder category. The amendment reads as follows:

FB. Have 0.9 percent or more organic carbon in the upper 15 cm of the argillic <u>or kandic horizon</u>;

The Koronivia series also illustrated the percentage clay decrease from its maximum by more than 20 percent of that maximum within a depth of 1.25 m below the soil surface, which defines the "Kanhapl" great group of Humults.

The data of Pedon ULT-1 of the Alaeloa series, in Hawaii lent support to the above pedon. It illustrated a clay content of less than 40 percent and an ECEC ≤ 12 meq per 100 g clay which indicated a kandic horizon. It was placed in the LAC Ultisols in consideration with the base saturation by sum of cations <35 percent. It also

Figure 22. Flow-diagram to test ICOMLAC's key to Humult great groups.



illustrated the concept of the suborder Humults with the organic carbon content >0.9 percent in the upper 18 cm of the argillic horizon. The clay distribution that decreases to more than 20 percent from the maximum within a depth of 1.5 m from the soil surface illustrated the less deeply developed kandic or argillic horizon. But the Alaeloa soil has thick and continuous clay skins. The ICOMLAC proposal recognizes the argillic horizon as the diagnostic horizon rather than the kandic horizon. Here ICOMOX proposed that in addition to the kandic horizon, an argillic horizon may also be used to define the LAC Ultisols if it has CEC ≤16 meq and/or ECEC ≤12 meq per 100 g clay.

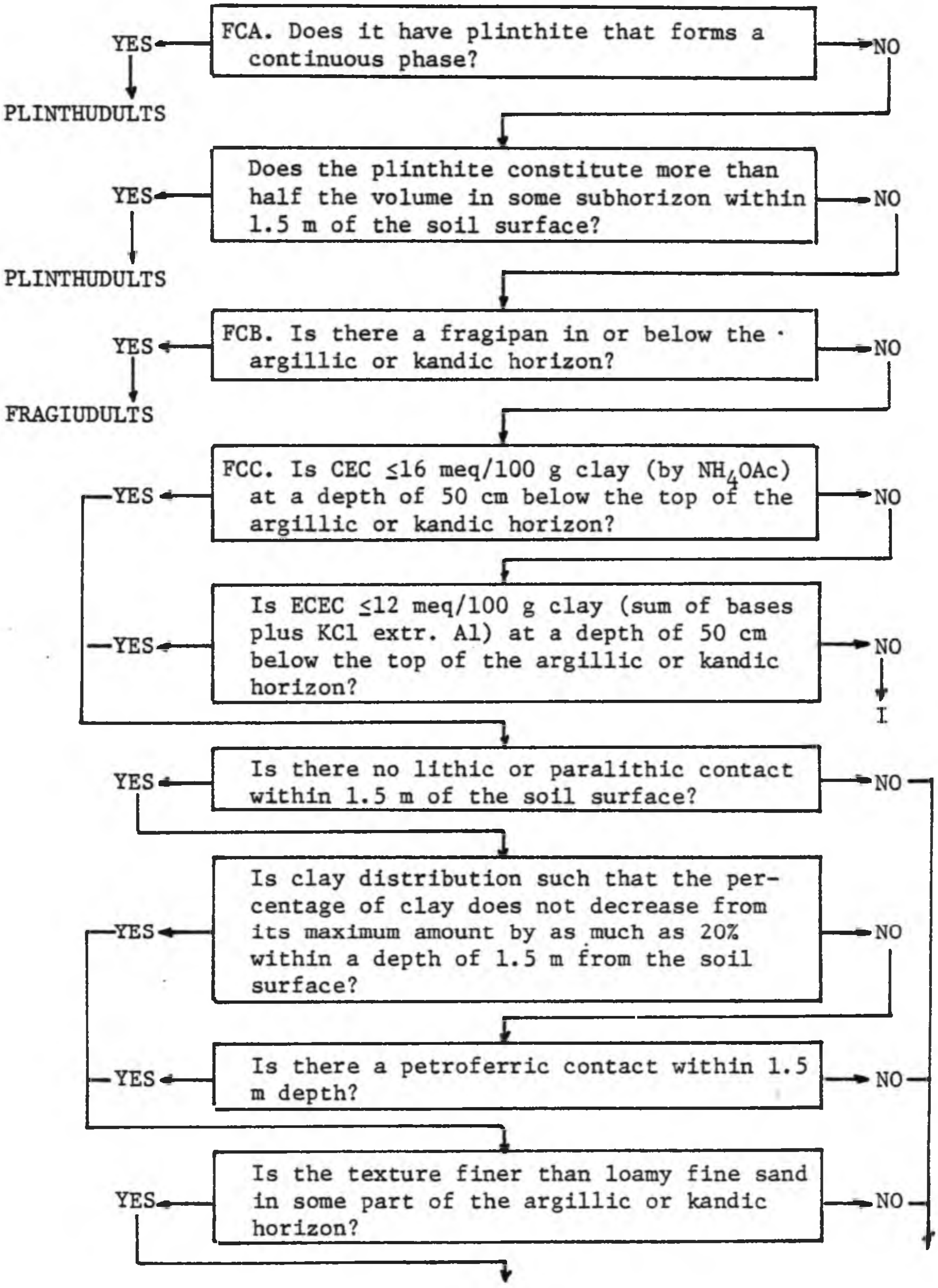
In this study, it was suggested earlier that the clay skin criterion of the kandic horizon be deleted so that the argillic horizon having low activity clays be placed in the kandic horizon.

5.4.3. Testing the Kandiudults and Kanhapludults

The ICOMLAC's key to the great groups of suborder Udults was tested in accordance with the flow-diagram in Figure 23, using the test pedons in Table 27.

The 3 pedons of Oxisols met the requirement of the Kandiudults. This was illustrated by the Donie series which has clay content less than 40 percent and has a kandic horizon. The plinthic characteristics of this soil makes the clay content increase in the B horizon very important because it helps retain moisture in the horizons where it has 15 percent by weight of very fine ironestone gravel that increases to 65 percent with increasing depth. Apparently the relatively higher clay content in the kandic horizon makes it capable to sustain production of upland rice, maize, cassava, forage and pasture

Figure 23. Flow-diagram to test ICOMLAC's key to Udult great groups.



FCA. Does it have plinthite that forms a continuous phase?

Does the plinthite constitute more than half the volume in some subhorizon within 1.5 m of the soil surface?

FCB. Is there a fragipan in or below the argillic or kandic horizon?

FCC. Is CEC ≤16 meq/100 g clay (by NH_4OAc) at a depth of 50 cm below the top of the argillic or kandic horizon?

Is ECEC ≤12 meq/100 g clay (sum of bases plus KCl extr. Al) at a depth of 50 cm below the top of the argillic or kandic horizon?

Is there no lithic or paralithic contact within 1.5 m of the soil surface?

Is clay distribution such that the percentage of clay does not decrease from its maximum amount by as much as 20% within a depth of 1.5 m from the soil surface?

Is there a petroferric contact within 1.5 m depth?

Is the texture finer than loamy fine sand in some part of the argillic or kandic horizon?

Figure 23 (Continued)

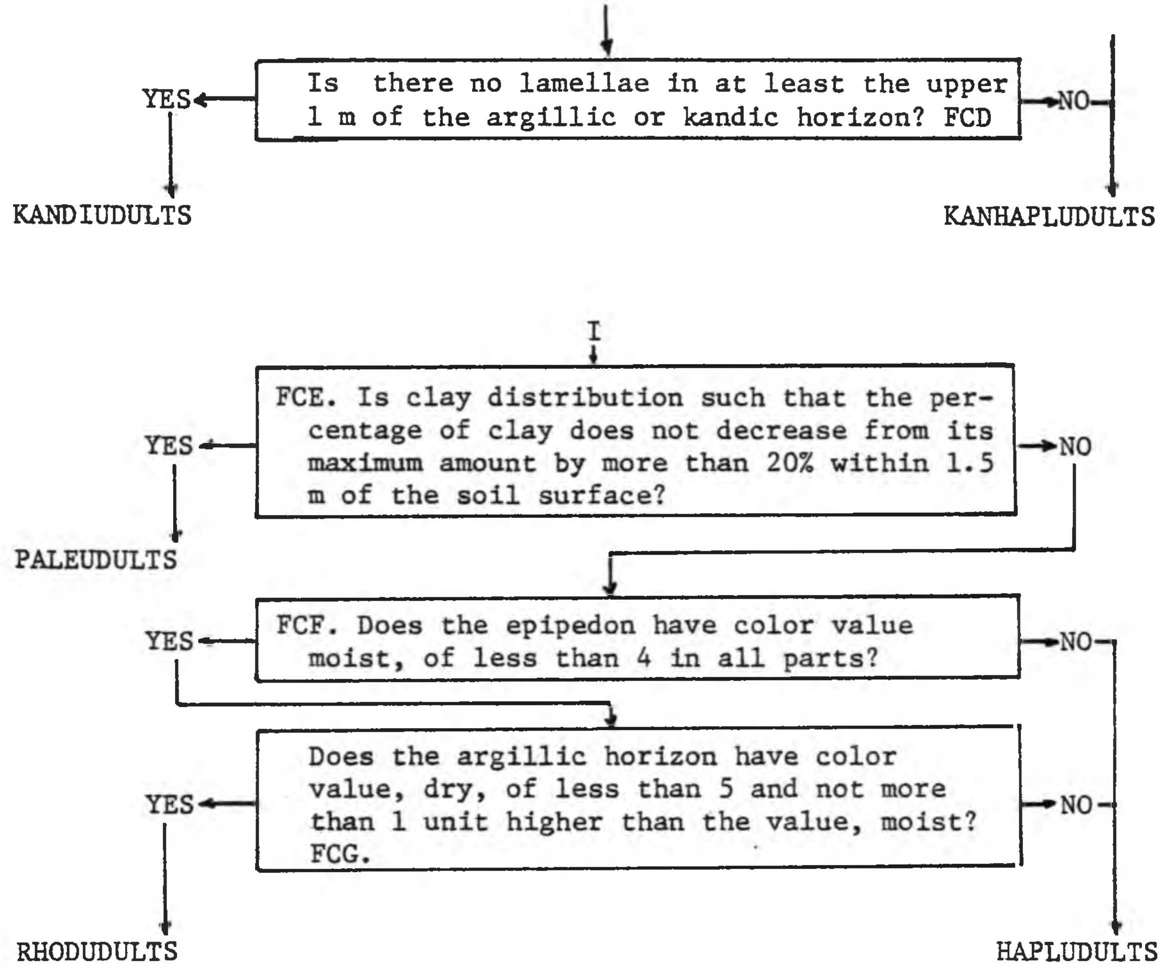


Table 27. Key attributes of selected Oxisols and Ultisols that were used to test the LAC Udults.

Depth	Horizon	Organic Carbon (%)	CEC	ECEC	Base Sat. (%)	Clay (<.002mm) (%)	Texture	Soil Color	Clay Skins	Mottles
-cm-			(meq/100 g clay)							
Pedon OX-12 of the Donie series, Plinthic Haplorthox, in Ivory Coast. Source: SSSR[*] (1967).										
0-6	A1	1.9	68.5		21	8.9	sl	10YR3/4	fw,tn	-
6-12	A3	1.2	39.5		10	11.4	cl	7.5YR4/6	fw,tn	-
12-102	IIB23	0.3	3.9		3	45.7	gr,c	7.5YR5/6	mn,tn	-
190-248	IIC	0.1	17.9		2	26.8	gr,c	7.5YR5/6	cn,tn	-
Pedon OX-1 of the Aburan series, Aquic Haplorthox, Sumatra. Source: SRI (1975).										
0-5	Ah	4.8	70.0	25.7	3	21	sc	7.5YR4/4		
5-10	ABh	1.4	28.4	16.3	4	19	sl	10YR6/3		
10-33	Bws1	0.5	12.4	9.2	3	25	sc	10YR6/4		
33-102	Bws2	0.3	11.5	8.1	0	27	scl	10YR7/4		7.5YR5/6
102-130	Bg	0.2	11.4	8.6	0	22	scl	10YR7/4		10YR7/2 10R5/8
130-150	Bn	0.1	11.8	9.7	0	34	cl	10YR7/1		10YR7/6
Pedon OX-5 of the Boka series, Plinthic Haplorthox, Ivory Coast. Source: SSSR (1967).										
0-3	A1	8.4	88.6		83	39.2	gr,cl	5YR3/2		
3-9	A3	3.5	50.6		60	32.2	gr,cl	5YR4/4		
42-119	IIB22	0.3	12.8		29	51.4	c	2.5YR5/6	cm,mo,tk	

[*] SSSR= Soil Survey of the Southwest Region, Republic of the Ivory Coast.

Texture: sl=silt loam, cl=clay loam, sc= silty clay, c= clay, gr= gravelly. Clay skins: fw=few, tn= thin, mn=many, cn= continuous, cm= common, mo= moderate, tk=thick.

Table 27 (Continued)

Depth -cm-	Horizon	Organic Carbon (%)	CEC (meq/100g clay)	ECEC	Base Sat. (%)	Clay (<.002mm) (%)	Texture	Soil Color	Clay Skins	Mottles
Pedon ULT-19 , "BR-30", Typic Paleudult, Pernambuco, Brazil. Source: Proc. 1st ISCW (1978).										
0-15	Ap	0.69	59.7	22.8	39	5.7	s	10YR4/2		
15-38	A2	0.47	29.4	6.4	21	10.9	ls	10YR5/3		
38-62	B21t	0.40	14.7	3.7	16	32.6	scl	10YR6/3		5YR5/6
62-82	B23	0.35	13.7	4.6	13	35.1	scl	10YR6/4		
1290-220	B3	0.20	11.2	2.6	6	31.2	sc	5YR6/6		2.5YR3/6
Pedon ULT-6 of the Saoa series, Plinthic Paleudult, Southwest Ivory Coast. Source SSSR (1967)										
0-5	A11	1.6	72.7		31	6.6	sl	10YR3/2		
5-14	A12	1.0	32.8		8	11.9	sl	10YR4/3		
14-40	B1	0.7	24.6		4	16.7	gr,scl	10YR4/4		
40-61	B21	0.5	14.2		1	29.5	gr,sl	10YR5/8	cm,tn	
61-102	IIB22	0.2	12.8		7	37.4	sc	10YR5/8	cm,tn	5YR4/6
102-138	IIB23cn	0.2	13.8		5	39.8	c	10YR5/8	wk,tn	7.5YR5/6, 5YR4/4
138-195	IIB24cn	0.2			6	39.6	sc	10YR5/8	wk,tn	10YR6/6, 5YR4/6
Pedon ULT-74 of the Toko series, Typic Paleudult, Southwest Ivory Coast. Source: SSSR (1967).										
0-4	A11	6.3	85.1		54	24.8	gr,scl	5YR3/2		
4-12	A12	2.4	41.9		44	21.7	gr,scl	5YR3/4		
12-26	B11	0.6	19.0		22	22.1	gr,cl	5YR4/6		
26-38	B12	0.5	14.7		19	29.2	gr,cl	5YR4/6	fw,tn	
38-61	B21	0.6	12.5		19	52.6	gr,cl	2.5YR4/6	mn,tn	
61-88	B22cn	0.4	11.5		19	62.7	gr,cl	2.5YR3/6	cn	
88-156+	B23cn	0.3	12.7		17	61.3	gr,cl	2.5YR3/6	cn	

Table 27 (Continued)

Depth -cm-	Horizon	Organic Carbon (%)	CEC (meq/100g clay)	ECEC (meq/100g clay)	Base Sat. (%)	Clay (<.002mm) (%)	Texture	Soil Color	Clay Skins	Mottles
Pedon ULT-35 of the Glouamo series, Aquic Paleudult, Southwest Ivory Coast. Source: SSSR (1967).										
0-6	A1	1.8	77.2		47	10.1	sl	10YR3/3		
6-21	B11	0.4	43.8		25	8.9	sl	10YR4/4		
21-44	B12	0.3	27.4		20	15.7	scl	10YR5/4	fw,tn	
44-66	IIB21	0.4	18.9		24	25.8	gr,scl	7.5YR5/6	fw,tn	
66-75	IIB22	0.3	10.9		34	26.6	gr,cl	7.5YR5/6	vtn	
75-120	IIB23	0.2	14.0		31	27.1	cl	7.5YR5/6	cm,mo,tk	
120-184	IIIB23	0.2	19.7		36	31.0	cl	10YR5/6	fw,tn	7.5YR8/2, 7.5YR7/4
Pedon ULT-28 of Dalek series, Typic Paleudults, Sumatra. Source: Williams and Harding 1979).										
0-3	Ap	5.06	112.1		100	19	l	10YR3/1		
3-13	AB	2.24	8.3		14	21	l	10YR6/3		
13-44	Bt1	0.33	4.1		0	27	cl	10YR6/3		
44-60	Bt2	0.24	4.0		0	30	cl	10YR6/3		
90-110	Bt4	0.10	4.4		0	38	cl	7.5YR6/4		
Pedon ULT-69 of the Sijaw series, Typic Paleudults, Sumatra. Source: Williams and Harding (1979).										
0-2	Ah	6.87	43.1		4	42	c	7.5YR4/2		
2-17	Eh	0.98	10.6		0	54	c	10YR5/4		
17-42	Bt1	0.55	7.6		0	62	c	10YR6/6		
42-116	Bt2	0.43	6.1		0	70	c	10YR6/6		
116-150	Bt3	0.30	6.6		2	71	c	7.5YR6/6		

Table 27 (Continued)

Depth -cm-	Horizon	Organic Carbon (%)	CEC (meq/100g	ECEC clay)	Base Sat (%)	Clay (<.002mm) (%)	Texture	Soil Color	Clay Skins	Mottles
Pedon ULT-6, "MU-11", Orthoxic Tropudults, Sumatra. Source: SRI* (1975).										
0-17	Ap	2.22	27.1		28	38	sc	10YR3/1		
17-28	B21t	0.86	14.3		17	49	c	7.5YR5.6		
28-46	B22t	0.54	13.3		14	42	c	7.5YR5/6		
46-73	B23t	0.46	12.7		8	49	c	7.5YR5/6-5/8		
73-90	B2cn	0.43	13.2		8	47	c	7.5YR5/6-5/8		
90-120	C	0.29	13.8		8	47	gr,c	7.5YR5/8		
Pedon ULT-57, "MU-13", Orthoxic Tropudults, Sumatra. Source: SRI (1975).										
0-14	Ap	1.41	24.6		22	28	sc	10YR4/1		
14-33	B1t	0.63	14.4		27	39	sc	10YR5/4		
33-63	B21t	0.35	11.4		13	42	c	7.5YR5/6		
63-89	B22t	0.21	10.5		9	55	c	7.5YR5/6-5/8		
89-110	BC	-	-		-	-	c	7.5YR6/8		

* SRI= Soil Research Institute, Indonesia.

as reported in the Soil Survey of the Southwest Region of the Ivory Coast (1967).

Pedon ULT-19 in Pernambuco, Brazil illustrated the placement of the Paleudults in the new great group of Kandiudults. This pedon illustrated the clay content of less than 40 percent in the surface 18 cm, after mixing, the presence of a kandic horizon, and the percentage base saturation by sum of cations <35 percent, in addition to a udic soil moisture regime and a clay distribution which did not decrease from its maximum by as much as 20 percent of that maximum within a depth of 1.5 m from the surface. This was supported by the data of the other pedons in Table 27.

Pedons ULT-56 and ULT-57 illustrated the "Kanhapl" great group of the LAC Udults showing the less deeply developed kandic horizons with a clay distribution that decreased from the maximum by more than 20 percent within 1.5 m from the surface (Table 27).

5.4.4. Testing the Kandiustults and Kanhaplustults

The ICOMLAC's key to the great groups of Ustults was tested in accordance with the flow-diagram in Figure 24, using the test pedons in Table 28. The Pak Chong series, illustrated the placement from the Ultisols having CEC ≤16 meq and/or ECEC ≤12 meq per 100 g clay that have clay contents >40 percent in the upper 18 cm of the soil surface to the Oxisols.

The clay content of the Pak Chong series of more than 8 percent in the finer textured subsurface horizon was that of a kandic horizon, but a kandic horizon cannot be used as a diagnostic horizon if the clay content of the eluvial horizon is >40 percent (SCS, Final draft

Figure 24. Flow-diagram to test ICOMLAC's key to Ustult great groups.

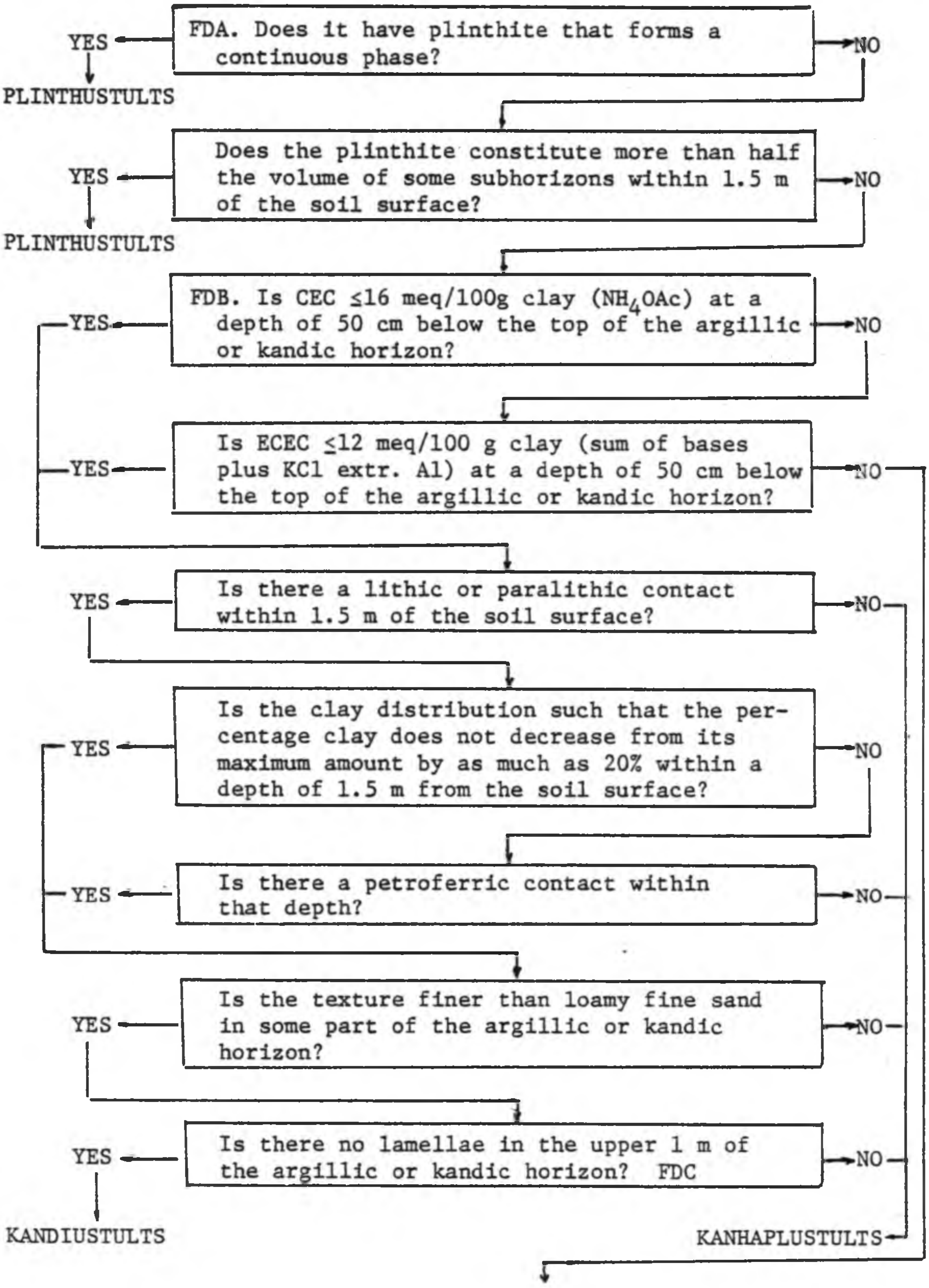
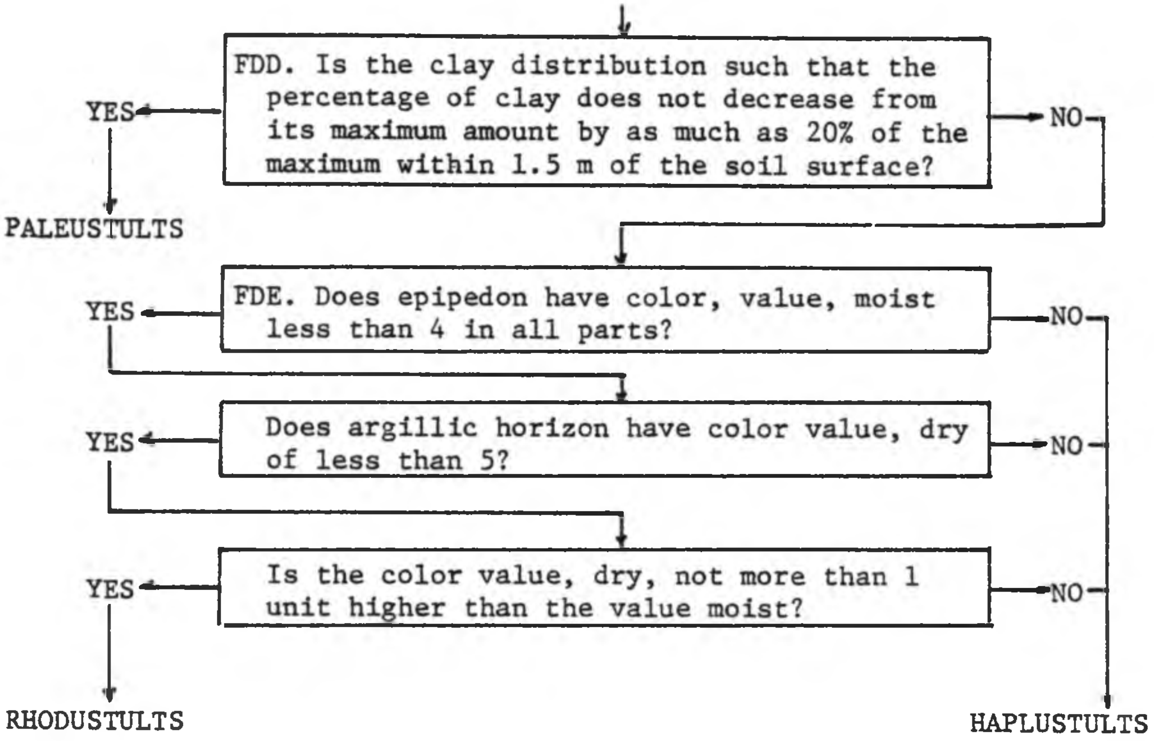


Figure 24 (Continued)



FDD. Is the clay distribution such that the percentage of clay does not decrease from its maximum amount by as much as 20% of the maximum within 1.5 m of the soil surface?

FDE. Does epipedon have color, value, moist less than 4 in all parts?

Does argillic horizon have color value, dry of less than 5?

Is the color value, dry, not more than 1 unit higher than the value moist?

Table 28. Key attributes of selected pedons used to test the LAC Ustults.

Depth	Horizon	Organic Carbon	CEC	ECEC	Base Sat.	Clay (<.002mm)	Texture	Soil Color	Clay Skins	Mottles
-cm-		(%)	(meq/100g clay)		(%)	(%)				
Pedon ULT-64 of the Pak Chong series, Oxic Paleustults, Thailand. Proc. 2nd ISCW Part II (1978).										
0-12	Ap	1.64	19.3	13.1	57	83.3	c	2.5YR3/4		
12-30	B21t	0.97	14.8	8.3	40	85.1	c	10R3/4	mo,tk	
30-53	B21t	0.56	13.1	7.1	17	89.6	c	10R3/4	mo,tk	
53-90	B22t	0.28	13.2	6.5	7	93.7	c	10R3/4	pc,mo,tk	
90-137	B22t	0.23	11.8	6.3	7	92.3	c	10R3/4	pc,mo,tk	
137-160	B23t	0.34	11.6	6.3	13	92.1	c	10R3/6	pc,tn	
Pedon ULT-8, "BR-4", Typic Paleustults, Rio de Janeiro, Brazil. Source: Proc. 1st ISCW (1978).										
0-11	Ap	1.09	48.3	12.4	24.67*	17.30	gr,sl	10YR3/2		
11-27	B3	0.66	26.1	7.2	23.96	28.32	gr,scl	10YR4/3	cm,wk	
27-46	B1t	0.60	17.3	5.2	27.50	41.89	gr,c	7.5YR4.5/4	cm,wk	
46-77	B21t	0.48	17.4	5.4	23.96	49.53	gr,c	7.5YR4/4	cm,mo	
77-110	B22t	0.44	15.5	5.2	23.96	50.37	gr,c	7.5YR4/4	cm,mo	
110-160+	B23t	0.39	15.7	4.9	21.84	48.67	gr,c	7.5YR5/5	cm,mo	10R4/8
Pedon "BR-16", Plinthic Paleustults,Sergipe, Brazil. Source; Proc. 1st ISCW (1978).										
0-26	A1	1.37	35.1	9.7	21.13*	31.71	gr,sc	10YR4/2		7.5YR5/6
26-40	IIA3	0.84	25.5	7.3	14.06	37.65	c	10YR4/3		7.5YR5/6
40-88	IIB2t	0.37	16.8	5.4	7.69	43.59	c	10YR7/6		7.5YR6/8
88-168	IIIBtpl	0.17	18.1	7.8	5.57	37.65	c	10YR6/6		7.5YR6/8
Pedon ULT-58 of the Mocambo series, Oxic Haplustults, Viti Levu, Fiji. Source: Proc. SPRFST** (1981).										
0-24	Ap	0.9	19.26	10.0	38*	27	sl	5YR3/3		
24-69	Bt1	0.3	13.61	10.3	75	36	cl	5YR5/8	fw	
69-109	Bt2	0.2	22.22	27.3	23	45	gr,c	5YR5/8		

* Base saturation by NH_4OAc. ** South Pacific Regional Forum on Soil Taxonomy.

of proposal for reclassification of LAC Alfisols and Ultisols, 1983). However, aside from the kandic horizon Item FDB (Figure 24) also employs an argillic horizon to define the "Kandi" great groups if it has a CEC ≤16 meq or ECEC ≤12 meq per 100 g clay. The presence of an argillic horizon was supported by the micromorphological analysis showing that clay translocation took place subsequent to deposition of the oxic material, suggesting that an argillic horizon had developed in oxic material (Proc. 2nd ISCW, Part II, 1979).

The case of this pedon has been discussed earlier in illustrating the definition of the kandic horizon. There, the rationale was that for heavy soils, the textural differentiation losses much of its significance, hence, the oxic characteristics takes precedence over the clay content increase of the kandic or argillic horizons. However, Item C.2 of the ICOMOX key definition to the order Oxisols excludes the LAC Ultisols with argillic horizon. Therefore, if the above rationale were to be adhered to, the definition of the kandic horizon should be amended and include an argillic horizon having CEC ≤16 and/or ECEC ≤12 meq per 100 g clay in the kandic horizon in order to delete argillic horizon with LAC in the definition of the kandi great groups of Ultisols. This can be done by modifying Item 2 of the definition of the kandic horizon by (a) changing the vertical distance of 12 cm or less to 30 cm to reach the required clay content increase as in the argillic horizon. This will place the LAC Ultisols having argillic horizon in the "Kandi" taxa, and Item 5 of the definition of the kandic horizon may be deleted to place the argillic horizon having CEC ≤16 meq and/or ECEC ≤12 meq per 100 g clay that have thick and continuous clay skins in the kandic horizon. The above suggestions mean that the kandic horizon becomes an exclusive differentiae for the LAC Ultisols as it was so intended.

Such modifications will also simplify the key definitions of the charge properties of the "Kandi" great groups as illustrated below:

In the flow-diagram (Figure 24), Item FDB defines the charge properties of the Kandiustults as,

"Have CEC $\leq$16 meq per 100 g clay (by NH_4OAc) or have ECEC $\leq$12 (sum of bases plus KCl extractable Al) at a depth of 50 cm below the top of the argillic."

If the above amendments are applied, the first provision of Item FDB will be; "Have a kandic horizon." This will also hold true with the LAC great groups of the other suborders of Ultisols.

Pedon ULT-8 in Brazil illustrated the usefulness of the kandic horizon in placing the Paleustults to the great group Kandiustults. It has a clay content of <40 percent in the surface 18 cm, after mixing and a kandic horizon that placed it in the Ultisols order (Table 28). The ustic soil moisture regime placed it in the suborder Ustults. It illustrated the clay content distribution that did not decrease from its maximum by as much as 20 percent of the maximum within a depth of 1.5 m from the soil surface that defines the Kandiustult great group.

The less deeply developed LAC Ustults were illustrated by the properties of Pedon ULT-58 of the Mocambo series in Levu, Fiji (Table 28). The clay content <40 percent in the surface 18 cm, after mixing, and a kandic horizon placed this pedon in the order Ultisols and the ustic moisture regime placed it in the suborder Ustults. The kandic horizon and a clay content distribution such that the percentage clay decreased from its maximum by as much as 20 percent of that maximum within a depth of 1.5 m from the soil surface illustrated the properties that define the Kanhaplustult great groups.

5.5. Suggested Addendum to the Key Definition of the Order Alfisols

The key definition of the order Alfisols in Soil Taxonomy, p 93 needed a provision to key the "kandi" taxa. This was achieved by inserting, "a kandic" after "Have an argillic," and before "or natric horizon..." in Item H.1 to read,

"H Other soils that

1. Have an argillic, <u>a kandic</u> or natric horizon but not fragipan; or
2. Have a fragipan that
   - a. Is in or underlies an argillic, or
   - b. Meets all requirements of an argillic horizon, or
   - c. Has clay skins 1 mm thick in some parts

The suggested amendment was illustrated by Pedon ALF-1 in Rio de Janeiro, Brazil with a kandic horizon that has a clay content <40 percent in the surface 18 cm, after mixing, and a base saturation that has <35 percent.

5.6. Key Definition to the Great Groups of LAC Alfisols

The key definition for the LAC Alfisols that was tested was obtained from the same sources as that of the LAC Ultisols.

The "Kandi" and "Kanhapl" great groups were introduced to recognize the more deeply developed and the less developed kandic horizons respectively.

Compared to the LAC Ultisols, the LAC Alfisols are proposed to be defined with higher class limits of ≤24 meq and ≤16 meq ECEC per 100 g clay.

5.7. Testing the ICOMLAC'S Key to the LAC Alfisols

The placement of the LAC great groups in the key varied with the suborders but in general, the "Kandi" and "Kanhapl" are keyed after the "Plinth", "Natr", "Dur", "Fragi", "Glass", and "Alb" taxa. They are also keyed before the great groups of "Umbr", "Pale", "Rhod", and "Hapl".

5.7.1. The Kandiaqualfs

The key to the great groups of suborder Aqualfs in Soil Taxonomy, p 109 was modified by ICOMLAC as follows:

HAA . . . . Plinthaqualfs

HAB . . . . Natraqualfs

HAC . . . . Duraqualfs

HAD . Other Aqualfs that have CEC ≤24 meq per 100 g clay (by NH_4OAc) or have ECEC ≤16 (sum of bases plus KCl extractable Al) at a depth of 50 cm below the top of the argillic or kandic horizon . . . . Kandiaqualfs

HAE . . . . Fragiaqualfs

HAF . . . . Glossaqualfs

HAG . . . . Albaqualfs

HAH . . . . Umbraqualfs

HAI . . . . Ochraqualfs

Here, no pedons were available to test the above.

5.7.2. The Kandiustalfs and Kanhaplustalfs

The ICOMLAC key to the LAC great groups of Ustalfs was tested in accordance with the flow-diagram in Figure 25.

Pedon ALF-2 in Alianca, Pernambuco, Brazil, illustrated the provisions of Item HCD of the Kandiustalfs with a kandic horizon that is reached within a vertical distance of <25 cm from the overlying coarser textured horizon. The maximum clay content of 45.3 percent in the B21t that decreased to 33.4 percent at B3t showed that the clay content did not decrease to more than 20 percent.

Pedon ALF-2, on the other hand, illustrated Item HCE with a clay content decrease of >20 percent from the maximum.

The significance of the change in classification from Paleustalfs to the Kandiustalfs may be viewed in terms of the accessory properties of the extremely weathered Alfisols inferred in the kandi taxa as evidenced by the low activity of the clay which may be more important than the evidence of clay movement in the Paleustalfs.

5.7.3. The Kandiudalfs and Kanhapludalfs

The ICOMLAC key to the LAC great groups of Udalfs was tested in accordance with the flow-diagram in Figure 26.

Pedon ALF-2 in Parana, Brazil illustrated the concept of the Kandiudalfs. It has CEC >24 meq per 100 g clay, but because it has ECEC <16 meq, it satistifed the charge requirement of a kandic horizon as per Item HEG, see Figure 26. Here, the Kandic horizon was not used as a diagnostic horizon because it has more than 40 percent clay in the surface horizon after mixing the upper 18 cm of the soil surface (SCS, Review draft of proposal for reclassification of LAC

Figure 25. Flow-diagram to test the ICOMLAC's key to the great groups of Ustalfs.

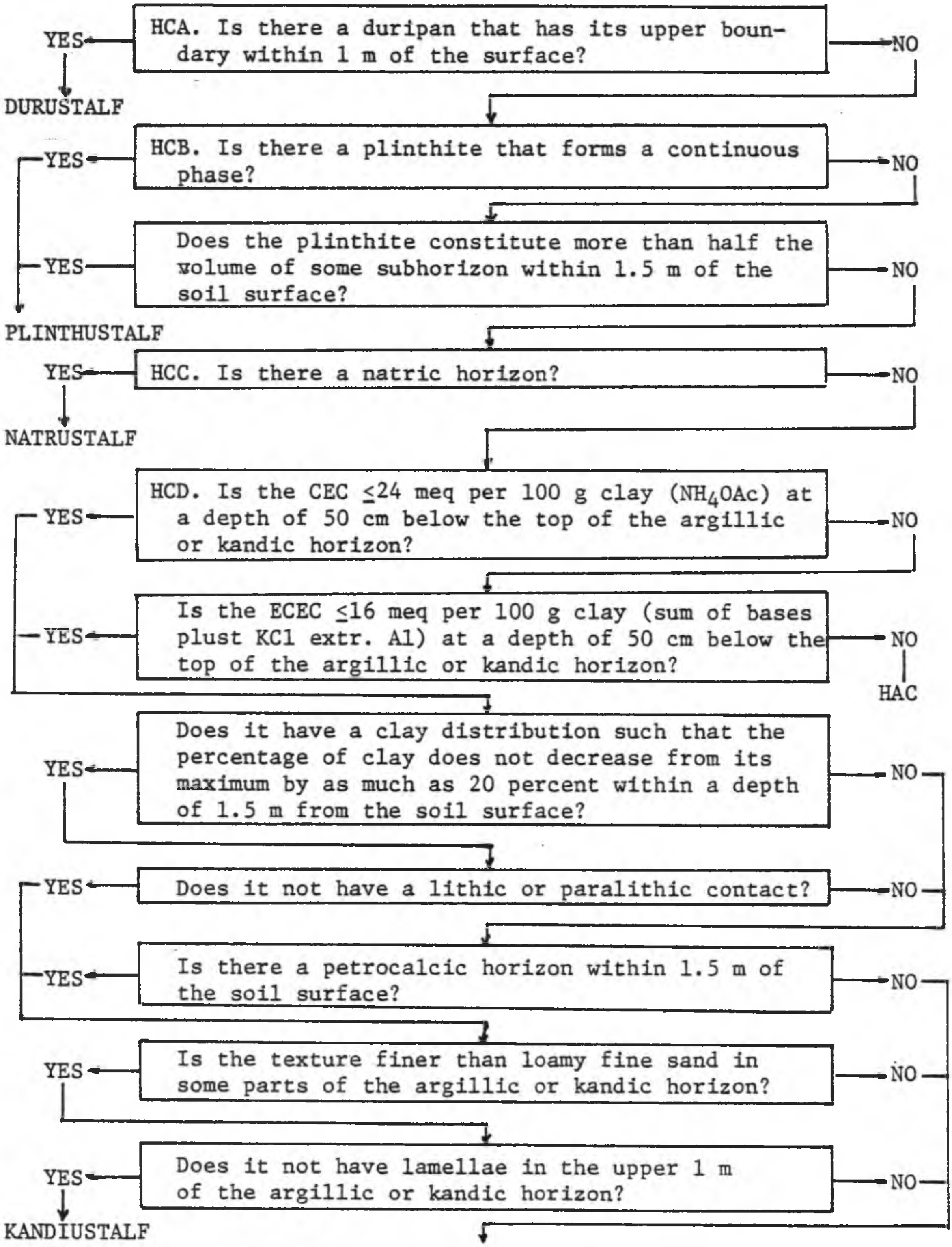


Figure 25 (Continued)

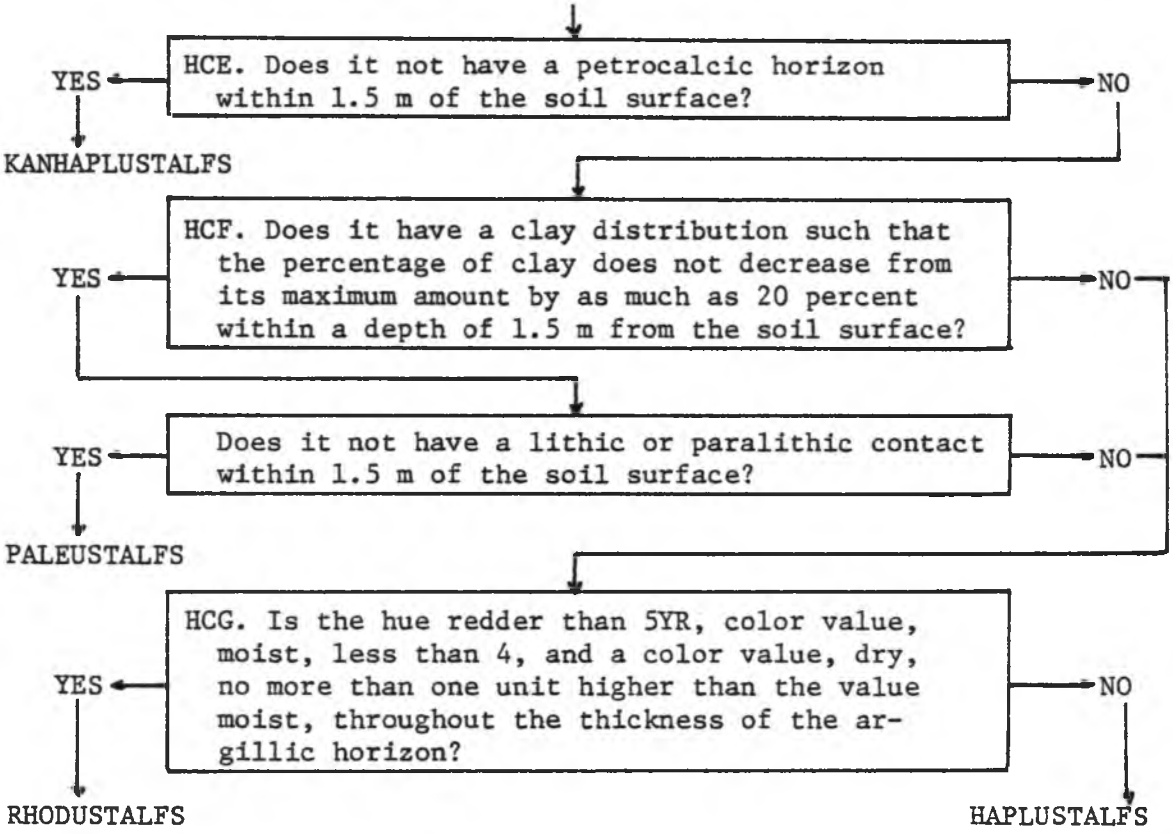


Figure 26. Flow-diagram to test the ICOMLAC's key to the great groups of Udalfs.

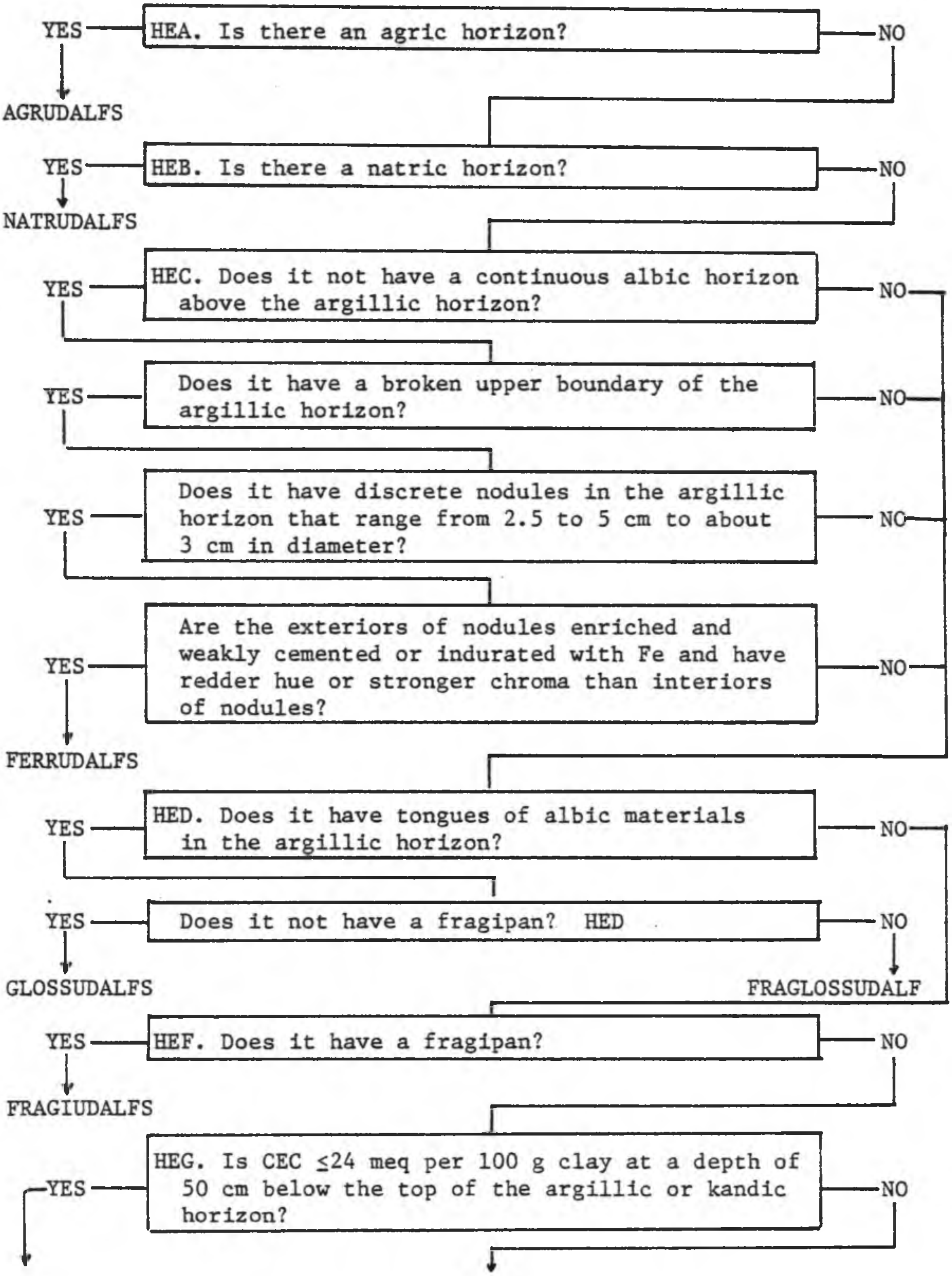
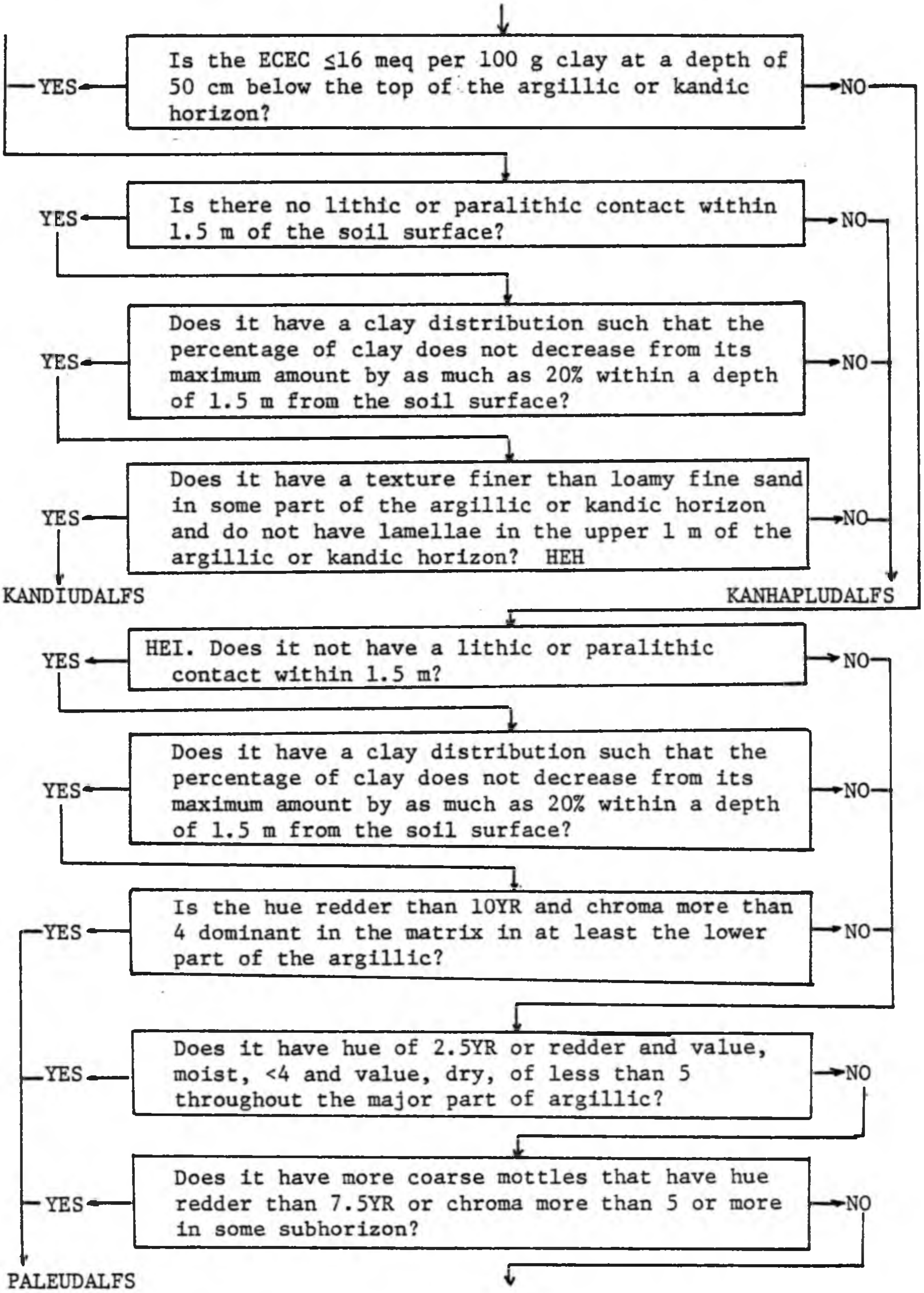


Figure 26. (Continued)



Is the ECEC ≤16 meq per 100 g clay at a depth of 50 cm below the top of the argillic or kandic horizon?

Is there no lithic or paralithic contact within 1.5 m of the soil surface?

Does it have a clay distribution such that the percentage of clay does not decrease from its maximum amount by as much as 20% within a depth of 1.5 m from the soil surface?

Does it have a texture finer than loamy fine sand in some part of the argillic or kandic horizon and do not have lamellae in the upper 1 m of the argillic or kandic horizon? HEH

HEI. Does it not have a lithic or paralithic contact within 1.5 m?

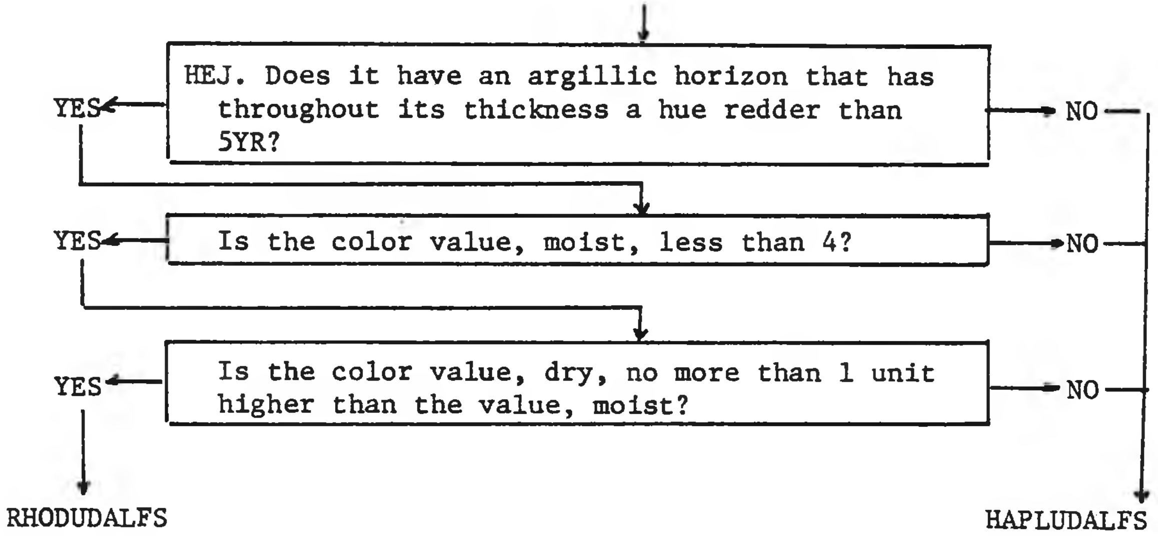
Does it have a clay distribution such that the percentage of clay does not decrease from its maximum amount by as much as 20% within a depth of 1.5 m from the soil surface?

Is the hue redder than 10YR and chroma more than 4 dominant in the matrix in at least the lower part of the argillic?

Does it have hue of 2.5YR or redder and value, moist, <4 and value, dry, of less than 5 throughout the major part of argillic?

Does it have more coarse mottles that have hue redder than 7.5YR or chroma more than 5 or more in some subhorizon?

Figure 26. (Continued)



Alfisols and Ultisols, 1983). Item HEG, however, uses the argillic horizon, as an alternate criterion for the "Kandi" great groups if the ECEC is ≤16 meq per 100 g clay at a depth of 50 cm below the top of the argillic. The presence of an argillic horizon was confirmed by the micromorphological description showing that clay illuviation was an intense process in this profile (Proc. 1st ISCW, 1978). The grainy appearance of cutans and the absence of more yellowish argillans were indicators of terminated translocation and that the cutans were beginning to be altered. The maximum clay content of 74.3 percent in the B21t horizon that decreased to as much as 17.6 percent in the B3t horizon illustrated the concept of the Kandiudalfs. The micromorphological description also revealed that the CEC >24 meq per 100 g clay was due to the pseudomorphs which consisted of altered biotite. The mineralogy of the sand fraction has 8 percent biotite, 3 percent potassium feldspars, 7 percent chlorites and 82 percent resistant minerals (Proc. 1st ISCW, 1978, p 117). In that seminar workshop, this pedon was believed to be transitional to a Mollisol. It was not placed in that order because the mollic epipedon was too thin.

The question that arises is, "If the LAC Alfisols are permitted to have CEC ≤24 meq or ECEC ≤16 meq per 100 g clay, can they be placed in the Oxisols if the clay content is >40 percent?" Here, the amount of weatherable minerals is >10 percent. The next question then is, "Is the CEC ≤24 meq or ECEC ≤16 meq per 100 g clay an appropriate limit to describe a LAC soil?" This is one of the most debated issues regarding the ICOMLAC proposal and both 16 and 24 meq per 100 g clay received strong support as the upper limit of the CEC for the "Kandic" and "Kanhapl" taxa (SCS, Review draft of Proposal for Reclassification of LAC Alfisols and Ultisols (1983).

The available data showed that the pedons of LAC Alfisol having CEC ≤16 or ECEC ≤12 have weatherable mineral content <10 percent. But those having CEC ≤24 or ECEC ≤16 meq exceeded the 10 percent class limit of the oxic characteristics. Therefore, the CEC ≤24 meq or ECEC ≤ 16 meq per 100 g clay may not be consistent with Item C.2 of the ICOMOX's key definition of the order Oxisols, where the LAC Alfisols having clay content >40 percent may be placed in the Oxisols. Uehara (1975) described these soils as medium activity clay (MAC) soils. This seems to suggest that the charge characteristics of the LAC Alfisols should also be ≤16 meq CEC and/or ECEC ≤12 meq per 100 g clay.

5.8. Suggested Amendment of the Definition of the Kandic Horizon with Respect to Both LAC Alfisols and Ultisols

The preceding tests of the keys to LAC Ultisols and Alfisols showed that the ICOMLAC's summary of properties of the kandic horizon did not cater to the LAC Alfisols. The reason was that the charge properties of the kandic horizon were defined with a CEC ≤16 meq per 100 g clay (by NH_4OAc) or with an ECEC ≤12 meq (sum of bases plus KCl extractable Al).

This led to the limited application of the kandic horizon in the definition of the "Kandi" and "Kanhapl" great groups of Ultisols and Alfisols, as illustrated below by the Udults and Udalfs.

FAD. Other Udults that meet all of the following requirements:

Have ≤16 meq per 100 g clay (by NH_4OAc) CEC or ECEC ≤12 meq (sum of bases plus KCl extractable Al) at a depth of 50 cm below the top of the argillic or kandic horizon . . . . . Kandiudults

In the Udalfs, the great group counterpart, Kandiudalfs is defined as, "Have CEC $\leq$24 meq per 100 g clay (by NH_4OAc) or have ECEC $\leq$16 meq (sum of bases plus KCl extractable Al) at a depth of 50 cm below the top of the argillic or kandic horizon."

The above illustration showed that the kandic horizon had not been adequate to define the charge properties of the Kandiudalfs because the class limits were greater than those of the kandic horizon. On the other hand, the charge characteristics of the kandic horizon were also repeated in the key definition of the Kandiudults. In this regard, it may be suggested that the charge properties of the LAC Alfisols should be changed to an ECEC $\leq$12 meq or CEC $\leq$16 meq per 100 g clay to conform with the definition of the kandic horizon.

In this respect, the charge properties of the "Kandi" and "Kanhapl" great groups of Alfisols will be simply defined as, "Have a kandic horizon;"

It will be noted that the argillic horizon in Item FAD.1 had been deleted. This was taken cared of by the earlier suggestion to delete Item 5 of the definition of the Kandic horizon so that the argillic horizon having CEC $\leq$16 meq or ECEC $\leq$12 meq per 100 g clay will be included in the Kandic horizon. The main purpose is to group together soils with low activity clays in the "Kandi" and "Kanhapl" great groups, using the kandic horizon as the differentiae to conform with the intent of the Kandi taxa. Besides the simplification of the key definition of the LAC great groups, the clay skin criterion which is very subjective will also be avoided.

5.9. Suggested Key to the LAC Interphase

The soil is a continuoum. Hence, the different LAC soils tend to grade into each other. Here, a given soil may possess an argillic horizon that has oxic characteristics. Others may be dominated by low activity clays but do not have argillic or oxic horizons. The argillic horizon is not sufficient to provide an adequate diagnostic criterion for all Ultisols and Alfisols from the Oxisols and Inceptisols (Review draft for reclassification of LAC Ultisols and Alfisols, SCS, 1983). Consequently, a pedon may be placed in more than one taxa or different pedons may be placed in one taxon. This is where the suggested modifications made in this study were integrated in order to establish mutual boundaries among the LAC soils.

The mutual boundary between the Oxisols and the LAC Alfisols and Ultisols is illustrated in Figure 27. Interphase A may have an oxic horizon or a kandic or argillic horizon that has CEC $\leq$16 meq or ECEC $\leq$12 meq per 100 g clay. It is an Oxisol belonging to the "Kandi" great groups if the clay content is >40 percent in the surface 18 cm, after mixing. Interphase B may have an oxic and/or a kandic or argillic horizon. It is a LAC Ultisol or Alfisol, if the clay content is <40 percent. Interphase C may have an oxic and/or an argillic or kandic horizon and clay content <40 percent. It is an Oxisol if there are some acric soil materials.

Figure 28 includes the LAC Inceptisols in the interphase. Interphase D has CEC $\leq$meq or ECEC $\leq$12 meq per 100 g clay. It is an Oxisol if the weatherable mineral is <10 percent and the pH in NaF is <10. Interphase E has also CEC $\leq$16 meq or ECEC $\leq$12 meq per 100 g clay.

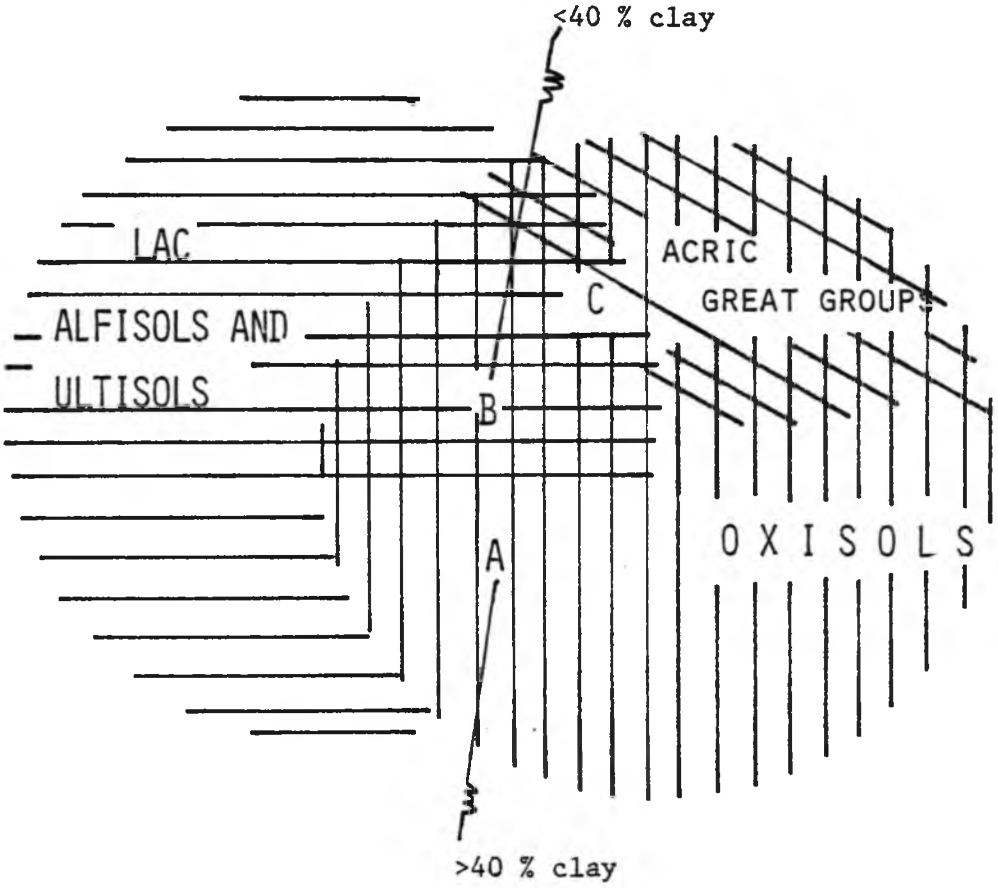


Figure 27. Diagram showing the Oxisols-LAC Alfisols and Ultisols interphase.

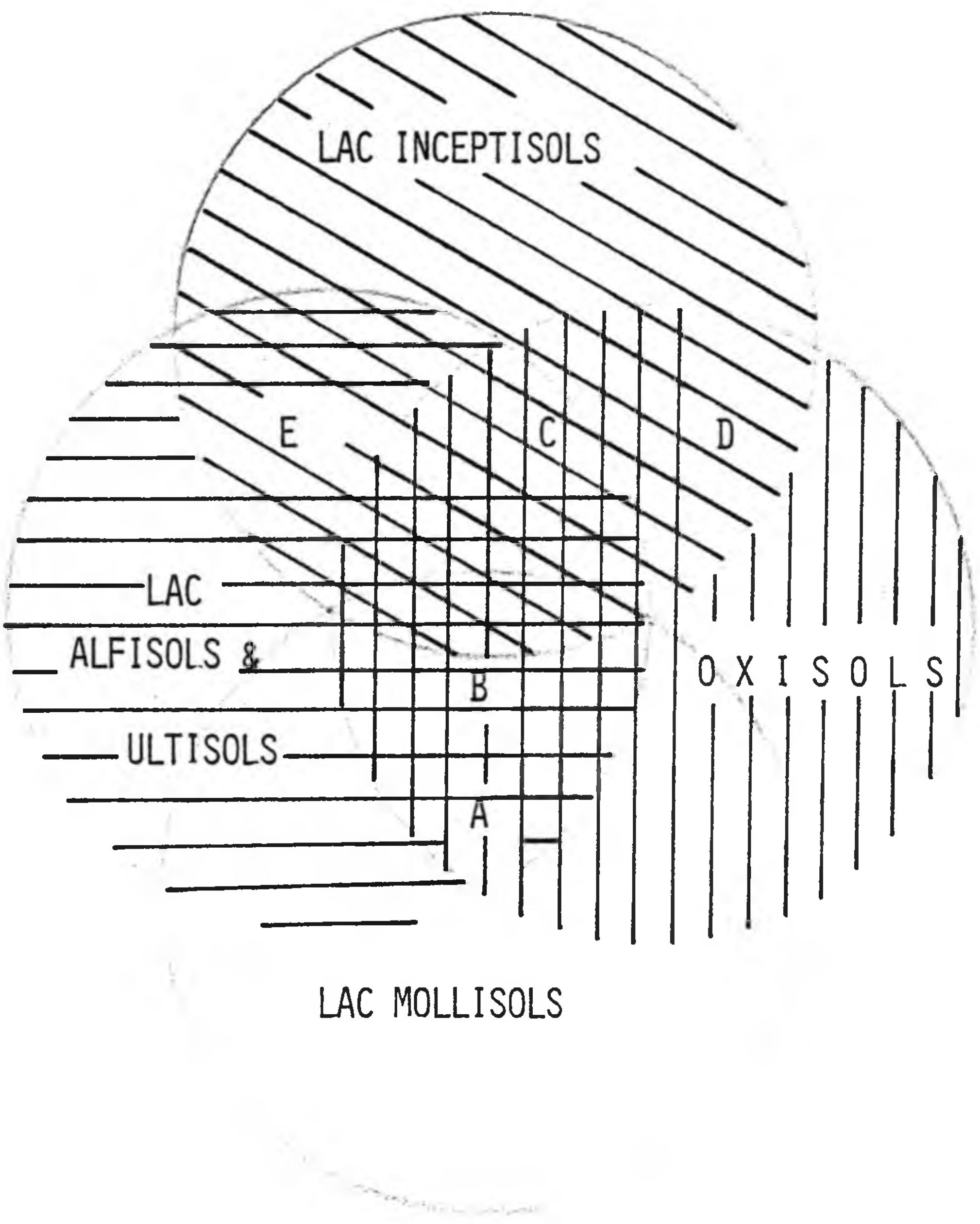


Figure 28. Diagram showing the low activity clay soils interphase.

It is a LAC Ultisol or Alfisol if there is an argillic or kandic horizon.

A LAC Mollisol can also grade into the LAC Alfisols. Here, the LAC Alfisols have base saturation (by NH_4OAc) that is <50 percent in some subhorizons of the kandic horizon. If it grades with the Oxisols, it is a LAC Mollisol if it does not have an oxic horizon. The LAC Alfisols and Ultisols that grade into the LAC Inceptisols are recognized by the presence of a kandic horizon.

The above interphase may be summarized into a flow-diagram key for LAC soils as shown in Figure 29.

5.10. Impact of the Proposed Revision on Agrotechnology Transfer

Uehara (1981) defined agrotechnology transfer as, "the taking of agricultural innovations, knowledge and experience from their site of origin to a new location where they are likely to succeed." The vehicle for transfer is a classification system where soils with similar physical and chemical properties that influence their behaviour to use and management are placed in the same taxa. Information about these properties are provided in the taxa name at the family category of Soil Taxonomy. This type of technology transfer is termed transfer by analogy (Nix, 1980).

5.10.1. The ICOMOX'S Revision

Table 29 shows that the test pedons of Oxisols in the Benchmark Soils Project were placed in different taxa by the ICOMOX'S key. Pedon WAI was placed in a different order category and Pedon COTO in a different great group category. The latter was placed from the Eutrustox to the Haplustox great groups because it fell short of the

FIGURE 29. Suggested flow-diagram key to the low activity clay soils.

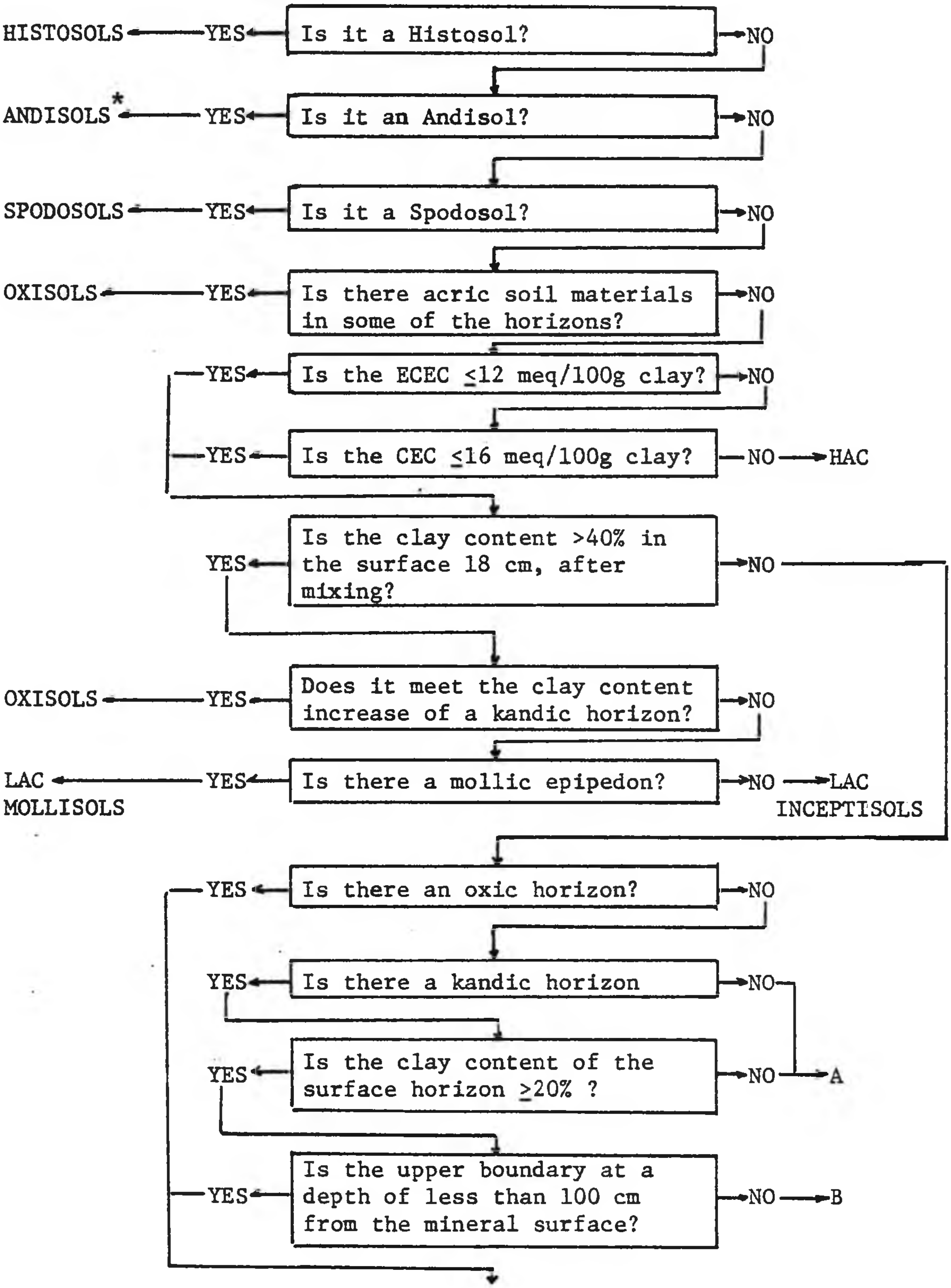


Figure 29. (Continued)

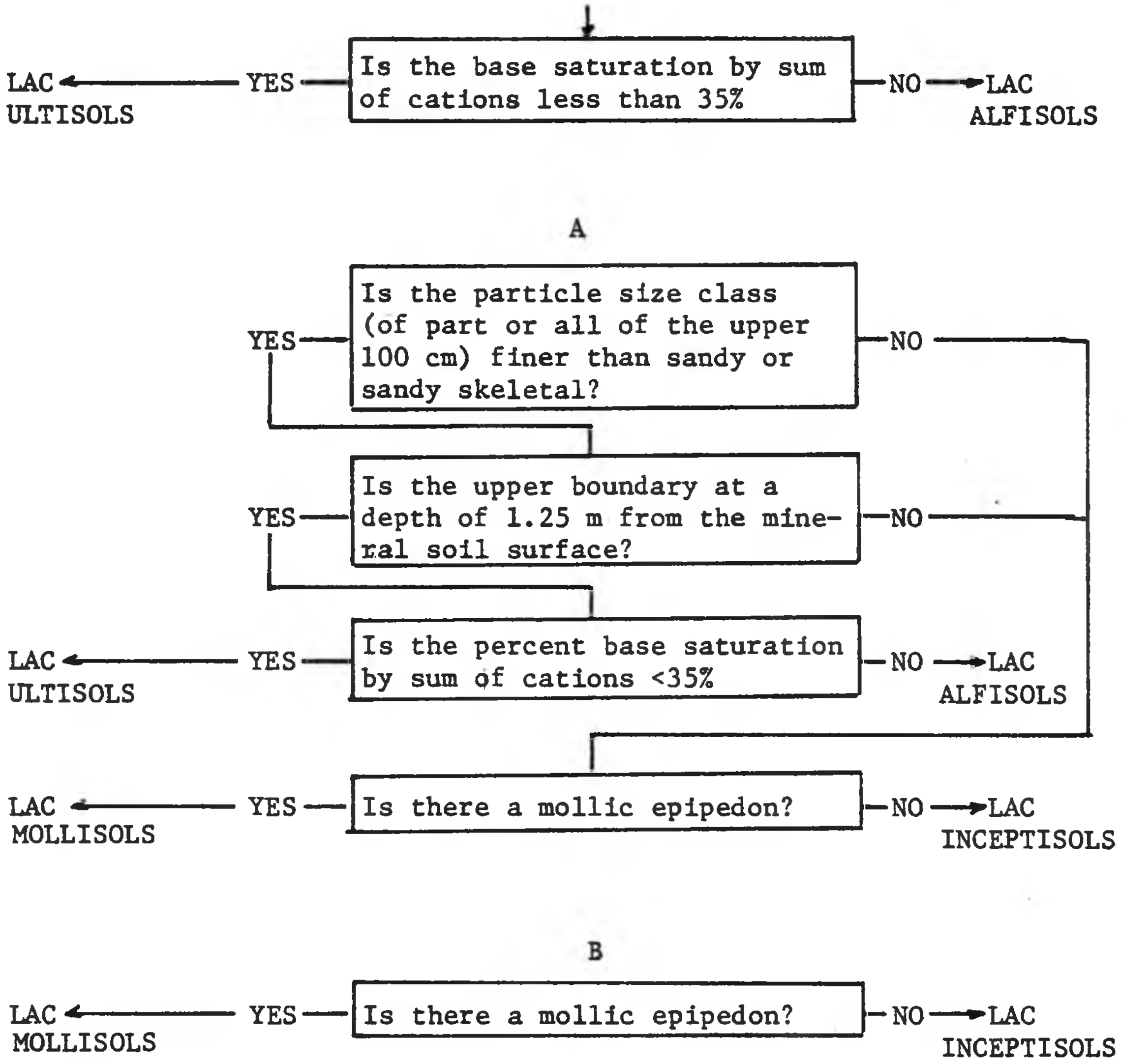


Table 29. Reclassification of the Benchmark network of soil families in accordance with the ICOMS proposals and with the suggested amendments in this study.

PEDONS	IN SOIL TAXONOMY	IN THE ICOMS PROPOSAL	IN THIS STUDY
WAI*	Tropeptic Eutrustox, clayey, kaolinitic, isohyperthermic.	LAC Inceptisols.	Tropeptic Eutrustox, very fine, kaolinitic, isohyperthermic.
COTO*	Tropeptic Eutrustox, clayey, kaolinitic, isohyperthermic.	Typic Haplustox, very fine, kaolinitic, isohyperthermic.	Tropeptic Eutrustox,very fine, kaolinitic, isohyperthermic.
JAI*	Tropeptic Eutrustox, clayey, kaolinitic, isohyperthermic.	Rhodic-Kuric Eutrustox, very fine, kaolinitic, isohyperthermic.	Tropeptic Eutrustox,very fine, kaolinitic, isohyperthermic.
DAV**	Ultic Tropudalf, very fine, halloysitic, isohyperthermic.	Mollic Kandiudalf, clayey, halloysitic,isohyperthermic.	Mollic Kandiudalf, very fine, halloysitic, isohyperthermic.
SOR**	Tropeptic Haplorthox, clayey, halloysitic, isohyperthermic.	Typic Haplorthox, very fine, halloysitic, isohyperthermic.	Tropeptic Haplorthox,very fine, halloysitic, isohyperthermic.
NAK**	Orthoxic Palehumult, clayey, kaolinitic, isohyperthermic.	Typic Kurorthox, very fine, kaolinitic, isohyperthermic.	Typic Kandiorthox, very fine, kaolinitic, isohyperthermic.
BUK**	Orthoxic Tropohumult, clayey, kaolinitic, isohyperthermic.	Typic Kurorthox, very fine, kaolinitic, isohyperthermic.	Typic Kandiorthox, very fine, kaolinitic, isohyperthermic.
BPMD*	Typic Paleudult, clayey, kaolinitic, isohyperthermic.	Typic Kurorthox, very fine, kaolinitic, isohyperthermic.	Typic Kandiorthox, very fine, kaolinitic, isohyperthermic.
CAM*	Typic Paleudult, clayey, kaolinitic, isohyperthermic.	Typic Kurorthox, very fine, kaolinitic, isohyperthermic.	Typic Kandiorthox, very fine, kaolinitic, isohyperthermic.

* Analysis by the Benchmark Soils Project Laboratory in Hawaii.
** Analysis by the National Soil Survey Laboratory, SCS, in Lincoln, Nebraska.

base saturation requirement, while the former was excluded from the Oxisols because the pH in NaF >9.4. This illustrated the case of soils that perform similarly being placed in different taxa.

Evidences of similarties of these soils were demonstrated in the Benchmark Soils Project (BSP Final Report, Puerto Rico, 1975-1981). Pedons WAI, JAI, and COTO have ustic moisture regimes that permitted at least two maize crops per year when irrigated during the dry season. This property was reflected in the prefix "Ust" of the taxon Ustox. It was supported with the performance of Pedon JAI in Table 30 where mulching was necessary to conserve moisture, suggesting that irrigation was indeed needed in some part of the year as inferred in taxon "Ust".

The BSP in Puerto Rico reported very similar maximum yields of maize in the COTO and JAIBA sites with comparable inputs. There was also no response to K fertilizer at both sites, and that one specific maize variety performed best in the two sites (BSP Final Report, Puerto Rico, 1975-1981). These seemed to illustrate the homogeneity in properties important to plant growth. It was further reported that the highest maize grain yield of all transfer trials in the COTO soil was 11,515 kg/ha. For that experiment, the overall mean was also high (10,223 kg/ha). In Hawaii, Pedon WAI gave maize yields as high as 11,530 kg/ha (BSP Report, 1980). The highest mean yield of maize in Pedon JAI was also 9,192 kg/ha. These are considered excellent yields for maize in the tropics (BSP Final Report, Puerto Rico, 1975-1981). The high production potential may be indicative of nutrient en-taxon "Eutr". Therefore, a change in the placement of Pedons COTO and

Table 30. Yield data from a mulching experiment with maize conducted at pedon JAI in 1980. Source: Puerto Rico BSP Final Report, 1982.

Levels of Maize Stoover Mulch	Grain Yield
- - - - - - - - - - - - - -kg/ha-	- - - - - - - - - -
0	657 c[1]
1042	1100 bc
2083	1280 bc
4167	1076 bc
6250	1046 bc
8333	1108 bc
10417	2017 ab
12500	2544 b

[1] Means with the same letter are not significantly different at the 0.05 level by Duncan Multiple Range Test.

WAI from Eutrustox to other taxa do not seem to match with the above performances.

In this study, it was suggested earlier to redefine the "Eutr" great group with a percentage base saturation >35 percent in the major part of the oxic horizon and to refine the pH in NaF of the oxic horizon from 9.4 to 10.0. These changes seemed to have improved the classification of the 3 pedons by placing them in the same taxa at the great group level (see Table 29).

At the subgroup level, the insignificant difference in maize yield between no tillage compared to the conventional tilling method in Pedon COTO (Table 31) evidently showed good physical condition of the soil which is appropriately reflected in the Tropeptic taxon. The change to Rhodic-Kuric in the ICOMOX's proposal may be viewed in terms of the information provided in the taxonomic name. The proposed definitions read, "Rhodic has 5YR or redder color hues in all parts of the oxic horizon above 1.25 m below the soil surface" and "Kuric has >40 percent clay in the surface 18 cm, after mixing."

Initially, the Rhod taxon was used to identify soils that do not have problems on soil structure under cultivation in the U.S.A. These soils have red color, hence, rhodic (Smith, as interviewed by Leamy, 1981)[*/] to imply the red color. In Malaysia, the rule of thumb is, "the redder the soil, the weaker the structure and the more friable it is. However, they often have very stable fine granular or crumb structure " (Paramananthan and Lim, 1979). In this respect, the

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[*/] Leamy, M. 1981. Conversation in Taxonomy. New Sealand Soil News Vol. 27, No. 2 pp 196-203.

Table 31. Maize grain yields from a tillage x plant spacing experiment conducted in pedon COTO in Isabela, Puerto Rico from Dec 1979 to April 1980. Source: Puerto Rico BSP Final Report, 1975-1981.

Plants per Ha	Tillage Treatments	
	Conventional	No Tillage
	- - - -grain yield, kg/ha- - -	
66666	9273	9446
57971	8623	9142
49383	7770	8174
Mean	8555a	8721a

[a] Means in the same line followed by the same letter are not significantly different at the 0.05 level of probability.

Tropeptic and the Rhodic taxa may imply favorable soil structure. However, it is oftenly mentioned that the hue of the soil becomes redder with increased amount of free iron, and that the red color implies high hematite content. But there are some yellow soils that contain high amounts of free Fe (Paramananthan and Lim, 1979). Isbell and Smith (1976) found that a red or yellow soil color may not give a reliable indication of iron content. This means that the "Rhod" taxon may not be exclusive for soils high in free iron content.

The Kuric subgroup is defined with a high clay content. This property may be indicated by adding the fine and very fine particle size class in Oxisols and Ultisols. In this case, the change from Tropeptic to Rhodic-Kuric may not provide a significant improvement in the classification, except perhaps that the latter are more quantitative and hence, less subjective than the determination of soil structure for the Tropeptic taxon. The structure criterion, however, is a very useful tool for soil surveyors in the field.

Tropeptic, in Soil Taxonomy, implies both structure and depth. Here, it is suggested that it should be defined only with the structure and that the depth criterion will be that of the Leptic subgroup as provided in Item b, page 331 in Soil Taxonomy.

The breakdown of clayey textural class into fine (40-60 percent clay) and very fine ($\geq$60 percent clay) by ICOMOX appears to be favorable, because the soil behaviour depends strongly on texture. For example, reliable estimates of water holding capacity, permeability, CEC, trafficability and rheology can be made from knowledge about particle size distribution (Uehara, 19750. Here, the class limits are more specific and, therefore, soil interpretation will be more precise.

The Halii and the Kapaa series in Hawaii illustrated the problem of two different soils placed in the same taxon. The ICOMOX's key placed the two soils in the great group of Gibbsiorthox.

However, Ikawa (1979) showed that the Halii and Kapaa series were quite different in some important respects. The Halii series has an isothermic temperature regime while Kapaa series has isohyperthermic. The latter has also a lower meanannual rainfall (MAR) and a higher mean annual temperature (MAT). These characteristics led to different economic uses and management properties for the two soils. For example, the Kapaa series is mainly used for water supply, wildlife habitat, pasture and may also be cropped to sugarcane. But in addition to the above, the Halii series is also utilized for pineapple, orchard, and truck crops.

In terms of fertilizer management, Fox (1962) showed that the Kapaa soil fixed more P than the Halii soil (Figure 30). Understandably, the P requirement of the Kapaa (Orthox) should be higher than the Halii (Humox). Fox attributed extreme availability of early-applied P in the Halii series to the abundance of the small nodules which constituted a large fraction of the soil. According to Fox, these nodules reacted with relative slowness at first because of the small surface area which they presented. As a result, late-applied P was taken up in relative abundance in the Halii series when compared with the Kapaa series.

It can also be seen in Figure 31 that as lime was added to increase the pH, the amount of added P remaining in solution did not

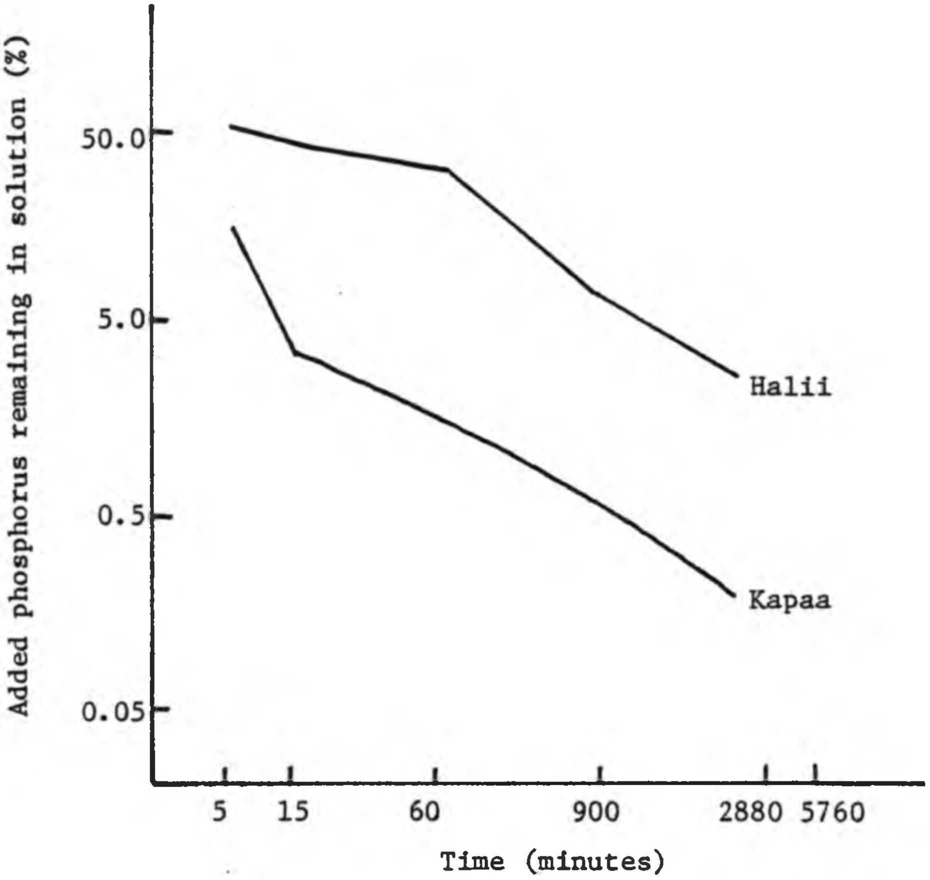

Figure 30. Immobilization of phosphate by Halii and Kapaa soils during four-day equilibration of soils with a phosphate solution. Source: Fox _et al_. (1963).

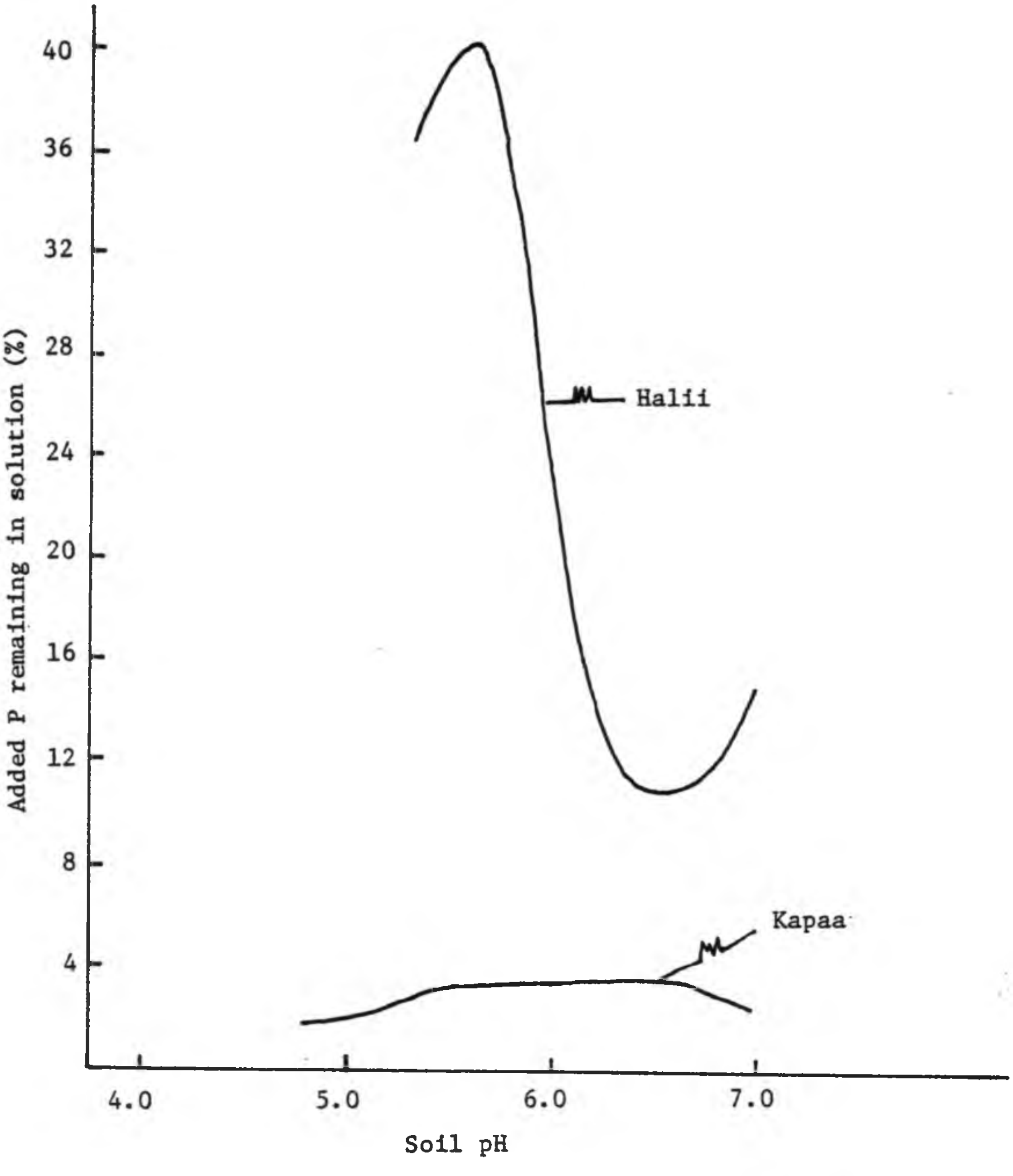

Figure 31. Influence of liming on the retention of phosphate by the Halii and the Kapaa soils. Source: Fox *et al.* (1963).

vary very much in the Kapaa series, while in the Halii series, liming to pH 6 drastically reduced the P in solution. In terms of crop performance, the P uptake of sudan grass was higher in both the limed and unlimed Halii soil, compared to the limed and unlimed Kapaa soil (Table 32). These performances were evidences showing different management properties of the two soils which in turn indicated that they should not be placed in the same taxon. In the suggested modification of the ICOMOX proposal, the Halii was placed in the Gibbsihumox, while the Kapaa soil was placed in the Gibbsiorthox.

5.10.2. The ICOMLAC Revision

The impact of the ICOMLAC proposal on agrotechnology transfer was tested against the characteristics and performance data of selected pedons of LAC Ultisols in the BSP network of soil family of the Ultisols.

The placement of Pedon DAV to the Alfisols illustrated the impact of the propsal in the stratification of agroenvironment into distinct agroproduction niches.

The characterization data obtained by the SCS on Pedon DAV supported its placement in the Ultic Tropudalf, clayey, halloysitic, isohyperthermic according to Soil Taxonomy. The ICOMLAC propsal placed this pedon in the Mollic Kandiudalf, very fine, halloysitic, isohyperthermic. This was in agreement with the classification made in this study and it is short of 1 percent base saturation in the B14 horizon to be in the order Mollisols. In fact, pedon DAV had appreciable amount of weatherable minerals such as 37 percent plagioclase feldspars, 8 percent hornblende, 4 percent muscovite in the very fine sand farction.

Table 32. Uptake of Al and fertilizer P by sudan grass from the Kapaa and the Halii series as influenced by liming.

Soil	Lime Treatment	P Yield (mg)	Utilization of added P (%)	Al uptake (mg/pot)	Plant Al (ppm)
Kapaa	Unlimed	0.23	0.12	0.10	313
	Limed	0.32	0.15	0.09	232
	Control[a]	0.18	-	0.07	358
Halii	Unlimed	0.44	0.44	0.09	208
	Limed	0.53	0.64	0.06	111
	Control[a]	0.26	-	0.13	400

Source: Fox *et al.* (1962).

[a] No lime or P applied.

Compared with the Oxisols and Ultisols of the Benchmark network of soil families, its placement in the Alfisols may be supported by the similar growth and development during the earlier stage of growth when the roots were still shallow and the marked increase in growth of nitrogen fixing trees in pedon DAV (Figure 32) at the later stage. The growth of the trees in Pedon NAK (paleudult) and Pedon WAI (Eutrustox) were poorer. Here, it seemed reasonable to supposed that the better performance of the trees in Pedon DAV may be related to the higher percentage base saturation throughout the profile from which the deep rooting nitrogen fixing trees were drawing sustained supply of nutrients without amendments.

The halloysitic mineralogy conformed with the relatively higher CEC and ECEC values of Pedon DAV than Pedons NAK, BUK, and SOR. The higher CEC and ECEC values seemed to be related to the consistently higher maize yield in Pedon DAV compared with the yields obtained in Pedons NAK, BUK, and SOR (Cady, personal communication).

Item HEG of the ICOMLAC key to the great groups of Udalfs placed Pedon DAV in the Kandiudalfs.

The data obtained by the SCS for Pedons SOR supported its place- in the Tropeptic Haplorthox, clayey, halloysitic, isohyperthermic according to Soil Taxonomy.

The ICOMOX's proposal placed it in the Typic Haplorthox, very fine, kaolinitic, isohyperthermic. Here, the Tropeptic subgroup was proposed to be deleted by the ICOMOX.

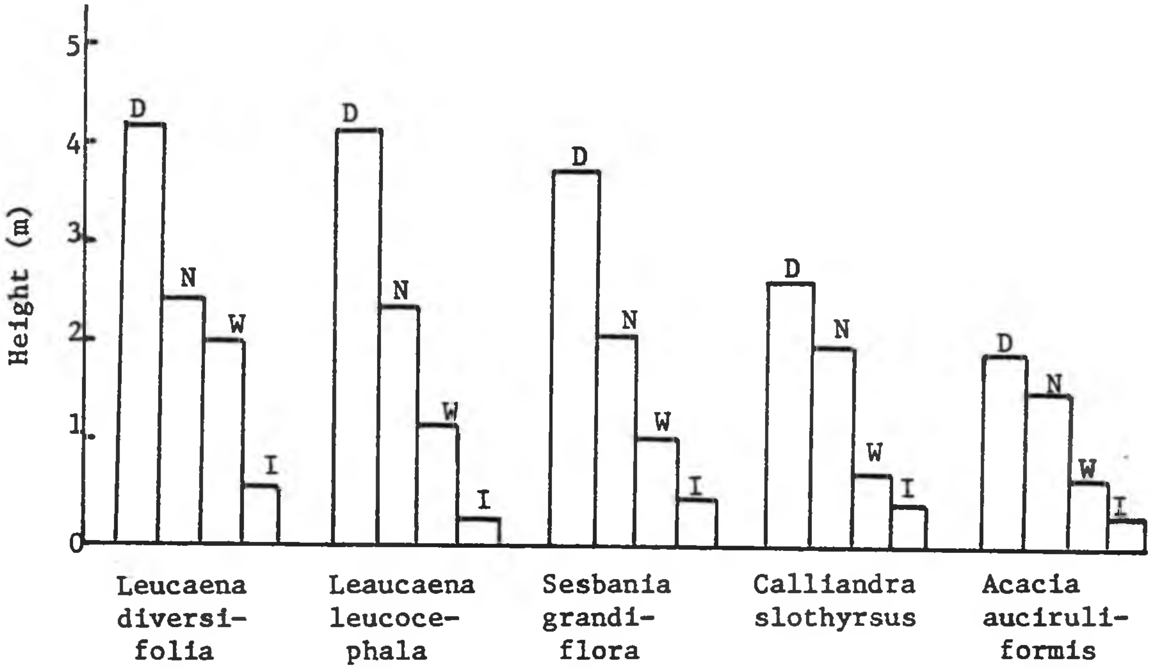

Figure 32. Average height of five nitrogen fixing tree species in replicated experiments at six months after planting in Pedons DAV (D), NAK (N), WAI (W) and IOLE (I). Source: BSP Prog Report 3 (1979-1982).

The suggested amendment to the ICOMOX's proposal placed it differently in the Tropeptic Haplorthox which is similar to its current classification in order to recognize and reflect in the taxa the discernible fine or medium granular structure.

The proposed changes by the ICOMS made considerable improvement in the classification of the LAC soils relative to agrotechnology transfer. However, the preceding exercise seem to indicate room for improvement. Suggestions were, therefore, made and the modifications seem to provide class units that have relative homogeneity in soil properties related to plant growth that led to the grouping together of soils having similar crop production potential.

VI. RESULTS AND DISCUSSION - STANDARDIZATION OF DATA, TEST OF EQUATION TO ESTIMATE CLAY CONTENT, AND RECLASSIFICATION OF TEST PEDONS

6.1. Standardization of some Laboratory Data

The data of a few test pedons were determined with procedures different from those prescribed in Soil Taxonomy. They were standardized to conform with methods required in Soil Taxonomy. It was done by establishing correlations between the data obtained by other countries with those obtained by the National Soil Survey Laboratory (NSSL) of the Soil Conservation Service in Lincoln, Nebraska on the same pedons.

The equations that were developed are shown in Table 33.

6.2. Test of Equations to Estimate Clay Content

The clay percentage in Item 2 of the summary of properties of the oxic horizon in Soil Taxonomy, p 39 is footnoted as follows:

"[15]The percentage of clay as measured by the pipette method or 2.5 x 15-bar water whichever value is higher but not more than 100."

The implication of the above is that low activity clays are difficult to disperse and, therefore, clay content may be estimated by its relation to the 15-bar water content. Here, the basis is that the moisture content is dependent on the clay and organic matter contents. Since Oxisols are generally low in organic matter, the use of the equation 2.5 x 15-bar water to estimate the clay content is permitted in Soil Taxonomy. Evidently, however, the factor 2.5 seem to underestimate the clay content of some Oxisols in Hawaii. This was illustrated by the data of the Wahiawa series (Table 34). Here, the

Table 33. Regression Equations of analytical data.

A. Data of pedons in Brazil by the NSSL, SCS (Y) and by the SNLCS Soil Laboratory (X). Source: Ikawa (1979).

VARIABLES	REGRESSION EQUATIONS	r	n
Sand	Y = 0.9907X + 2.6718	0.996	28
Silt	Y = 1.2972X - 1.3355	0.948	28
Clay	Y = 0.8480X + 1.1844	0.977	28
Organic Carbon	Y = 1.1552X - 0.0581	0.993	28
N	Y = 0.9298X - 0.0208	0.983	15
pH_{CaCl_2} vs pH_{KCl}	Y = 1.0003X + 0.0843	0.859	28
pH_{H_2O}	Y = 0.9975X - 0.2334	0.927	28
Na	-	-	-
K	Y = 1.3733X - 0.0357	0.939	27
Ca & Mg	Y = 0.9949X - 0.0683	0.998	28
Al	Y = 1.0998X + 0.0073	0.990	28
Base Saturation	Y = 0.7074X - 2.9177	0.975	28
Sum of Bases	Y = 1.3923X + 0.8333	0.990	28

B. Data of pedons in Thailand by the NSSL, SCS (Y) and by the Thailand Soils Laboratory (X). Source: Calculated from the Proc 2nd ISCW Part II, 1979.

Clay	Y = 1.1371X - 0.1093	0.989	51
CEC	Y = 1.0586X + 1.2323	0.977	51
Al	Y = 1.0365X + 0.2085	0.979	43
Organic Carbon	Y = 0.7818X + 0.0236	0.912	51
Ca	Y = 1.0578X - 0.0704	0.991	51
Mg	Y = 0.9715X + 0.2698	0.949	51
Na	Y = 0.9975X - 0.0098	0.865	51
K	Y = 1.0740X - 0.0430	0.918	39
Base Saturation	Y = 0.8505X - 4.2675	0.965	51
Sum of Bases	Y = 1.0556X - 0.1343	0.991	45
15-Bar Water	Y = 0.8421X + 1.3865	0.962	51
pH	Y = 0.7959X + 1.3865	0.997	51

Table 34. Calculated cation exchange capacity of the Wahiawa series* in the Benchmark Soils Project in terms of estimated clay by 2.5 x 15-bar water content.

Depth (cm)	Horizon	15-Bar Water (%)	CEC (meq per 100 g)		
			Soil	Clay (2.5 x 15-bar)	Clay (Measured)
0-10	Ap1	24.8	20.81	35.3	34.8
10-27	Ap2	24.3	18.43	29.7	19.3
27-40	AB	24.9	17.58	27.8	31.5
40-65	B21	24.4	13.74	22.2	26.2
65-90	B22	24.4	13.01	20.0	17.9
90-120	B23	25.1	14.11	21.5	18.8
120-150	B24	26.3	14.42	22.3	20.6

* Original profile samples.

clay content as estimated by the relationship of 2.5 x 15-bar water gave CEC values >16 meq per 100 g clay. Similarly, the low recovery of clay by the pipette method also resulted to a CEC >16 meq per 100 g clay (Table 35). The current placement of the Wahiawa series, therefore, in the Oxisols (BSP Tech. Report 1, 1979) is incorrect if Soil Taxonomy is strictly applied.

Soil Taxonomy prescribes the pipette method of Kilmer and Alexander (1949) for the determination of particle size distribution. The method has lower values of measured clay content than the actual clay content of some Hawaiian Oxisols (Tsuji, et al. 1974) and most oxide soils of the tropics (Ikawa, 1978) suggesting that this method may not be suitable for some Oxisols. The degree of clay dispersion by the pipette method was, therefore, compared with the ultrasonic vibration technique. The result in Table 35 showed a considerable increase of clay recovery with the ultrasonic vibration technique.

The sand- and silt-sized particles were examined by means of X-ray diffraction and it turned out that the minerals detected in the clay fraction were also those in the sand- and silt-sized particles . This seemed to confirm that the sand- and silt-sized particles were aggregates of clay that were not dispersed by the pipette method.

The experimental value of the factor used to multifly the percentage of 15-bar water content was calculated from the new data as the ratio of the measured clay to 15-bar water content. The result agreed with the factor 2.5 by using the pipette method, while the ultrasonic vibration technique gave an average factor of 3.5 (Table 36). The value of 3.5 was supported by the data of some Brazilian soils

Table 35. Clay analysis by the Pipette Method (PM) and the Ultrasonic Vibration Technique (UVT) for two pedons of the Wahiawa series of the Benchmark Soils Project in Waipio, Hawaii.

Depth	Horizon	Percentage Clay	
		PM	UVT
Pedon WAI (BSP original profile pit)			
0-10	Ap1	59.8	84.9
10-27	Ap2	62.9	82.6
27-40	AB	55.8	86.8
40-65	B21	52.4	88.5
65-90	B22	73.6	92.0
90-120	B23	74.9	88.7
120-150	B24	69.9	87.4
Pedon WAI (BSP new profile pit)			
0-23	Ap1	61.9	88.4
23-38	Ap2	69.5	85.5
38-53	B	70.1	92.3
53-91	Bw	65.8	91.3
91-125	Bw1	64.5	75.3
125-147	Bw2	38.3	45.2
147-178	Bw3	36.5	59.3

Table 36. The ratio of percent clay to 15-bar water content as influenced by the method of clay determination of Wahiawa silty clay.

Depth	Ratio of percent clay to 15-bar Water	
	Pipette Method	Ultrasonic Vibration
Original BSP profile		
0-10	2.4	3.4
10-27	2.6	3.4
27-40	2.2	3.5
40-65	2.1	3.6
65-90	3.0	3.8
90-120	2.9	3.5
120-150	2.7	3.3
Second BSP profile		
0-23	2.6	3.6
23-38	2.8	3.4
38-53	2.7	3.5
53-91	2.5	3.6
91-125	2.5	3.1
125-147	1.5	2.7
147-178	1.4	2.8

obtained by the pipette method of Kilmer and Alexander (1949), Pedons OX-10 of the COTO and OX-16 of the JAI soils in Puerto Rico and in Brazil, respectively, OX-9 of the Chock Chai (Table 1, Appendix VI), and the Pack Chong and the Yasothon series in Thailand (Table 2, Appendix VI).

The impact of the new factor was tested with the data of the Molokai (SSIR No. 29, p 180) and the Wahiawa series (SSIR No. 29, p 188) both of which are classified as Oxisols but failed to meet the CEC requirement of the oxic horizon when the clay content was computed by 2.5 x 15-bar water content. With the factor Of 3.5, the CEC's were lowered to 16 meq per 100 g clay or less (Table 37). It also reduced the CEC values of some oxic subgroups of Inceptisols (Table 3, Appendix VI) but they did not qualify for an oxic horizon because the upper textural boundary was not diffuse and the weatherable mineral content was high.

These are evidences that the factor 3.5 is a suitable value to keep some Oxisols that are difficult to disperse in their proper placement.

On that basis, the footnote for clay content in Soil Taxonomy, p 38 was suggested to be modified in the folliwing manner:

"[15] The percentage clay as measured by the pipette method of 3.5 times 15-bar water whichever value is higher but not more than 100."

6.3. Final Classification of Test Pedons

Applying the amendments made in this study, the test pedons were reclassified as shown in Table 28.

Table 37. Comparison of the CEC of selected pedons expressed in percantage clay content as estimated by factors 2.5 of Soil Taxonomy and the recommended value of 3.5.

Depth	CEC[a]	CEC[b]	CEC[c]	Source
Wahiawa silty clay, Hawaii.				SSIR No. 29 p 188 (1976)
0-15	25.7	42.1	30.1	
15-30	24.2	38.5	27.5	
30-40	16.5	26.3	18.8	
40-83	13.1	21.6	15.4	
83-113	13.5	21.9	15.7	
113-150	12.8	20.7	14.8	
Molokai silty clay, Hawaii.				SSIR No. 29 p 180 (1976)
0-15	23.5	42.5	30.1	
15-38	20.9	37.1	26.5	
38-65	11.6	20.9	14.9	
65-100	14.4	24.9	17.81	
100-150	10.2	19.2	13.7	

[a] Meq per 100 g soil.

[b] Meq per 100 g clay where percent clay = 2.5 x 15-bar water.

[c] Meq per 100 g clay where percent clay = 3.5 x 15-bar water.

Table 38. Final classification of test pedons.

PEDONS	SERIES	CURRENT CLASSIFICATION	CLASSIFICATION IN THE STUDY
OX-1	Aburan	Haplorthox	Kandiorthox
OX-2	Alai	Ochraquox	Ochraquox
OX-3	Babeko	Ochraquox	Ochraquox
OX-4	Bayoman	Eutrorthox	Eutrorthox
OX-5	Boka	Haplorthox	Haplorthox
OX-6	"BR-7"	Eutrorthox	Eutrorthox
OX-7	"BR-14"	Acrohumox	Acrohumox
OX-8	Catalina	Haplorthox	Haplorthox
OX-9	Chock Chai	Haplustox	Haplustox
OX-10	Coto	Eutrustox	Eutrustox
OX-11	Delicias	Haplorthox	Haplorthox
OX-12	Donie	Haplorthox	Haplorthox
OX-13	Farmhill	Gibbsihumox	Acrohumox
OX-14	Gedang	Umbraquox	Umbraquox
OX-15	Halii	Gibbsihumox	Gibbsihumox
OX-16	Jaiba	Eutrustox	Eutrustox
OX-17	Jerangau	Acrorthox	Acrorthox
OX-18	Kapaa	Gibbsiorthox	Gibbsiorthox
OX-19	Kersic	Ochraquox	Ochraquox
OX-20	Kuala Pilah	Acrorthox	Acrorthox
OX-21	Kuamang	Haplorthox	Kandiorthox
OX-22	Kuamang	Ochraquox	Ochraquox
OX-23	Kuamang	Haplorthox	Haplorthox
OX-24	Kuantan	Acrorthox	Acrorthox
OX-25	Lawai	Umbriorthox	Umbriorthox
OX-26	Lihue	Eutrustox	Eutrustox
OX-27	Mahana	Acrohumox	Acrohumox
OX-28	Makapili	Umbriorthox	Acrorthox
OX-29	Matanzas	Eutrorthox	Eutrorthox
OX-30	Merangin	Haplorthox	Kandiorthox
OX-31	Molokai	Torrox	Haplorthox
OX-32	Molokai	Torrox	Haplorthox
OX-33	Molokai	Torrox	Haplorthox
OX-34	Nipe	Acrorthox	Acrorthox
OX-35	Phuket	Haplorthox	Kandiorthox
OX-36	Pooku	Acrohumox	Acrohumox
OX-37	Puhi	Umbriorthox	Haplorthox
OX-38	"P-1"	Not classified	-
OX-39	"P-2"	Not classified	-
OX-40	Rebah	Umbrquox	Umbraquox
OX-41	Regosari	Haplorthox	Kandiorthox
OX-42	Rukani	Haplorthox	Ochraquox
OX-43	Sadao	Haplorthox	Haplorthox
OX-44	Segamat	Haplorthox	Kandiorthox

Table 38. (Continued)

PEDONS	SERIES	CURRENT CLASSIFICATION	CLASSIFICATION IN THE STUDY
OX-45	Senai	Acrorthox	Acrorthox
OX-46	"SP1"	Haplohumox	Haplohumox
OX-47	"SP3"	Haplorthox	Haplorthox
OX-48	"SP5"	Acrorthox	Acrorthox
OX-49	"SP6"	Acrorthox	Acrorthox
OX-50	"SP7"	Acrorthox	Acrorthox
OX-51	"SP8"	Acrorthox	Acrorthox
OX-52	"SP10"	Gibbsiorthox	Gibbsiorthox
OX-53	"SP11"	Gibbsiorthox	Gibbsiorthox
OX-54	"SP12"	Acrorthox	Acrorthox
OX-55	"SP14"	Haplorthox	Haplorthox
OX-56	"SP15"	Eutrorthox	Eutrorthox
OX-57	"SP17"	Eutrustox	Eutrustox
OX-58	Tabri	Haplorthox	Kandiorthox
OX-59	Wahiawa	Eutrustox	Eutrustox
OX-60	Wahiawa	Eutrustox	Eutrustox
OX-61	Wahiawa	Eutrustox	Eutrustox
OX-62	Profile 1	Haplorthox	Haplorthox
OX-63	Profile 2	Umbriorthox	Umbriorthox
ULT-1	Alaeloa	Tropohumult	Tropohumult
ULT-2	Aibonito	Tropohumult	Tropohumult
ULT-3	Ban Bong	Paleustult	Paleustult
ULT-4	Ban Chong	Paleustult	Kandiustox
ULT-5	Bedoule	Paleudult	Kandiudult
ULT-6	Besara	Paleudult	Kandiudult
ULT-	BPMD	Paleudult	Kandiorthox
ULT-7	"BR-3"	Haplustult	Kanhaplustult
ULT-8	"BR-4"	Paleustult	Kandiustult
ULT-9	"BR-8"	Palehumult	Kandiorthox
ULT-10	"BR-10"	Hapluhumult	Kandirothox
ULT-11	"BR-12"	Paleudult	Kandiorthox
ULT-12	"BR-19"	Haplustalf	Kandiustalf
ULT-13	"BR-20"	Fragiudult	Fragiudult
ULT-14	"BR-22"	Tropudult	Kanhpaludult
ULT-15	"BR-23"	Paleudult	Kandiudult
ULT-16	"BR-24"	Paleudult or Haplorthox	Kandiudult
ULT-17	"BR-25"	Paleudult	Kandiorthox
ULT-18	"BR-27"	Paleustult	kandiustult
ULT-19	"BR-30"	Paleudult	Kandiudult
ULT-20	"BR-31"	Paleudult	Kandiudult
ULT-21	BUK	Tropohumult	Kandiorthox
ULT-22	Bungor	Paleudult	Kandiudult
ULT-23	CAM	Paleudult	Kandiorthox

Table 38. (Continued)

PEDONS	SERIES	CURRENT CLASSIFICATION	CLASSIFICATION IN THE STUDY
ULT-24	Cecil	Hapludult	Kanhapludult
ULT-25	Chalong	Plinthustult	Plinthustult
ULT-26	Cialitos	Tropohumult	Kandiorthox
ULT-27	Daguey	Tropohumult	Tropohumult
ULT-28	Dalek	Paleudult	Kandiudult
ULT-29	Daobli	Paleudult	Kandiudult
ULT-30	DAV	Tropudalf	Tropudalf
ULT-31	Drasa	Paleustult	Kandiustox
ULT-32	Dunmore	Paleudult	Kandiudult
ULT-33	Faceville	Paleudult	Kandiudult
ULT-34	Gamboro	Paleustult	Kandiustult
ULT-35	Glouamo	Paleudult	Kandiudult
ULT-36	Grady	Paleaquult	Ochraquox
ULT-37	Guire	Paleudult	Kandiudult
ULT-38	Hayesville	Hapludult	Hapludult
ULT-39	Humatas	Tropohumult	Tropohumult
ULT-40	Haiku Taxadjunct	Tropohumult	Kandiorthox
ULT-41	Jagueyes	Tropudult	Kandiorthox
ULT-42	Kabin Buri	Haplustult	Kandiustox
ULT-43	Kalae	Tropohumult	Kandiustox
ULT-44	Kening	Paleudult	Haplorthox
ULT-45	Khlong Chak	Haplustult	Kandiudult
ULT-46	Kho Hong	Paleudult	Kandiudult
ULT-47	Kolea	Paleudult	Kandiudult
ULT-48	Koronivia	Tropohumult	Kanhaplohumult
ULT-49	Lanchang	Paleudult	Acrorthox
ULT-50	Limones	Paleudult	Kandiorthox
ULT-51	Mab Bon	Paleudult	Kandiudult
ULT-52	Malan	Plinthudult	Plinthorthox
ULT-53	Marlboro	Paleudult	Kandiudult
ULT-54	Muse	Hapludult	Hapludult
ULT-55	"MU-7"	Tropaquult	Kanhaplaquult
ULT-56	"MU-11"	Tropudult	Kanhapludult
ULT-57	"MU-13"	Tropudult	Kanhapludult
ULT-58	Mokambo	Haplustult	Kanhaplustult
ULT-59	NAK	Palehumult	Kandiorthox
ULT-60	Neira	Paleudult	Paleudult
ULT-61	Niagui	Paleudult	Paleudult
ULT-62	Nonoua	Paleudult	Kandiudult
ULT-63	Paaloa	Tropohumult	Kandihumox
ULT-64	Pak Chong	Paleustult	Haplustox
ULT-65	Pauwela	Tropohumult	Kandiorthox
ULT-66	Phangnga	Paleudult	Kandiudult

Table 38. (Continued)

PEDONS	SERIES	CURRENT CLASSIFICATION	CLASSIFICATION IN THE STUDY
ULT-67	Sabana	Plinthaquult	Plinthaquox
ULT-68	Saoa	Paleudult	Kandiudult
ULT-69	Sijau	Paleudult	Kandiorthox
ULT-70	Songkhla	Paleaquult	Kandiaquult
ULT-71	SOR	Haplorthox	Haplorthox
ULT-72	Tabau	Plinthudult	Plinthudult
ULT-73	Telico	Rhodudult	Rhodudult
ULT-74	Toko	Paleudult	Paleudult
ULT-75	Warin	Paleudult	Paleudult
ULT-76	Waynsboro	Paleudult	Paleudult
ULT-77	Yasothon	Rhodustult	Haplustox
ULT-78	Profile 3	Palehumult	Kandiorthox
ULT-79	Profile 4	Paleudult	Kandiorthox
OLL-1	Keahua	Haplustolls	
OLL-2	Makaweli	Haplustolls	
OLL-3	Paia	Haplustolls	
ALF-1	"BR-2"	Paleustalf	Kandiustalf
ALF-2	"BR-6"	Paleudalf	Paleudalf
ALF-3	"BR-28"	Paleustalf	Kandiustalf
ALF-4	Puo Opae	Rhodustalf	Kandiustox
EPT-1	Akaka	Hydrandept	
EPT-2	Hilo	Hydrandept	
EPT-3	Hoolehua	Ustropept	
EPT-4	ITKA	Dystrandept	
EPT-5	Kohala	Humitropept	
EPT-6	Kohala	Humitropept	
EPT-7	Koolao	Tropaquept	
EPT-8	Kukaiau	Dystrandept	
EPT-9	PUC	Dystrandept	
EPT-10	"S.V.2.4"	Tropaquept	
EPT-11	"S.V.9.2"	Dystrandept	
EPT-12	Uwala	Ustropept	
EPT-13	Waimea	Eutrandept	

VII. CONCLUSIONS

The ICOMOX and ICOMLAC proposals were tested against the data of 163 pedons representing various environments of LAC soils in many parts of the world.

With respect to the first objective of this study of testing the ICOM's proposals, it made considerable improvements in the classification of LAC soils in Soil Taxonomy. However, some pedons still could not be placed in the classification scheme because of deficiencies of definition of taxa or others could not be placed because no taxon is provided to accommodate them. On the other hand, similar pedons could be placed in different taxa or pedons with diverse characteristics could be placed in the same taxon.

With respect to the second objective of determining the impact of the ICOM's proposals on agrotechnology transfer, in general, there was improvement in the groupings of soils that have relative homogeneity in properties important to plant growth. However, some test pedons having similar crop production potential were placed in different taxa while others were placed in the same taxon but have different management requiremens.

With respect to the third objective of recommending, if necessary, improvements in the proposed classification schemes, amendments or certain alternatives were suggested to overcome the above limitations. Some diagnostic limits were refined, certain criteria were deleted and/or added and certain definitions were modified.

Therefore, the ICOM's proposals were modified according to the amendments suggested in this study as presented below.*

I. <u>Suggested Amendments to the ICOMOX'S Summary of Properties of the Oxic Horizon</u>.

In summary, the oxic horizon is a subsurface horizon that

1. Is at least 30 cm thick;

2. Has a fine-earh fraction (<2 mm) that has an apparent ECEC (NH_4OAc bases plus 1N KCl extractable Al percent clay) ≤12 meq per 100 g clay or apparent CEC of 16 meq or less per 100 g clay by NH_4OAc at pH 7.

3. *Has a pH value in N NaF (1:50) in 2 minutes of <10.0.*

4. Has less than 10 percent weatherable minerals of the 50-250 micron fraction if that size fraction constitute at least 20 percent of the soil material less than 2 mm in diameter or have less than 40 meq of K + Mg + Ca + Na/100 g of soil on a total elemental analysis basis after coated gravel removal if the soil has less than 20 percent fine sand and very fine sand (50-250 micron);

5. Has a diffuse upper textural boundary (i.e. <1.2 x clay increase within a vertical distance of 12 cm), *unless there is acric soil material in some parts of any horizon to a depth of 1.25 m.***

6. Has a texture of sandy loam or finer in the fine-earth fraction and has more than <u>10</u> percent clay;

7. Has less than 5 percent by volume that show rock structure unless the lithorelics containing weatherable minerals are coated

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*/ Modifications or suggestions as a result of this study are given in italics.

**/ Suggested criterion for further study.

with a continuous sesquioxide skin.

8. Does not have more than 85 percent gravel by volume.

II. Suggested Definition of the Acric Soil Materials

Acric soil materials are mineral soil materials of at least 25 cm thick, that have an effective cation exchange capacity (ECEC) as the sum of bases by NH_4OAc at pH 7 plus 1N KCl extractable Al, of <1.5 meq per 100 g clay and a delta pH (pH_{KCl} - pH_{H_2O}) of -0.2 or more positive.

III. Suggested Amendments to Key the LAC Soils in the order Category

Key to Soil Order

A. . . . . Histosols

B. . . . . Andisols[*]

C. . . . . Spodosols

D.[**] Other soils that

1. *Have acric soil materials within 1.25 m of the soil surface, or*
2. *Have less than 40 percent clay in the upper 18 cm, after mixing, and an oxic horizon with its upper boundary within 1.25 m of the soil surface and which do not meet the clay increase requirement of a kandic horizon; or*
3. *Have 40 percent or more clay in the upper 18 cm of the soil surface, after mixing, and an oxic horizon with its upper boundary within 1.24 m of the soil surface . . Oxisols*

E. . . . . Vertisols

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[*] Proposed placement of Andisols in the key (personal communication, Eswaran).

[**] Suggested amendment to ICOMOX'S proposal.

F. . . . . Aridosols

*G** *Other soils that have a mesic, isomesic, or warmer temperature regime... but have one of the following combination of characteristics;*

1. *Have an argillic or kandic horizon but not a fragipan* . . . . *Ultisols*

H. . . . . Mollisols

I** Other soils that *have an argillic or kandic horizon but not a fragipan, or* . . . . Alfisols

J. . . . . Inceptisols

K. . . . . Entisols

IV. Suggested Amendments to the Oxisol Keys

Key to Suborders

CA. Oxisols that are either saturated with water within 30 cm of the surface for at least 30 days per year in most years or are artifically drained and have one or both of the following characteristics associated with wetness:

a. A histic epipedon, and/or;

b. If free of mottles, immediately below any epipedon that has a moist color value of less than 3.5 there is a dominant chroma of 2 or less; or if there are distinct or prominent mottles within 50 cm of the soil surface, the dominant chroma is 3 or less or the hue is 2.5Y or yellower. Aquox

CB. Other Oxisols that have an Aridic (Torric) soil moisture regime . . . . Torrox

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* Suggested addendum in Soil Taxonomy.

CC. Other Oxisols that have an Ustic soil moisture regime . . . . Ustox

CD. *Other Oxisols that have a mollic or umbric epipedon and organic carbon of 16 kg per* m^2 *to a depth of 1 m from the surface* . . . . Humox

CE. Other Oxisols . . . . Orthox

Key to Aquox Great Groups

CAA. *Aquox with Acric soil materials within 1.5 m of the soil surface.* . . . . Acraquox

CAB. Other Aquox that have within 1.5 m of the mineral soil surface, sheets containing 30 percent or more gibbsite or a subhorizon that has 20 percent or more by volume, gravel-sized aggregates that contain 30 percent or more gibbsite . . . . Gibbsiaquox

CAC. Other Aquox that have plinthite forming a continuous phase of 50 percent or more ironestone gravel within 1.5 m of the soil surface . . . . Plinthaquox

CAD. *Other Aquox that have a subsurface horizon that meets the clay increase requirements of an argillic horizon* . . . . Kandiaquox

CAE. Other Aquox that have an umbric, mollic, or histic epipedon . . . . Umbraquox

CAF. Other Aquox . . . . Ochraquox

Key to Torrox Great Groups

CBA. *Torrox that have base saturation (*NH_4OAc*, pH 7) less than 35 percent in the major part of the oxic horizon* *within a depth of 1.5 m* . . . . Dystorrox

CBB. *Other Torrox* . . . . Haplotorrox

Key to Ustox Great Groups

CCA. *Ustox that have Acric soil materials within 1.5 m of the soil surface* . . . . Acrustox

CCB. Other Ustox that have within 1.5 m of the mineral surface sheets that contain 30 percent or more gibbsite or a subhorizon that has 20 percent or more by volume gravel-size aggregates that contain 30 percent or more gibbsite . . . . Gibbsiustox

CCC. *Other Ustox that have ≥35 percent base saturation (NH_4OAc, pH 7) in the major part of the oxic horizon to a depth of 1.5 m* . . . . Eutrustox

CCD. *Other Ustox that have a subsurface horizon that meets the clay increase requirement of an argillic horizon* . . . . Kandiustox

CCE. Other Ustox . . . . Haplustox

Key to Humox Great Groups

CDA. *Humox that have Acric soil materials within 1.5 m of the soil surface* . . . . *Acrohumox*

CDB. *Other Humox that have within 1.5 m of the mineral surface, sheets, containing 30 percent or more gibbsite or 20 percent or more by volume, gravel-sized aggregates that contain 30 percent or more gibbsite* . . . . . *Gibbsihumox*

CDC. *Other Humox that have ≥35 percent base saturation (NH_4OAc, pH 7) in the major part of the oxic horizon within a* *depth of 1.5 m . . . . Eutrohumox*

CDD. *Other Humox that have a subsurface horizon that meets the clay increase requirement of an argillic horizon . . . . Kandihumox*

CDE. *Other Humox . . . . Haplohumox*

Key to Orthox Great Groups

CEA. *Orthox that have Acric soil materials within 1.5 m of the soil surface . . . .* Acrorthox

CEB. Other Orthox that have within 1.5 m of the mineral surface sheets that contain 30 percent or more gibbsite or a subhorizon that has 20 percent or more by volume gravel-size aggregates that contain 30 percent or more gibbsite . . . . Gibbsiorthox

CEC. *Other Orthox that have ≥35 percent base saturation (NH_4OAc, pH 7) in the major part of the oxic horizon within a depth of 1.5 m . . . .* Eutrorthox

CED. *Other Orthox that have a kandic horizon. .* Kandiorthox

CEE. Other Orthox . . . . Haplorthox

V. Suggested Amendments to the ICOMLAC'S summary of Properties of the Kandic Horizon

In summary, the kandic horizon is a subsurface horizon which has a CEC of ≤16 meq per 100 g clay (by NH_4OAc) or have ECEC ≤12 (sum of bases plus KCl extractable Al) in the fine earth fraction at a depth of 50 cm below the top of the horizon or immediately above a lithic, paralithic, or petroferric contact that is shallower.

1. A coarser textured surface horizon. The minimum thickness of the surface horizon is 18 cm after mixing, or 5 cm if the transition to the kandic horizon is abrupt.

2. More total clay than the overlying horizon and the increased clay content is reached within a vertical distance of 12 cm or less as follows:

    a. If the surface horizon overlying has less than 20 percent total clay, the kandic horizon must contain at least 4 percent or more clay; or

    b. If the surface horizon has >20 percent total clay, the kandic horizon must have 1.2 times more clay than the overlying horizon or at least 8 percent more clay.

3. A thickness of at least 30 cm or at least 15 cm if a lithic, paralithic, or petroferric contact occur within 50 cm of the mineral soil surface.

4. The layers or horizons overlying the kandic horizon do not show any stratification and their content of organic carbon does not decrease irregularly with increasing depth.

5. *The top of the kandic horizon is normally within one of the following depths:*

    a. If the clay content of the surface horizon is 20 percent or more, the upper boundary is within 100 cm from the mineral soil surface.

    b. If the clay content of the surface horizon is less than 20 percent and the particle size class (of part or all of the upper 100 cm) is finer than sandy or sandy skeletal, the *upper boundary is within less than 125 cm from the mineral soil surface.*

c. If the particle size class of the upper 100 cm is sandy or sandy skeletal, the upper boundary is at a depth between 100 cm and 200 cm from the mineral soil surface.

The above definition of the kandic horizon is suggested to be diagnostic to both the LAC Ultisols and Alfisols, hence the succeeding amendments.

VI. Suggested Amendments to ICOMLAC'S Keys to the LAC Ultisols

Key to Aquult Great Groups

FAA . . . . Plinthaquults

FAB . . . . Fragiaquults

FAC . . . . Albaquults

FAD Other Aquults that

1. *Have a kandic horizon; and*
2. Do not have a lithic or paralithic contact within 1.5 m of the soil surface; and
3. Have a clay distribution such that the percentage of clay does not decrease by as much as 20 percent within a depth of 1.5 m from the soil surface.. . . . . Kandiaquults

FAE *Other Aquults that have a kandic horizon.* . . Kanhaplaquults

FAF . . . . Paleaquults

FAG . . . . Ochraquults

Key to Humult Great Groups

FBA . . . . Sombriaquults

FBB . . . . Plinthohumults

FBC Other Aquults that

1. *Have kandic horizon; and*

2. Do not have a lithic or paralithic contact within 1.5 m of the soil surface;

3. Have a clay distribution such that the percentage clay does not decrease from its maximum amount by as much as 20 percent within a depth of 1.5 m from the soil surface, or the soil has a petroferric contact within that depth.

. . . . Kandihumults

FBD *Other Humults that have kandic horizon* . . . Kanhaplohumults

FBE . . . . Haplohumults

Key to Udult Great Groups

FCA . . . . Plinthudults

FCB . . . . Fragiudults

FCC Other Udults that

1. *Have a kandic horizon; and*

2. Do not have a lithic or paralithic contact within 1.5 m of the soil surface; and

3. Have clay distribution such that the percentage of clay does not decrease from its maximum amount by as much as 20 percent within a depth of 1.5 m from the soil surface, or have a petroferric contact within that depth.. Kandiudults

FCD *Other Udults that have kandic horizon*. . . . . Kanhapludults

FCE . . . . Paleudults

FCF . . . . Rhodoudults

FCG . . . . Hapludults

Key to Ustult Great Groups

FDA . . . . Plinthustults

FDB Other Ustults that

1. *Have a kandic horizon; and*

2. Do not have a lithic or paralithic contact within 1.5 m of the soil surface;

3. Have a clay distribution such that the percentage clay does not decrease from its maximum amount by as much as 20 percent within a depth of 1.5 m from the soil surface or the soil has petroferric contact within that depth; and

4. Have texture finer than loamy fine sand in some part of the kandic horizon. . . . . Kandiustults

FDC *Other Ustults that have a kandic horizon* . . Kanhaplustults

FDD . . . . Paleustults

FDE . . . . Rhodustults

FDF . . . . Haplustults

VII. Suggested Amendments to the ICOMLAC'S Key to the LAC Alfisols

Key to Aqualf Great Groups

HAA . . . . Plinthaqualfs

HAB . . . . Natraqualfs

HAC . . . . Duraqualfs

HAD *Other Aqualfs that have a kandic horizon* . . Kandiaqualfs

HAE . . . . Fragiaqualfs

HAF . . . . Glossaqualfs

HAG . . . . Albaqualfs

HAH . . . . Umbraqualfs

HAI . . . . Ochraqualfs

Key to Udalf Great Groups

HEA . . . . Agrudalfs

HEB . . . . Natrudalfs

HEC . . . . Ferrudalfs

HED . . . . Glossudalfs

HEE . . . . Fraglossudalfs

HEF . . . . Fragiudalfs

HEG Other Udalfs that have all the following requirements:

1. Have a kandic horizon;

2. Do not have a lithic or paralithic contact within 1.5 m of the soil surface;

3. Have a clay distribution such that the percentage of clay does not decrease from its maximum amount by as much as 20 percent within a depth of 1.5 m from the soil surface.

. . . . Kandiudalfs

HEH *Other Udalfs that have kandic horizon* . . . Kanhapludalfs

HEI . . . . Paleudalfs

HEJ . . . . Rhodudalfs

HEK . . . . Hapludalfs

Key to Ustalf Great Groups

HCA . . . . Durustalfs

HCB . . . . Plinthustalfs

HCC . . . . Natrustalfs

HCD Other Ustalfs that meet all of the following requirements:

1. Have a kandic horizon; and

2. Do not have a lithic or paralithic contact or a petrocalcic horizon within 1.5 m of the soil surface;

3. Have a clay distribution such that the percentage of clay does not decrease from its maximum by as much as 20 percent within a depth of 1.5 m from the soil surface.

. . . . Kandiustalfs

HCE *Other Ustalfs that have a kandic horizon* . Kanhaplustalfs

HCF . . . . Paleustalfs

HCG . . . . Rhodustalfs

HCH . . . . Haplustalfs

VIII. Suggested Limits among the LAC Soils

The definition of Oxisols must provide criteria to separate Oxisols from all other LAC soils. These criteria define the limits of Oxisols in relation to all other known kinds of soil.

1. *To distinguish the Oxisols from the LAC Ultisols and Alfisols, Oxisols must have:*

   a. Acric soil materials within 1.5 m from the mineral soil surface; or

   b. Clay content >40 percent in the upper 18 cm of the soil surface and an oxic horizon; or

   c. Clay content ≤40 percent in the upper 18 cm of the soil surface and an oxic horizon and no kandic horizon.

2. *To distinguish the Oxisols from the LAC Inceptisols, Oxisols must have an oxic horizon, unless it is burried horizon;*

3. *To distinguish the Oxisols from the LAC Mollisols, Oxisols must have an oxic horizon and no kandic horizon.*

The definition of LAC Alfisols and Ultisols must provide criteria to separate LAC Alfisols and Ultisols from all other LAC soils. These criteria define the limits of LAC Alfisols and Ultisols in relation to other known kinds of soil.

1. *To distinguish LAC Alfisols from LAC Mollisols, LAC Alfisols have a base saturation (by NH_4OAc) that is less than 50 percent in some subhorizon of the kandic horizon.*
2. *To distinguish LAC Alfisols and Ultisols from LAC Inceptisols, LAC Alfisols and Ultisols have kandic horizon.*

IX. Suggested modification of the footnote in Soil Taxonomy, page 39

For soils that are very difficult to disperse, the footnote should read, "*The percentage of clay as measured by the pipette method or 3.5 times 15-bar water, whichever value is higher but not more than 100.*"

APPENDIX I

Table 1. List of pedons and/or profiles used to test the ICOMS proposals.

PEDON/ PROFILE	SERIES	LOCATION	PRESENT CLASSIFICATION	SOURCE
OX-1	Aburan	Sumatra	Aquic Haplorthox	(K)
OX-2	Alai	Jambi, Sumatra	Typic Ochraquox	(K)
OX-3	Babeko	Jambi, Sumatra	Typic Ochraquox	(K)
OX-4	Bayoman	Puerto Rico	Tropeptic Eutrorthox	(H)
OX-5	Boka	Ivory Coast	Plinthic Haplorthox	(L)
OX-6	"BR-7"	Parana, Brazil	Typic Eutrorthox	(E)
OX-7	"BR-14"	Pernam., Brazil	Typic Acrohumox	(E)
OX-8	Catalina	Puerto Rico	Tropeptic Haplorthox	(H)
OX-9	Chock Chai	Thailand	Typic Haplustox	(G)
OX-10	COTO	Puerto Rico	Tropeptic Eutrustox	(C)
OX-11	Delicias	Puerto Rico	Typic Haplorthox	(H)
OX-12	Donie	Ivory Coast	Plinthic Haplorthox	(L)
OX-13	Farmhill	South Africa	Typic Gibbsihumox	(X)
OX-14	Gedang	Jambi, Sumatra	Typic Umbraquox	(K)
OX-15	Halii	Hawaii	Typic Gibbsihumox	(F)
OX-16	JAIBA	Jaiba, Brazil	Tropeptic Eutrustox	(C)
OX-17	Jerangau	Malaysia	Haplic Acrorthox	(F)
OX-18	Kapaa	Hawaii	Typic Gibbsiorthox	(A)
OX-19	Kersic	Sumatra	Typic Ochraquox	(K)
OX-20	Kuala Pilah	Malaysia	Haplic Acrorthox	(F)
OX-21	Kuamang	Sumatra	Aquic Haplorthox	(K)
OX-22	Kuamang	Sumatra	Typic Ochraquox	(K)
OX-23	Kuamang	Sumatra	Typic Haplorthox	(K)
OX-24	Kuantan	Malaysia	Haplic Acrorthox	(F)
OX-25	Lawaii	Hawaii	Tropeptic Umbriorthox	(A)
OX-26	Lihue	Hawaii	Tropeptic Eutrustox	(A)
OX-27	Mahana	Hawaii	Typic Acrohumox	(A)
OX-28	Makapili	Hawaii	Tropeptic Umbriorthox	(A)

Sources: (A) SSIR No. 29 (1976), Hawaii; (B) Recel (1981); (C) Benchmark Soils Project (1979); (D) Soil Research Institute, Indonesia; (E) Proc. 1st ISCW (1978); (F) Proc. 2nd ISCW, Part I (1979); (G) Proc. 2nd ISCW, Part II (1979); (H) SSIR No. 12 (1967), Puerto Rico; (I) ICOMOX CL No. 9 (1982); (J) Leamy et al.(1979); (K) Williams and Harding (1979); (L) Soil Survey Rep. of Southwest Ivory Coast (1975); (M) SSIR No. 15 (1967), Tennessee; (N) Proc. South Pacific Forum on Soil Taxonomy (1981); (O) SSIR No. 16 (1967), Georgioa; (P) Yaibuathes (1969); (Q) Ikawa (1979); (R) Lepsch and Buol (1973); (S) de Alwis (1967);(T) SSIR No. 14, (1967), Kentucky; (U) SSIR No. 15 (1967), Tennessee; (V) Chotimon (1969); (W) Periaswamy (1969); (X) Eswaran (1983); and (Y) Mausbach (1983).

Table 1. (Continued)

PEDON/ PROFILE	SERIES	LOCATION	PRESENT CLASSIFICATION	SOURCE
OX-29	Matanzas	Puerto Rico	Tropeptic Eutrorthox	(H)
OX-30	Merangin	Sumatra	Aquic Haplorthox	(F)
OX-31	Molokai	Hawaii	Typic Torrox	(A)
OX-32	Molokai	Hawaii	Typic Torrox	(A)
OX-33	Molokai	Hawaii	Typic Torrox	(P)
OX-34	Nipe	Puerto Rico	Typic Acrorthox	(H)
OX-35	Phuket	Thailand	Tropeptic Haplorthox	(G)
OX-36	Pooku	Hawaii	Typic Acrohumox	(P)
OX-37	Puhi	Hawaii	Tropeptic Umbriorthox	(A)
OX-38	"P-1"	Indonesia	Not classified	(I)
OX-39	"P-2"	Indonesia	Not classified	(I)
OX-40	Rebah	Sumatra	Typic Umbraquox	(K)
OX-41	Regosari	Sumatra	Aquic Haplowthox	(K)
OX-42	Rukani	Sumatra	Aquic Haplorthox	(K)
OX-43	Sadao	Thailand	Haplorthox	(P)
OX-44	Segamat	Malaysia	Tropeptic Haplorthox	(F)
OX-45	Senai	Malaysia	Aquic Acrorthox	(F)
OX-46	"SP1"	New Hebrides	Typic Haplohumox	(J)
OX-47	"SP3"	New Hebrides	Tropeptic Haplorthox	(J)
OX-48	"SP5"	Solomon Islands	Typic Acrorthox	(J)
OX-49	"SP6"	Solomon Islands	Typic Acrorthox	(J)
OX-50	"SP7"	Solomon Islands	Leptic Acrorthox	(J)
OX-51	"SP8"	Solomon Islands	Haplic Acrorthox	(J)
OX-52	"SP10"	Western Samoa	Typic Gibbsiorthox	(J)
OX-53	"SP11"	Solomon Islands	Typic Gibbsiorthox	(J)
OX-54	"SP12"	Western Samoa	Typic Acrorthox	(J)
OX-55	"SP14"	Western Samoa	Tropeptic Haplorthox	(J)
OX-56	"SP15"	Vanua Levu, Fiji	Tropeptic Eutrorthox	(J)
OX-57	"SP17"	Lakeva, Fiji	Tropeptic Eutrustox	(J)
OX-58	Tabri	Sumatra	Aquic Haplorthox	(F)
OX-59	Wahiawa	Waipio, Hawaii	Tropeptic Eutrustox	(C)
OX-60	Wahiawa	Waipio, Hawaii	Tropeptic Eutrustox	(C)
OX-61	Wahiawa	Hawaii	Tropeptic Eutrustox	(A)
OX-62	Profile 1	Sao Paulo,Brazil	Typic Haplorthox	(R)
OX-63	Profile 2	Sao Paulo,Brazil	Typic Umbriorthox	(R)
ULT-1	Alaeloa	Hawaii	Orthoxic Tropohumult	(W)
ULT-2	Aibonito	Puerto Rico	Orthoxic Topohumult	(H)
ULT-3	Ban Bong	Thailand	Arenic Paleustult	(G)
ULT-4	Ban Chong	Thailand	Oxic Paleustult	(G)
ULT-5	Bedoule	Ivory Coast	Plinthic Paleudult	(L)
ULT-6	Besara	Malaysia	Typic Paleudult	(F)
ULT-7	"BR-3"	Brazil	Oxic Haplustult	(E)
ULT-8	"BR-4"	Brazil	Typic Paleustult	(E)

Table 1. (Continued)

PEDON/ PROFILE	SERIES	LOCATION	PRESENT CLASSIFICATION	SOURCE
ULT-9	"BR-8"	Parana Brazil	Orthoxic Palehumult	(E)
ULT-10	"BR-10"	Pernam., Brazil	Typic Haplohumult	(E)
ULT-11	"BR-12"	Pernam., Brazil	Typic Paleudult	(E)
ULT-12	"BR-19"	Alagoas, Brazil	Oxic Haplustalf	(E)
ULT-13	"BR-20"	Alagoas, Brazil	Arenic Fragiudult	(E)
ULT-14	"BR-22"	Alagoas, Brazil	Orthoxic Tropudult	(E)
ULT-15	"BR-23"	Alagoas, Brazil	Typic Paleudult	(E)
ULT-16	"BR-24"	Pernam., Brazil	Epiaquic Paleustult	(E)
ULT-17	"BR-25"	Pernam., Brazil	Rhodic Paleudult	(E)
ULT-18	"BR-27"	Pernam., Brazil	Epiaquic Paleustult	(E)
ULT-19	"BR-30"	Pernam., Brazil	Typic Paleudult	(E)
ULT-20	"BR-31"	Pernam., Brazil	Typic Paleudult	(E)
ULT-21	BUK	Indonesia	Orthoxic Topohumult	(Y)
ULT-22	Bungor	Malaysia	Typic Paleudult	(F)
ULT-23	CAM	Cameroon	Typic Paleudult	(C)
ULT-24	Cecil	N. Carolina, USA	Typic Hapludult	(O)
ULT-25	Chalong	Thailand	Oxic Plinthustult	(G)
ULT-26	Cialitos	Puerto Rico	Orthoxic Tropohumult	(H)
ULT-27	Daguey	Puerto Rico	Orthoxic Tropohumult	(H)
ULT-28	Dalek	Singkut, Sumatra	Typic Paleudult	(K)
ULT-29	Daobli	Ivory Coast	Typic Paleudult	(L)
ULT-30	DAV	Philippines	Ultic Tropudalf	(Y)
ULT-31	Drasa	Levu, Fiji	Oxic Paleustult	(N)
ULT-32	Dunmore	Tennessee, USA	Typic Paleudult	(M)
ULT-33	Faceville	Georgia, USA	Typic Paleudult	(O)
ULT-34	Gambora	Ceylon	Paleustult	(S)
ULT-35	Glouamo	Ivory Coast	Aquic Paleudult	(L)
ULT-36	Grady	Georgia, USA	Typic Paleaquult	(O)
ULT-37	Guire	Ivory Coast	Typic Paleudult	(L)
ULT-38	Hayesville	S. Carolina, USA	Typic Hapludult	(O)
ULT-39	Humatas	Puerto Rico	Typic Tropohumult	(H)
ULT-40	Haiku taxadjunct	Hawaii	Humoxic Tropohumult	(A)
ULT-41	Jagueyes	Puerto Rico	Oxic Tropodult	(H)
ULT-42	Kabin Buri	Thailand	Oxic Haplustult	(G)
ULT-43	Kalae	Hawaii	Ustoxic Tropohumult	(A)
ULT-44	Kening	Malaysia	Typic Paleudult	(F)
ULT-45	Khlong Chack	Thailand	Oxic Haplustult	(G)
ULT-46	Kho Hong	Thailand	Typic Paleudult	(G)
ULT-47	Kolea	Ivory Coast	Typic Paleudult	(L)
ULT-48	Koronivia	Fiji	Humoxic Tropohumult	(N)
ULT-49	Lanchang	Malaysia	Typic Paleudult	(F)
ULT-50	Limones	Puerto Rico	Typic Paleudult	(H)
ULT-51	Mab Bon	Thailand	Oxic Paleudult	(G)

Table 1. (Continued)

PEDON/ PROFILE	SERIES	LOCATION	PRESENT CLASSIFICATION	SOURCE
ULT-52	Malan	Ivory Coast	Typic Plinthudult	(L)
ULT-53	Marlboro	Georgia, USA	Typic Paleudult	(O)
ULT-54	Muse	Kentucky, USA	Typic Hapludult	(T)
ULT-55	"MU-7"	Sumatra	Umbric Tropaquult	(D)
ULT-56	"MU-11"	Sumatra	Orthoxic Tropudult	(D)
ULT-57	"MU-13"	Sumatra	Plinthic Tropudult	(D)
ULT-58	Mokambo	Fiji	Oxic Tropudult	(N)
ULT-59	NAK	Indonesia	Orthoxic Palehumult	(Y)
ULT-60	Neira	Ivory Coast	Typic Paleudult	(L)
ULT-61	Niagui	Ivory Coast	Typic Paleudult	(L)
ULT-62	Nonoua	Ivory Coast	Typic Paledult	(L)
ULT-63	Paaloa	Hawaii	Humoxic Tropohumult	(A)
ULT-64	Pak Chong	Thailand	Oxic Paleustult	(G)
ULT-65	Pauwela	Hawaii	Humoxic Tropohumult	(A)
ULT-66	Phangnga	Thailand	Typic Paleudult	(G)
ULT-67	Sabana	Puerto Rico	Oxic Plinthaquult	(H)
ULT-68	Saoa	Ivory Coast	Plinthic Paleudult	(L)
ULT-69	Sijau	Sumatra	Typic Paleudult	(K)
ULT-70	Songkhla	Thailand	Aeric Paleaquult	(G)
ULT-71	SOR	Philippines	Typic Haplorthox	(C)
ULT-72	Tabau	Ivory Coast	Typic Rhodudult	(Y)
ULT-73	Telico	Tennessee, USA	Typic Rhodudult	(U)
ULT-74	Toko	Ivory Coast	Typic Paleudult	(L)
ULT-75	Warin	Thailand	Typic Paleudult	(G)
ULT-76	Waynsboro	Teneessee, USA	Typic Paleudult	(U)
ULT-77	Yasothon	Thailand	Typic Rhodustult	(G)
ULT-78	Profile 3	Sao Paulo, Brazil	Orthoxic Palehumult	(R)
ULT-79	Profile 4	Sao Paulo, Brazil	Typic Paleudult	(R)
OLL-1	Keahua	Hawaii	Torroxic Haplustoll	(A)
OLL-2	Makaweli	Hawaii	Torroxic Haplustoll	(A)
OLL-3	Paia	Hawaii	Oxic Haplustoll	(A)
ALF-1	"BR-2"	Brazil	Oxic Paleustalf	(E)
ALF-2	"BR-6"	Parana, Brazil	Rhodic Paleudalf	(E)
ALF-3	"BR-28"	Pernam., Brazil	Oxic Paleustalf	(E)
ALF-4	Puu Opae	Kauai, Hawaii	Oxic Rhodustalf	(V)
EPT-1	Akaka	Hawaii	Typic Hydrandept	(B)
EPT-2	Hilo	Hawaii	Typic Hydrandept	(B)
EPT-3	Hoolehua	Hawaii	Oxic Ustropept	(A)
EPT-4	ITKA	Indonesia	Hydric Dystrandept	(Y)
EPT-5	Kohala	Hawaii	Ustic Humitropept	(A)
EPT-6	Kohala	Hawaii	Ustic Humitropept	(D)

Table 1. (Continued)

PEDON/ PROFILE	SERIES	LOCATION	PRESENT CLASSIFICATION	SOURCE
EPT-7	Koolao	Kauai, Hawaii	Plinthic Tropaquept	(A)
EPT-8	Maile	Hawaii	Hydric Dystrandept	(A)
EPT-9	Naiwa	Maui, Hawaii	Andic Humitropept	(A)
EPT-10	Kukaiau	Hawaii	Hydric Dystrandept	(B)
EPT-11	PUC	Philippines	Hydric Dystrandept	(C)
EPT-12	"S.V.2.4"	Sumatra	Typic Tropaquept	(D)
EPT-13	"S.V.1.2"	Sumatra	Orthoxic Dystrandept	(D)
EPT-14	Uwala	Hawaii	Oxic Ustropept	(A)
EPT-15	Waimea	Hawaii	Typic Eutrandept	(B)

APPEDNIX II

Table 1. Some diagnostic features of selected pedons used to test Item 4 of the proposed definition of the oxic horizon.

Depth (cm)	Horizon	Clay (%)	Calculated Total Elements (meq/100g soil)* Ca	Mg	Na	K	Total Elem.	CEC (meq/100g clay)	ECEC (meq/100g clay)
Lihue series, Tropeptic Eutrustox , Hawaii (SSIR No. 29, 1976, p 184).									
0-15	Ap1	84.5	2.86	49.34	6.13	33.96	-	22.6	14.4
15-30	Ap2	84.0	t	54.32	5.48	33.96	-	20.6	10.7
30-53	B21	80.8	t	28.90	7.09	33.08	69.07	9.8	6.6
53-68	B22	82.5	t	31.89	6.45	32.79	71.13	8.8	5.3
68-120	B23	85.5	t	23.42	6.13	23.72	53.28	8.6	5.3
120-150	B24	87.5	t	3.49	5.16	15.83	24.46	9.5	6.6
Kapaa series, Typic Gibbsiorthox, Hawaii (SSIR No. 29,1976, p 164).									
0-30	Ap	75.0	t	15.95	0.97	5.96		21.2	3.1
30-40	B21	89.0	-	12.45	0.97	2.34	15.77	4.2	1.2
40-63	B22	76.3	-	3.99	0.97	1.49	6.45	3.4	1.8
63-90	B23	80.3	-	6.48	0.97	1.49	8.94	2.4	1.4
90-123	B24	79.3	-	5.48	0.97	1.49	7.94	4.7	1.6
123-150	B25	87.0	t	18.94	0.97	1.49	21.40	7.0	1.8
Makapili series, Tropeptic Umbriorthox, Hawaii (SSIR No. 29, 1976,p176).									
0-30	Ap	79.5	1.07	34.39	3.23	23.80	-	27.1	5.8
30-35	B1	-	-	-	-	-	-	18.8	2.2
35-55	B21	87.0	t	19.94	2.90	17.85	-	16.3	2.1
55-70	B22	84.3	t	14.95	2.58	12.96	30.45	14.6	1.7
70-110	B23	61.5	t	15.95	1.61	5.31	22.87	9.4	0.8
110-150	B24	75.3	t	-	-	-	-	4.9	0.4
Puhi series, Tropeptic Umbriorthox, Hawaii (SSIR No. 29, 1976, p 178).									
0-23	Ap	85.5	t	101.67	3.55	15.96	-	22.6	14.4
23-53	B21	-	t	77.75	2.58	10.85	-	20.6	10.7
53-75	B22	-	t	69.78	3.55	7.02	80.35	9.8	6.6
75-98	B23	97.0	t	24.42	3.55	3.19	31.16	8.8	5.3
98-120	B24	86.3	t	29.41	4.19	2.34	35.94	8.6	5.3
Segamat series, Tropeptic Haplorthox, Malaysia (Proc 2nd ISCW,PartII 1979, p 296).									
0-4	A1	51.2	10.71	4.98	3.23	2.13		21.3	24.2
4-33	B1ox	65.8	7.14	t	t	2.13	9.27	8.6	5.8
33-66	B21ox	70.2	7.14	t	t	2.13	9.27	8.6	5.8
66-115	B22ox	73.7	3.57	t	t	2.13	5.70	5.6	1.3
115-147	B23ox	66.4	3.57	t	t	2.13	5.70	6.0	2.2

* Calculations made from the oxide forms.

Table 1 (Continued)

Depth (cm)	Horizon	Clay (%)	Calculated Total Elements (meq/100g soil)				Total Elem.	CEC	ECEC
			Ca	Mg	Na	K		(meq/100g clay)	
Kuantan series, Haplic Acrorthox, Malaysia (Proc 2nd ISCW, Part I, 1979 p 308).									
0-18	A1-3	59.8	3.57	4.98	t	2.13		15.4	4.7
18-46	B21ox	65.2	t	4.98	t	t	4.98	8.0	1.7
46-121	B22ox	65.3	t	4.98	t	t	4.98	6.2	1.5
121-200	B23ox	69.1	3.57	4.98	t	t	8.55	4.6	1.1
Kuala Pilah, Haplic Acrorthox, Malaysia (Proc 2nd ISCW, Part I, 1979, p 328).									
0-10	A1-3	26.8	3.57	4.98	t	2.13	-	22.4	6.9
10-57	B21ox	28.2	3.57	4.98	3.32	2.13	13.91	6.7	4.4
57-171	B22ox	41.5	t	4.98	t	t	4.98	3.7	2.6
171-213	B23ox	43.1	t	4.98	t	t	4.98	3.4	1.8
213-283	B24	34.4	3.57	4.98	3.23	2.13	13.91	7.7	2.5

APPENDIX II

Table 2. Some diagnostic features of the Sadao series, an Ustox in Amphoe Muang, Changwat, Pattalung, Thailand, used to test Item 5 of the proposed definition of the oxic horizon by the ICOMOX. Source: Yaibuathes (1969).

Depth	Horizon	Particle Size Analysis			Texture	CEC	ECEC
		Sand	Silt	Clay		(meq/100 g clay)	
(cm)		- - - - - pct- - - - -					
0-7	A1	82.5	1.8	15.7	ls	14.3	2.6
7-19	A3	79.0	6.2	15.7	ls-sl	13.6	1.6
19-33	B1	78.3	6.1	15.7	sl	11.9	1.5
33-80	B1ox	77.4	9.0	11.6	sl	11.1	1.9
80-100	B2ox	74.5	6.2	19.3	sl	7.6	1.7

APPENDIX II

Table 3. Some diagnostic features of selected pedons used to test Item 6 of the proposed definition of the oxic horizon by ICOMOX.

Depth (cm)	Horizon	Horizon bdry.	Clay (%)	CEC meq/100g	ECEC clay	(X)	(Y)	(Z)
Phuket series, Tropeptic Haplustox, Thailand (Proc 2nd ISCW Part II, 1979, p 363).								
0-16	A1	CS	21.0	27.6	9.0	21.0	25.2	43.8
16-35	B21	GS	43.8	11.4	4.3			
35-68	B22t	GS	42.0	11.4	3.6			
68-90	B23t	GS	43.5	10.6	4.1			
90-117	B23t	GS	43.1	10.9	5.3			
117-144	B24t	GS	44.2	10.9	4.1			
144-180	B3t	-	45.2	11.7	4.9			
Senai series, Haplic Acrorthox, Malaysia (Proc 2nd ISCW Part I, 1979, p 320).								
0-10	Ap1	C	25.9	22.3	9.4	34.5	41.5	55.0
10-25	Ap2	S	40.2	12.4	1.9			
25-52	B1ox	D	56.4	6.0	1.0			
52-110	B21ox	D	64.2	5.0	0.7			
110-140	B22ox	D	66.6	3.2	0.6			
140+	B3	-	51.9	3.9	0.7			

(X) = Percent clay content of overlying coarser textured horizon.
(Y) = 1.2x clay content of overlying coarser textured horizon.
(Z) = Percent clay content within a vertical distance of 12 cm from the overlying coarser textured horizon to the oxic horizon.
Horizon Boundary: C= clear, S= smooth, G= gradual and D= diffuse.

APPENDIX II

Table 4. Key attributes of selected pedons that are affected by Item 7 of the proposed ICOMOX definition of the oxic horizon.

Depth (cm)	Horizon	CEC (meq/100g clay)	Saprolite (%)
Kapaa series, Typic Gibbsiorthox, Hawaii. Source: SSIR No. 29 (1976).			
0-30	Ap	21.2	-
30-40	B21	4.2	5
40-63	B22	3.4	20
63-90	B23	2.4	40*
90-123	B24	4.7	60*
123-150	B25	7.0	-
Makapili series, Tropeptic Umbriorthox, Hawaii. Source: SSIR No. 29 (1976).			
0-25	Ap	24.1	-
25-33	B1	13.8	-
33-53	B21	12.2	-
53-83	B22	11.5	-
83-125	B23	5.0	5
125-163	B24	5.1	50

* Strongly weathered with loam texture and sandy appearance.

APPENDIX II

Table 5. Selected pedons of Oxisols illustrating thin oxic horizons.

Depth (cm)	Horizon	CEC[a] (meq/100g clay)	Clay Content[a] (%)	Distinctness of Horizon Boundary	Rock Structure
Pedon OX-47, Tropeptic Haplorthox, New Hebrides. Source: Leamy et al.(1979).					
0-15		27.5	82.8	I	Structure of strongly weathered rock at 60 to 90 cm.
15-60		14.6	83.5	I	
60-90		34.2	84.0		
Pedon OX-50, Leptic Acrorthox, Solomon Islands . Source: Leamy et al. (1979)					
0-15	Ao	18.7	35.8	S	Large fragments of strongly weathered rocks at 76 cm depth and below.
15-76	AC	3.8	45.3	I	
76+	AC	3.3	15.0		
Pedon OX-52, Typic Gibbsiorthox, Western Samoa. Source: Leamy et al. (1979)					
0-8	A	33.8	46.5	D	Very strong clay, rock fragments and well weathered at 72 cm.
8-31	B	11.2	43.0	D	
31-72	BC	5.4	42.3	D	
Pedon OX-54, Typic Acrorthox, Western Samoa. Source: Leamy et al. (1979)					
0-15	A	30.8	48.0	M	Few weathered boulders, becoming very numerous below 120 cm.
15-30	B	11.5	48.0	M	
30-76	C	1.8	48.8		
Pedon OX-55, Tropeptic Haplorthox, Western Samoa. Source: Leamy et al. (1979).					
0-15	A	49.0	73.0	M	Mainly boulders below 97 cm.
15-46	B	14.9	59.8	D	
46+	C				

a= Percent clay was estimated by 2.5 x 15-bar water.

S= sharp (almost a line); D= distinct (less than 2.5 cm); I= indistinct (2.5 to 6 cm); D= diffuse (>6 cm). Ref. Newzealand Soil Survey Manual.

APPENDIX III

Table 1. Diagnostic features of selected pedons used to test the impact of Item C.1 of the ICOMOX's proposed key definition of the Oxisols on the LAC Ultisols.

Depth	Horizon	CEC	ECEC	Clay	Clay	(X)	(Y)	(Z)
-cm--		(meq/100g clay)		-%-	Skins			
Kho Hong Series, Typic Paleudults, Amphoe Muang, Rayong,Thailand (Proc. 2nd ISCW, Part II, 1979, pp 385-393).								
0-28	Ap	19.7	12.3	12.2	-	12.2	16.2	17.5
28-41	B1	15.4	8.6	17.5	-			
41-76	B21t	14.0	8.7	20.7	pt			
76-100	B22t	14.9	8.9	20.2	pt			
100-135	B22t	18.5	8.5	19.9	-			
Chalong series, Oxic Haplustults, Amphoe Muang, Rayong, Thailand (Proc. 2nd ISCW, Part II, 1979, pp 395-401).								
0-10	A1	44.3	22.4	11.5	-	15.5	19.4	20.6
10-40	B1	13.3	6.8	20.6	pt			
40-63	B21t	10.0	5.4	34.8	bt			
63-96	B22tcn	7.9	4.5	45.6	bmT			
96-130	B23tcn	9.9	3.7	49.2	bmT			
130-150	B24t	13.7	3.8	45.9	bmT			
150-180	B24t	8.2	3.9	56.2	bmT			
Mab Bon series, Oxic Paleustult, Amphoe Ban Kai, Thailand (Proc. 2nd ISCW, Part II, 1979, pp 409-414).								
0-20	A1	26.7	11.4	18.4	-	18.4	22.4	29.9
20-42	B21t	15.9	8.8	29.9	pt			
42-60	B22t	10.3	6.5	48.4	bmT			
60-90	B22t	9.6	6.3	55.0	bmT			
90-120	B23t	9.3	4.6	55.0	bmT			
120-152	B23t	10.1	5.0	54.2	bmT			
152-175	B3	8.6	4.1	60.0	bmT			
175-200	B3	10.3	4.7	55.0	bmT			

(X)-clay content of overlying coarser textured horizon, (Y)-required clay increase at the finer textured subsurface horizon, (Z)-clay content of the finer textured subsurface horizon.

T=thick; t=thin; p=patchy; b=broken; m=moderate; w=weak; d=discontinuous; C-continuous; c=common; n=nearly.

Table 1 (Continued)

Depth	Horizon	CEC	ECEC	Clay	Clay skins	(X)	(Y)	(Z)
-cm--		(meq/100g clay)		-%--				
Phangnga series, Typic Paleudults, Amphoe Makham, Chanthaburi, Thailand (Proc. 2nd ISCW, Part II, 1979, pp 353-358).								
0-16	A1	23.8	7.8	21.3	-	23.0	27.6	37.1
16-33	B1t	10.1	4.6	37.1	-			
33-62	B21t	9.6	3.6	47.7				
62-85	B22t	7.1	4.1	49.5	pmT			
85-112	B22t	9.7	3.9	50.9	bmT			
112-135	B23t	8.4	3.8	51.6	bmT			
135-155	B3t	8.3	4.2	52.4	-			
155-180	B3t	7.5	4.3	58.1	-			
Khlong Chak series, Typic Paleudults, Amphoe Muang, Chanthaburi, Thailand (Proc. 2nd ISCW, Part II, 1979, pp 383-384).								
0-15	A1	27.5	13.5	23.7	-	28.7	34.4	53.7
15-45	B21t	8.4	4.1	53.7	-			
45-75	B22t	7.4	3.3	51.0	-			
75-110	B22t	8.6	3.8	48.3	-			
110-140	B23t	7.3	3.9	51.8	-			
Songkhla series, aeric Paleaquults, Amphoe Laem Sing, Chanthaburi, Thailand (Proc. 2nd ISCW, Part II, 1979, pp367-372).								
0-15	A11	35.9	12.9	11.2	-	12.4	14.9	32.0
15-34	A12	27.9	9.2	13.4	-			
34-60	B21t	11.7	6.7	32.0	bt			
60-85	B22t	11.3	6.5	33.9	bt			
85-125	B23tg	9.2	4.8	44.0	bmT			
125-150	B24tg	9.7	4.8	43.9	bmT			
150-180	B24tg	10.4	6.2	42.5	-			
Podzolico Vermelho-Amarelo Distrofico, Typic Paleudult, Frexeiras, Alaguas, Brazil (Proc. 1st ISCW, 1978, pp 237-245).								
0-22	Ap	26.9	8.1	28.3	-	30.9	37.1	46.5
22-37	A3	18.2	4.6	34.7	-			
37-68	B1t	14.6	3.0	46.5	fw			
68-102	B21t	8.3	2.4	57.8	cw			
102-154	B22t	8.6	2.9	51.0	cw			
154-214	B23t	11.1	3.3	42.3	fw			

Table 1 (Continued)

Depth	Horizon	CEC	ECEC	Clay	Clay	(X)	(Y)	(Z)
-cm--		(meq/100g clay)		-%--	skins			
Podzolico Vermelho-Amarelo Alico, Typic Paleusult, Goeana, Pernambuco, Brazil (Proc. 1st ISCW, 1978, pp 388-396).								
0-15	Ap	59.7	22.8	5.7	-	8.8	10.6	32.6
15-38	A2	29.4	6.4	10.9	-			
38-62	B21t	14.7	3.7	32.6	-			
62-82	B23	13.7	4.6	35.1	-			
190-220	B3	11.2	2.6	31.2	-			
Dalek series, Typic Paleudult, Singkut, Sumatra (Williams and Harding, 1979).								
0-3	Ap	112.1	-	19.0	-	22.3	26.8	27.0
3-13	Eh	8.3	-	21.0	-			
13-44	Btg1	4.1	-	27.0	-			
44-60	Bt2	4.0	-	30.0	pt			
60-90	Bt3	nd	-	nd	pt			
90-110	Btg4	4.4	-	38.0	-			
Bedoule series, Plinthic Paleudult, Southwest Ivory Coast								
0-3	A11	56.3	-	11.9	-	21.0	31.2	36.5
3-8	A12	46.7	-	13.5	-			
8-18	B1	15.6	-	36.5	-			
18-30	B21	13.4	-	44.7	ft			
30-50	B22	14.6	-	46.7	ft			
50-80	IIB23cn	11.1	-	50.4	ft			
80-112	IIB24cn	10.7	-	51.5	ft			
112-159+	IIB31cn	10.1	-	49.3	ft			
Daobli series, Typic Paleudult, Southwest Ivoery Coast								
0-3	A11	73.9	-	9.6	-	27.3	32.8	35.0
3-7	A12	49.5	-	10.3	-			
91-125	B24	11.9	-	49.5	MCmt			

Table 1 (Continued)

Depth -cm--	Horizon	CEC	ECEC	Clay -%--	Clay skins	(X)	(Y)	(Z)
		(mel/100g clay)						
Toko series, Typic Paleudult, Southwest Ivory Coast								
0-4	A11	85.1	-	24.8	-	22.4	26.9	29.2
4-12	A12	41.9	-	21.7	-			
12-26	B11	19.0	-	22.1	-			
26-38	B12	14.7	-	29.2	-			
38-61	B21	12.5	-	52.6	ft			
61-88	B22cn	11.5	-	62.7	Mt			
88-156	B23cn	12.7	-	61.3	C			
156-196	B31	9.4	-	57.9	C			
196-240	B22	10.8	-	42.0	ct			
Malan series, Typic Plinthudult, Southwest Ivory Coast								
0-2	A11	120.9	-	4.3	-	34.6	41.5	56.3
2-8	A12	41.9	-	8.6	-			
76-132	IIB24cn	12.1	-	56.3	Mt			
180-240	IICcn	16.2	-	35.7	Mt			
Tabau series, Typic Plinthudult, Southwest Ivory Coast								
5-12	A12	31,3	-	22.4	-	25.6	30.7	32.0
51-78	B22	14.7	-	32.0	ct			
78-240	IIC2cn	16.3	-	48.5	-			
Nonoua series, Plinthic Paleudult, Southwest Ivory Coast								
0-2	A1	96.8	-	30.9	-	53.9	61.9	63.7
2-6	B1	26.6	-	36.2	-			
13-202	IIB24cn	13,5	-	63.7	Ct-Mmt			
202-240	IIB25cn	17.9	-	53.4	ct			
Dunmore series, Typic Paleudult clayey, kaolinitic, mesic, Blount County, Tennessee (SSIR No. 15, 1967, pp 96-97).								
0-18	Ap	32.4	-	18.1	-	18.1	21.7	58.2
18-33	B1	12.2	-	58.2	-			
33-56	B21	9.5	-	74.2	-			
56-71	B22	11.7	-	75.7	-			
71-127	C	11.8	-	74.7	-			

Table 1 (Continued)

Depth	Horizon	CEC	ECEC	Clay	Clay	(X)	(Y)	(Z)
-cm--		(meq/100g clay)		-%--	skins			
Bungor series, Typic Paleudult, Malaysia (Proc. 2nd ISCW, Part I, 1979, pp 304-307).								
0-20	Ap	16.9	10.9	18.1	-	18.1	21.7	30.7
20-35	B1	10.2	7.7	30.7	-			
35-52	B21t	10.0	6.8	35.3	tc			
52-70	B22t	8.4	6.3	36.1	c			
70-90	B23t	8.2	5.6	41.2	p			
90-135	B31	7.6	5.2	44.3	fp			
135-190	B32	7.1	5.0	47.1	-			
190-226	C1	7.2	6.0	39.0	-			
Lanchang series, Typic Paleudult, Malaysia (Proc. 2nd ISCW, Part I, 1979, pp 291-295).								
0-15	Ap	24.5	12.1	35.2	-	37.8	45.4	50.9
15-33	B1t	11.2	5.9	50.9	pd			
33-58	B21t	9.5	4.4	58.2	Cd			
58-89	B22t	7.7	3.4	61.3	pd			
89-120	B23t	6.8	3.1	63.9	dC			
120-167	B24t	6.5	1.3	63.6	dC			
167-210	B25t	6.6	1.3	66.7	dC			
210-237	B3t	6.4	1.3	65.3	dC			
237-250	C	7.2	1.4	47.1	-			
Kening series, Typic Paleudult, Malaysia (Proc. 2nd ISCW, Part I, 1979, pp 300-301).								
0-8	A13	23.5	11.3	18.0	-	28.5	34.2	44.8
8-27	B21t	10.4	5.5	36.9	p			
27-57	B22t	7.7	3.9	44.8	p			
57-91	B23t	6.3	3.4	50.3	-			
91-125	IIBtc	6.9	4.8	47.3	pd			
125-170	IIIBtc	6.7	3.9	43.1	pd			
170-209	IVBtc	7.4	3.9	39.3	pd			
209-250	VBtc	6.6	3.8	39.2	pd			

Table 1 (Continued)

Depth (cm)	Horizon	CEC	ECEC	Clay Content (%)	Clay Skins	(X)	(Y)	(Z)
		(meq/100g clay)						
Saoua series, Plinthic Paleudult, Southwest Ivory Coast.								
0-5	A11	72.7	-	6.6	-	12.2	14.6	29.5
5-14	A12	32.8	-	11.9	-			
14-40	B1	24.6	-	16.7				
40-61	B21	14.2	-	29.5	ct			
61-102	IIB22	12.8	-	37.4	ct			
102-138	IIB23cn	13.8	-	39.8	wt			
138-195	IIB24cn	-	-	39.6	wt			
195-240	IIB3cn	13.9	-	39.7	wt			
Glouamo series, Aquic Paleudult, Southwest Ivory Coast.								
0-6	A1	77.2	-	10.1	-	9.2	13.2	15.7
6-21	B11	43.8	-	8.9	-			
21-44	B12	27.4	-	15.7	ft			
44-66	IIB21	18.9	-	25.8	ft			
66-78	IIB22	10.9	-	26.6	cmt			
78-120	IIB23	14.0	-	27.1	cmt			
120-184	IIIB23	19.7	-	31.0	ft			
Farmhill series, Typic Acrohumox (temtative)*, South Africa.								
0-16	A1	219.0	29.2	16.8	-	12.6	15.0	22.0
16-28	A2	280.0	12.0	10.0	-			
28-62	B1	74.8	4.3	11.5	-			
62-113	BT1	12.0	2.5	22.0	m			
113-149	BT2	15.2	2.2	22.4	c			
149-165	BT3	16.6	3.4	20.4	m			

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* Has a positive delta pH in some horizons.

APPENDIX III

Table 2. Key attributes of some Ultisols that qualify them into the order Oxisols by virtue of Item C.2 of the ICOMOX's proposed definition of Oxisol.

Depth	Horizon	CEC	ECEC	Clay Content	Clay Skins	(X)	(Y)	(Z)
-cm-		(meq/100g clay)		--%--				
Pauwela series, Humoxic Tropohumult, Maui, Hawaii (SSIR No.29, 1976, pp 132-133).								
0-18	Ap1	27.5	3.8	57.8	-	58.7	70.4	83.4
18-30	Ap2	22.2	3.0	60.0	-			
30-43	B21t	16.2	2.0	83.8	-			
43-60	B22t	14.5	0.7	88.5	nC			
60-75	B23t	13.3	0.9	89.5	nC			
75-103	B3t	10.3	2.3	78.0	-			
103-138	C1	11.0	3.2	53.0	-			
Haiku Taxadjunct, Humoxic Tropohumult, Maui, Hawaii (SSIR No. 29, 1976, pp 134-135).								
0-18	Ap1	24.9	2.4	63.8	-	62.5	75.0	96.0
18-33	Ap2	23.4	2.3	61.0	-			
33-45	B21	16.1	1.8	96.0	-			
45-70	B22	12.5	2.1	97.5	nC			
70-98	B23	15.3	4.5	83.0	c			
98-155	B3	14.3	3.3	83.8	Pt			
155-175	C1	19.9	3.9	62.3	T			
Paaloa series, Humoxic Tropohumult, Honolulu, Hawaii (SSIR No. 29, 1976, pp 144-145).								
0-43	Ap	21.5	5.1	66.0	-	65.3	53.3	76.3
43-63	B21t	11.0	3.3	63.8	TnC			
63-90	B22t	8.1	2.4	76.3	tP			
90-113	B23t	9.2	2.9	78.3	tP			
113-150	B24t	17.5	3.5	83.5	tP			
Sijau series, Typic Paleudult, Alai Hilir, Sumatra (Williams & Harding, 1979, p 32).								
0-2	Ah	43.1	15.0	42	-	53.1	61.1	62.0
2-17	Eh	10.6	7.0	54	none			
17-42	Bt1	7.6	5.3	62	"			
42-116	Bt2	6.1	4.1	70	"			
116-150	Bt3	6.6	4.2	71	"			

Table 2. (Continued)

Depth	Horizon	CEC	ECEC	Clay Content	Clay Skins	(X)	(Y)	(Z)
-cm-		(meq/100g clay)		-%-				
Drasa series, Oxic Paleustult, Viti Levu, Fiji (Proc South Pacific Regional Forum on Soil Taxonomy, 1981, p 381).								
0-10	Au	34.1	14.5	42	-	44.2	53.1	54.0
25-35	B1t	23.4	6.4	47	-			
50-60	B2t	7.2	5.6	54	f			
80-90	B3t	14.2	10.0	45	f			
120-125	Bs	19.5	9.3	42	-			
Pak Chong series, Oxic Paleustult, Amphoe Pak Chong, Ratchasima, Thailand (Proc 2nd ISCW Part II, 1979, p 259).								
0-12	Ap	19.3	13.1	83.3	-	83.9	91.3	93.7
12-30	B21t	14.8	8.3	85.1	bmT			
30-53	B21t	13.1	7.1	89.6	bmT			
53-90	B22t	13.2	6.5	93.7	pmT			
90-137	B22t	11.8	6.3	92.3	pmT			
137-160	B3	11.6	6.3	92.1	-			
Ban Chong series, Oxic Paleustult, Amphoe Kabin Buri, Prachin Buri, Thailand (Proc 2nd ISCW Part II, 1979, p 331)								
0-13	B1	21.2	6.5	53.6	-	56.6	64.6	67.4
13-33	B21t	13.4	4.6	64.5	pt			
33-53	B22t	9.7	3.4	67.4	-			
53-80	B22t	13.0	3.6	66.4	-			
80-106	B22t	13.1	3.9	64.1	-			
106-127	B23t	13.2	3.9	64.8	-			
127-143	B23t	12.3	3.8	68.0	-			
143-173	B3t	13.6	5.3	59.8	-			
Kabin Buri series, Oxic Haplustult, Amphoe Kabin Buri, Thailand (Proc ISCW Part II, 1979, p 341).								
0-7	A1	31.6	10.8	38.3	-	48.3	56.3	63.2
7-26	B1	15.9	3.9	54.6	-			
26-62	B21t	11.8	3.1	63.2	mT			
62-95	B22t	10.8	2.8	71.5	mT			
95-130	B22t	9.8	3.7	65.4	mT			
130-180	B3	17.0	5.3	36.6	-			
Terra Roxa Estruturada Distrofico, Orthoxic Palehumult, Ortiguiera, Parana, Brazil (Proc 1st ISCW, 1978, p 128).								
0-10	Ap	45.5	20.2	45.3	-	48.7	56.7	59.7
10-25	B1t	28.4	9.6	52.9	cm			
25-73	B21t	19.1	4.9	59.7	cm			
73-167+	B22t	15.5	3.3	56.3	cm			

Table 2. (Continued)

Depth	Horizon	CEC	ECEC	Clay Content	Clay Skins	(X)	(Y)	(Z)
-cm-		(meq/100g clay)		-%-				
Limones series, Orthoxic Tropohumult, Puerto Rico (SSIR No. 12, 1967, pp 124-125).								
0-13	Ap	21.7	10.9	46.6	-	48.5	56.5	59.0
13-23	B1	16.7	7.5	53.3	ftp			
23-41	B21t	11.9	5.8	59.0	tC			
41-66	B22t	11.6	5.9	54.3	tC			
66-102	B3	14.3	9.3	46.3	tp			
102-137	C1	18.5	15.1	37.8	-			
137-183	C2	17.6	13.0	33.0	-			
Grady series, Typic Paleaquult, Houston Georgia, USA (SSIR No. 16, 1967, pp 40-41).								
0-15	Ap	53.6	17.1	38.5	-	40.9	48.9	52.7
15-28	B1g	16.2	10.4	52.7	-			
28-46	B21g	14.8	8.7	50.4	-			
46-74	B22g	9.2	5.6	62.3	-			
74-99	B23g	18.2	10.5	45.7	-			
99-114	B3g	13.4	8.5	50.4	-			
114-127	Cg	15.1	9.5	31.7	-			

APPENDIX IV

Table 1. Key attributes of selected pedons used to test the proposed key to suborder Aquox.

Depth	Horizon[a]	Organic Carbon	Base Sat.	Color		CEC meq/ 100g clay	Moisture	Clay
				Horizon	Mottles			
-cm-		- - - pct - -						
Pedon OX-14, Typic Umbraquox, Kuamang Kuning, Jamib, Sumatra.								
0-10	Hg	30.00	9	5YR3/2		161.9	W	27
10-25	ABhr	2.40	4	7.5YR5/2		38.0	W	15
25-80	Br1	0.41	0	10YR7/1	10YR5/3	11.8	W	17
80-100	Br2	0.31	0	2.5YR6/2	10YR5/3	11.0	W	20
100-125	Br3	0.25	3	10YR7/1	10YR6/2	11.2	W	33
Pedon OX-2, Typic Ochraquox, Kubang Ujo, Jambi, Sumatra.								
0-3	Ah	14.29	3	10YR3/2		91.1	W	37
3-8	ABh	9.09	2	10YR4/2		38.4	W	61
8-15	Br1	7.58	2	10YR6/2		34.1	W	59
15-75	Br2	1.03	1	10YR7/1	7.5YR6/8	15.6	W	52
75-130	Br2	0.43	4	10YR7/1	7.5YR6/8	20.1	W	78
130-150	Br3	0.25	6	5GY7/1	2.5YR4/6	26.7	-	-
Pedon OX-40, Typic Umbraquox, Singkot Rentis, Jambi, Sumatra.								
0-29	He	18.00	20	10YR2/2			S	
29-44	Ah	4.32	31	10YR4/3		53.8	W	6
44-66	BAh	2.92	19	10YR5/3		18.0	W	18
66-83	Br1	2.05	33	10YR6/2		5.1	W	47
83-100	Br2	0.98	19	2.5YR6/2		14.6	W	35
Pedon OX-20, Typic Ochraquox, Singkot, Jambi, Sumatra.								
0-4	Ap	4.22	33	10YR3/1		66.8	W	22
4-25	BAw	1.53	11	10YR5/2		23.8	M	26
25-43	Bg1	0.29	6	10YR6/3		8.0	M	35
43-71	Bg2	0.23	6	10YR6/3	7.5YR6/4	9.0	M	40
71-120	Br1	0.14	0	10YR7/1	10R4/8	9.0	M	41
120-150	Br2			10YR7/1	10R4/8		W	
Pedon OX-19, Typic Ochraquox, Hitam Ulu, Jambi, Sumatra.								
0-8	Ah	12.25	9	7.5R3/2		54.0	M	67
8-32	BAh	1.67	2	10YR5/6		11.4	M	72
32-75	Br1	0.68	0	2.5Y6/2	2.5YR4/8	8.6	W	72
75-112	Br1	0.35	0	10YR6/1	7.5YR5/8	11.3	W	67
112-150	Brcs	0.11	0	5BG6/1	5YR4/2	13.3	W	46

Source: Williams and Harding (1979).

[a] Horizons described according to FAO-UNESCO, Soil Map of the World. Vol. I, Legend (1974) pp 21-23. Moisture: W-wet, S=saturated,M=moist.

Table 1. (Continued)

Depth	Horizon[a]	Organic Carbon	Base Sat.	Color		CEC meq/ 100g clay	Mois- ture	Clay
				Horizon	Mottles			
-cm-		- - - pct- - -						
Pedon OX-3, Typic Ochraquox, Singkot, Jambi, Sumatra.								
0-4	Ah	3.53	9	7.5YR3/2		78.5	M	13
4-18	ABh	2.04	11	10YR5/4	7.5YR5/8	23.8	M	15
18-40	Br1	1.68	11	2.5YR6/4	5YR5/8	21.2	M	17
40-118	Br2	1.23	13	10YR6/2	7.5YR6/8	11.6	M	34
118-150	Br3	1.19	39	10YR8/1	7.5YR6/8	3.3	W	70

APPENDIX IV

Table 2. Key attributes of selected pedons to test the key definition of suborder Torrox.

Depth (cm)	Horizon	CEC (meq/100g clay)	ECEC (meq/100g clay)	ΔpH	Base Sat. (%)	Matrix color	Clay Content (%)
Molokai series, Typic Torrox, Honolulu County, Oahu, Hawaii. Source: SSIR No. 29, 1976, p 180.							
0-15	Ap1	42.2[a]	18.4	-0.7	41[b]	2.5YR2/4	52.8[c]
15-38	Ap2	37.2	15.6	-0.7	42	2.5YR3/4	56.3
38-65	B21	20.9	10.7	-0.6	51	2.5YR2/4	55.3
65-100	B22	24.9	12.3	-0.5	49	5YR3/3	57.8
100-150	C	19.2	9.1	-0.8	47	5YR3/4	53.0
Molokai series, Typic Torrox, Kunia, Oahu, Hawaii. Source: Yaibuathes (1969).							
0-30	Ap1	27.7[a]	13.4	-0.6	48	2.5YR3/4	52.2[c]
30-82	Ap2	19.1	6.5	-0.4	34	10R3/6	49.8
82-110	B21	15.2	6.0	-0.2	38	10R3/6	51.0
110-130	B22	13.4	6.3	-0.4	46	10R3/6	54.3

[a] By sum of cations.

[b] By sum of cations.

[c] Clay content by 2.5 x 15-bar water.

APPENDIX IV

Table 3. Key attributes of pedons in the "Acr" great groups of suborder Orthox.

Depth (cm)	Horizon	ECEC (meq/ 100g clay)	pH			Organic Carbon (kg/m^3)	Color of epipedon
			H_2O	KCl	ΔpH		
Mahana series, Typic Acrohumox, Kauai, Hawaii (SSIR No. 29, 1976, p158).							
0-13	A1	5.8	5.6	4.6	-1.0	32.6	2.5YR3/3
13-30	B21	1.3	4.8	4.6	-0.2		
30-58	B22	1.2	5.0	4.8	-0.2		
58-88	B23	0.5	5.1	4.8	-0.2		
88-138	IIC	3.2	4.4	4.4	0		
Jerangau series, Haplic Acrorthox, Malaysia (ISCW, Part I, 1978, p 317).							
0-25	Ap	3.6	4.5	3.9	-0.6	15.0	7.5YR4/4
25-57	B	1.2	4.5	4.1	-0.4		
57-89	B21	0.5	4.7	4.3	-0.4		
89-130	B22	0.5	4.5	4.3	-0.2		
130+	B23	0.47	4.6	4.6	0		
SP4, Typic Acrorthox, Sta. Isabel, Solomon Islands (Leamy *et al.* 1979).							
0-8		3.0	4.5	3.9	-0.6	11.9	2.5YR3/2
15-84		0.1	5.6	6.0	+0.4		
84-137		<0.1	5.7	6.2	+0.5		
137-213		0.1	5.6	6.1	+0.5		
OX-48, Typic Acrorthox, San Cristobal, Solomon Islands (Leamy *et al.* 1979).							
0-15		0.1	5.0	4.6	-0.4	24.0	7.5YR5/6
15-66		0.3	5.4	5.6	-0.1		
66-74		0.1	5.1	5.6	+0.5		
74-99		0.1	5.4	6.0	+0.6		
OX-49, Leptic Acrorthox, Sta. Isabel, Solomon Islands (Leamy *et al.* 1979)							
0-15		2.9	4.7	4.2	-0.5	21.4	10R3/3
23-46		0.1	5.8	5.8	0.0		
46-91		0.1	5.7	6.0	+1.0		
OX-50, Haplic Acrorthox, Kolombangara, Solomon Islands (Leamy *et al.* 1978)							
0-15	A1	1.7	4.4	4.0	-0.4	8.0	7.5YR5/6
15-76	A1g	0.1	5.2	5.5	+0.3		
76+	AC	0.2	5.7	6.0	+0.3		

Table 3. (Continued)

Depth (cm)	Horizon	ECEC (meq/ 100g clay)	pH			Organic Carbon (kg/m^3)	Color of epipedon
			H_2O	KCl	ΔpH		
OX-51, Haplic Acrorthox, Kolombangara, Solomon Island (Leamy *et al*. 1979).							
0-10	A11	8.7	4.3	3.7	-0.6	18.0	2.5YR4/4
10-28	A12						
28-81	B	0.1	4.9	4.8	-0.1		
81-127							
Kuantan series, Haplic Acrorthox, Malaysia (Proc ISCW, Part I, 1979, pp 308-310).							
0-18	A13	4.7	4.3	3.9	-0.4	7.5	
18-46	B21ox	1.7	4.6	4.1	-0.5		
46-121	B22ox	1.5	4.8	4.8	0.0		
121-200	B23ox	1.2	4.8	4.3	-0.5		
Senai series, Haplic Acrorthox, Malaysia (Proc. ISCW, Part I, 1979, pp 320-322).							
0-10	Ap1	9.4	4.1	3.9	-0.2	13.1	7.5YR3/3
10-25	Ap2	1.9	4.4	4.0	-0.4		
25-52	B1ox	1.0	4.6	4.1	-0.5		
52-110	B21ox	0.7	4.6	4.3	-0.3		
110-140	B22ox	0.9	4.7	4.4	-0.3		
140+	B3	0.7	4.9	4.7	-0.2		
Nipe series, Typic Acrorthox, Puerto Rico (SSIR No. 12, 1967)							
0-11	A1	7.9	5.1	4.3	-0.8	38.0	2.5YR2/4
11-18	B1	1.7	5.0	4.4	-0.6		
18-25	B21		5.0	4.7	-0.3		
25-38	B22		5.2	5.7	+0.5		
38-48	B23	0.2	5.5	6.1	+0.6		
48-62	B24	t	5.7	6.4	+0.7		
62-70+	C1	t	5.8	6.7	+0.9		

APPENDIX IV

Table 4. Key attributes of pedons of the "Umbr" great groups of Orthox that were placed into different great groups by virtue of the proposed key definition.

Depth	Horizon	Organic Carbon		Sum of bases	KCl Extr. Al	ΔpH
(cm)		kg/m^3	(%)	- - - meq/100 g clay- - -		
Makapili series, Tropeptic Umbriorthox, Kauai, Hawaii (SSIR No. 29, 1976, p 174).						
0-25	Ap	24.4	4.53	4.3	t	-1.3
25-33	B1		2.31	1.7	0.2	-1.5
33-53	B21		1.83	1.4	t	-0.2
53-83	B22		1.53	1.0	-	-0.2
83-125	B23		0.83	0.3	-	+0.2
125-163	B24		0.57	0.2	-	+0.4
Lawai series, Tropeptic Umbriorthox, Kauai, Hawaii (SSIR No. 29, 1976, pp 172-173).						
0-20	Ap1	15.1	2.76	1.5	1.3	-0.5
20-35	Ap2		1.88	1.2	1.5	-0.6
35-65	B21		1.28	1.9	1.7	-0.5
65-105	B22		0.66	1.7	3.6	-0.6
105-133	B23		0.40	1.7	4.4	-0.6
133-150	B24		0.37	1.5	2.5	-0.5
Puhi series, Tropeptic Umbriorthox, Kauai, Hawaii (SSIR No. 29, 1976, pp 178-179).						
0-23	Ap	18.4	4.39	5.2	0.2	-0.1
23-53	B21		1.72	2.0	0.1	0.0
53-75	B22		1.27	2.4	-	0.0
75-98	B23		0.62	2.7	-	-0.1
98-120	B24		0.52	2.9	-	-0.1
120-150	B3		0.41	3.2	-	-0.3

APPENDIX IV

Table 5. Some genetic factors of the Makapili, Lawaii and Puhi series in Hawaii.

Genetic Factors	Makapili series	Puhi series	Lawai series
Parent Material	Basalt	Basalt	Colluvium
Elevation (m)	72	90	225
Mean Annual Rainfall (cm)	188	175	250
Mean Annual Temperature (°C)	22.2	22.2	20.0
Uses	sugarcane grazing woodland forest reserve	sugarcane grazing woodland wild life habitat pineapple truck crops ocrhcard	sugarcane pinapple

Sources: SSIR No. 29, 1976; LSB Cir. No. 9 (1967) and; Soil Survey Staff (1972).

APPENDIX IV

Table 6. Key attributes of selected pedons of the great groups of Eutrorthox.

Depth	Horizon	Matrix color	Clay	Organic Carbon		CEC	ECEC	Base Sat.	ΔpH	Horizon Bdry.	Clay Skins
(cm)			(%)	kg/m^3	(%)	(meq/100 g clay)		(%)			
Bayoman series, Tropeptic Eutrorthox, Puerto Rico (SSIR No. 12, 1967, p 157).											
0-20	Ap	5YR3/4	73.3	10.3	2.73	20.7	14.9	72	-0.7	CS	-
20-46	B21	2.5YR3/6	81.2		0.94	11.7	8.4	68	-0.7	GS	tp
46-69	B22	2.5YR3/6	85.5		0.55	10.1	8.3	83	-0.5	GS	tp
69-99	B23	2.5YR4/6	89.5		0.35	10.9	9.1	83	-0.4	GS	tp
99-130	B3	2.5YR4/6	90.6		0.25	15.6	13.8	89	0.0	AS	-
Matanzas series, Tropeptic Eutrorthox, clayey, oxidic, isohyperthermic, Puerto Rico (SSIR No. 12, 1967, p 159).											
0-35	A1	2.5YR3/4	51.5	15.1	2.84	28.9	-	-	-	-	-
35-68	B21	10Y- 2.5YR3/4	83.0		1.03	10.1	-	-	-	-	-
68-97	B22	2.5YR5/6	87.0		0.55	8.2	9.4	115	-	-	-
Latossolo Roxo Eutrofico, Typic Eutrorthox, Londrina, Parana, Brazil (Proc. 1st ISCW, 1978,pp 123-127).											
0-18	Ap	1YR3/3	59.7	14.2	2.54	35.4	19.2	53	-1.1	CS	-
18-30	A3	1YR3/3	61.4		1.79	30.4	15.9	52	-1.1	CS	-
30-80	B1	1YR3/4	69.0		0.82	19.2	8.8	46	-1.0	DS	-
80-150	B21	1YR3/4	65.6		0.57	16.2	6.4	40	-0.5	DS	-
150-235	B22	1YR3/5	65.6		0.31	13.4	4.8	37	+0.4	DS	-
235-275+	B23	1YR3/6	63.9		0.22	13.5	5.4	42	+0.2	-	-

APPENDIX IV

Table 7. Key attributes of selected pedons to the Aquic subgroups of Haplorthox.

Depth (cm)	Horizon	Color of Mottles	Clay Content (%)	CEC meq/100 g clay	Moisture	Clay* Ratio
Merangin series, Aquic Haplorthox, Hitam Ulu, Sumatra. Source: Williams and Harding (1979), p 194.						
0-11	Ah	-	43	28.1	M	
11-40	BAh	-	51	15.3	M	
40-60	Bws	2.5YR5/8	64	10.5	M	1.4
60-91	Bwsg1	10YR6/1	71	10.3	M	
91-133	Bwsg2	10YR6/1	73	11.6	M	
133-150	Br	10YR7/1	75	11.6	M	
Tabri series, Aquic Haplorthox, Hitam Ulu, Sumatra. Source: Williams and Harding (1979), p 184.						
0-10	Ah	-	71	16.5	M	
10-40	Bws	-	77	9.6	M	
40-60	Bg1	10YR6/1	79	9.0	M	1.0
60-115	Bg2	N7	78	8.5	M	
115-150	Bg3	N7	76	9.3	M	
Regosari series, Aquic Haplorthox, Hitam Ulu, Sumatra. Source: Williams and Harding (1979), p 180.						
0-17	Ah	-	41	20.5	M	
17-47	Bws1	-	47	11.3	M	
47-90	Bws2	-	50	9.6	M	1.2
90-111	Bgcs	10YR6/1	52	9.8	W	
111-150	Brcs	10YR6/1	48	10.4	W	
Kuamang series, Aquic Haplorthox, Kuamang Kuning, Sumatra. Source: Williams and Harding (1979), p 122.						
0-12	Ah	-	26	52.7	M	
12-50	Bws	-	31	11.3	M	1.1
50-73	Bg	10YR7/2	29	9.3	W	
73-90	Br1	-	13	11.5	W	
90-120	Br2	-	22	9.5	W	

Moisture: M= moist and W= wet.

* Ratio of clay content of the finer textured subhorizon to the caorser textured overlying horizon.

Table 7. (Continued)

Depth (cm)	Horizon	Color of Mottles	Clay Content (%)	CEC meq/100 g clay	Moisture	Clay Ratio
Aburan series, Aquic Haplorthox, Kuamang Kuning, Sumatra. Source: Williams and Harding (1979), p 118.						
0-5	Ah	-	21	70.0	M	
5-10	ABh	-	19	28.4	M	
10-33	Bws1	-	25	12.4	M	
33-102	Bws2	-	27	11.5	M	1.2
102-130	Bg	10YR7/2	22	11.4	M	
130-150	Br	-	34	11.8	W	
Rukani series, Aquic Haplorthox, Hitam Ulu, Sumatra. Source: Williams and Harding (1979), p 202.						
0-3	Ah	-	51	39.0	M	
3-19	ABh	-	52	19.8	M	
19-58	Bws	7.5YR6/8	62	12.6	M	
58-110	Br1	2.5YR4/6	68	11.9	M	1.3
110-150	Br2	2.5YR4.8	75	13.6	M	

APPENDIX IV

Table 8. Key attributes of slected pedons used to test the Plinthic definition at the subgroup level. Source: Soil Survey of the Southwest Region (Technical Appendix), Ivory Coast (1967).

Depth (cm)	Horizon	Clay Content (%)	CEC meq/100 g clay	Description
Boka series, Plinthic Haplorthox, Southwest Ivory Coast.				
0-3	A1	38.2	88.6	34% by weight ironstone gravel.
3-9	A3	32.2	50.6	70% by weight ironstone & quartz gravel & iron cemented rocks.
42-119	IIB22	51.4	12.8	38-24% by weight ironstone gravel and schist.
119-240	IIC	21.8	10.1	Much hard and soft plinthite.
Donie series, Plinthic Haplorthox, Southwest, Ivory Coast.				
0-6	A1	8.9	58.5	-
6-12	A3	11.4	39.5	-
65-102	IIB23	45.7	3.9	15-65% by weight fine ironstone gravel & quartz fragments.
102-248	IIC	26.8	17.9	Soft & hard plinthite that form continuous phase.
Bedoule series, Plinthic Paleudult, Southwest, Ivory Coast.				
0-3	A11	11.9	56.3	15% by weight ironstone gravel.
3-8	A12	13.5	46.7	52% by weight fine ironstone gravel.
8-18	B1	36.5	15.6	55% by weight fine & medium ferrogenous gravel.
18-30	B21	44.7	13.4	26% by weight fine ferrogenuous gravel.
30-50	B22	46.7	14.6	24% by weight fine ironstone gravel.
50-80	IIB23cn	50.4	11.1	20% by weight hard plinthite and quartz fragments.
80-112	IIB24cn	51.5	10.7	12% by weight fragments of hard plinthite.
112-159+	IIB37cn	49.3	10.1	9% by weight quartz fragments and gneissic pseudomorphs.
Nonoua series, Plinthic Paleudult, Southwest Ivory Coast.				
0-2	A1	30.9	96.8	5% by weight ironstone gravel.
2-6	B1	36.2	26.6	Less than 5% by weight ironstone gravel.
113-202	IIB24cn	63.7	13.5	14-70% by weight ironstone gravel.
202-240	IIB25cn	53.4	17.9	-

APPENDIX V

Table 1. Properties of selected Inceptisols that were used to test Item 2 of the proposed definition of the oxic horizon by ICOMOX.

Depth	Horizon	ECEC	CEC	Texture	Clay Content	Organic Carbon
		meq/100g clay				
(cm)					(%)	(%)
Koolau series, Plinthic Tropaquept, Kauai, Hawaii (SSIR No. 29, 1976 p 74).						
0-15	A11	3.8	89.8	sicl	70.7	8.65
15-28	A12g	1.2	56.9	sic	58.9	1.73
28-40	A2g	5.5	34.6	sic	34.6	0.78
40-100	B21g	8.8	169.7	sicl	25.1	0.94
100-130	B22t	7.1	217.5	sicl	25.2	2.29
130-180	C	13.5	325.3	sicl	17.0	1.08
Naiwa series, Andic Humitropept, Maui, Hawaii (SSIR No. 29, 1976 p 78).						
0-10	Ap	17.8	27.1	sicl	40.0	5.05
10-28	A12	10.8	26.3	sicl	43.6	4.10
28-35	B1	3.1	42.7	sil	48.2	3.99
35-65	B2	5.3	80.4	sil	28.5	9.66
65-100	B3	6.2	89.6	1	22.5	10.34
100-130	IIC1	5.4	88.7	1	25.9	10.34
Kohala series, Ustic Humitropept, Hawaii, Hawaii (SSIR No. 29, 1976, p 82).						
0-18	Ap1	16.6	45.8	sic	70.5	2.68
18-35	Ap2	16.4	49.9	sic	69.0	2.40
35-68	B21	11.5	33.1	sic	72.0	0.97
68-98	B22	7.5	26.5	sic	72.0	0.66
98-113	C1	14.0	35.5	-	77.3	0.80
113-133	C2	14.5	43.4	-	71.5	0.30
Uwala series, Oxic Ustropept, Maui, Hawaii (SSIR No. 29, 1976, p 90).						
0-20	Ap1	13.3	24.2	sicl	57.8	2.13
20-40	Ap2	12.7	21.1	sicl	66.3	1.42
40-70	B2	12.3	18.0	sicl	70.0	0.46
70-105	C1	11.8	18.8	sicl	77.0	0.54
105-155	IIC2	10.3	21.0	sicl	78.5	0.24
Pedon SV.2.4, Typic Tropagquept, Lampung, Sumatra (SRI, 1975).						
0-14	A1	9.0	44.8	scl	27.0	1.40
14-45/50	B21	4.3	26.1	scl	33.0	0.47
45/50-72	BC	2.5	21.6	scl	37.0	0.21

APPENDIX VI

Table 1. Some physical characteristics of selected Oxisols.

Depth (cm)	Clay Content (%)	15-Bar Water Content (%)	$\frac{\text{\% Clay}}{\text{15-Bar Water}}$
Pedon OX-62, Typic Umbriorthox, Sao Paulo, Brazil. Source: Lepsch and Buol (1973).			
0-12	74	23.3	3.2
12-33	75	24.3	3.1
33-64	77	26.4	2.9
64-90	79	27.2	2.9
90-140	79	26.8	2.9
Pedon OX-63, Typic Haplorthox, Sao Paulo, Brazil. Source: Lepsch and Buol (1973).			
0-15	70	26.4	2.7
15-36	77	25.1	3.1
36-65	79	25.3	3.1
65-140	77	25.7	3.0
140-180	76	26.2	2.9
Phuket series, Tropeptic Haplustox, Thailand. Source: Proc 2nd ISCW, Part II, 1979.			
35-68	42.0	13.0	3.2
68-90	43.5	16.4	2.7
90-117	43.1	15.5	2.8
117-144	44.2	17.0	2.6
Coto Taxadjunct, Tropeptic Eutrustox, Isabela, Puerto Rico. Source: BSP Tech. Report No. 5 (1979).			
0-13	70.7	22.5	3.1
13-25	71.1	22.8	3.1
25-45	75.9	23.7	3.2
45-65	79.6	26.4	3.0
65-90	81.9	26.8	3.1
Jaiba series, Tropeptic Eutrustox, Minas Gerais, Jaiba, Brazil. Source: BSP Tech. Report No. 5 (1979).			
0-10	56.4	22.2	2.5
10-20	63.1		
20-50	58.3	20.4	2.9
50-120	52.2		
120-200	53.2		

Table 1. (Continued)

Depth (cm)	Clay Content (%)	15-Bar Water Content (%)	% Clay / 15-Bar Water
Choc Chai series, Typic Haplustox, Thailand. Source: Proc 2nd ISCW, Part II, 1979, p 317.			
0-14	56.8	15.0	3.8
14-36	69.7	17.2	4.1
36-60	66.9	17.1	3.9
60-86	68.9	17.6	3.9
86-120	68.7	17.2	4.0
120-156	69.8	17.3	4.0
156-185	67.5	17.0	4.0
185-200	67.9	17.3	3.9

APPENDIX VI

Table 2. Clay content and soil water retention characteristics and ratio of percent clay to 15-bar water content of selected Ultisols.

Depth (cm)	Clay Content (%)	15-Bar Water Content (%)	% Clay / 15-Bar Water
Pak Chong series, Thailand. Source: Proc 2nd ISCW Part II, 1979, p 163.			
0-12	83.3	21.9	3.8
12-30	85.1	23.1	3.7
30-53	89.6	24.1	3.7
53-90	93.7	25.3	3.7
90-137	92.3	25.3	3.7
137-160	92.1	24.3	3.8
160-200	92.5	24.4	3.8
Yasothon series, Thailand. Source: Proc 2nd ISCW Part II, 1979, p 301.			
0-14	4.5	1.9	2.4
14-34	6.1	2.3	2.6
34-62	7.7	-	-
62-85	15.8	5.0	3.2
85-115	18.6	5.5	3.4
115-150	14.9	4.8	3.1
150-175	14.1	4.4	3.2
175-200	14.5	4.7	3.1
Orthoxic Palehumult, Sao Paulo, Brazil. Source: Lepsch and Buol (1973).			
0-10	68	19.7	3.5
10-25	68	20.5	3.3
25-40	67	20.5	3.3
40-47	75	22.6	3.3
47-82	76	24.3	3.1
82-100	77	25.4	3.0
Typic Palehumult, Sao Paulo, Brazil. Source: Lepsch and Buol (1973).			
0-10	59	18.1	3.5
10-19	61	18.9	3.2
19-27	60	19.0	3.2
27-64	78	26.5	2.9
65-95	81	17.7	2.9
95-100	82	28.4	2.9

APPENDIX VI

Table 3. Efffect of the proposed factor 3.5 as an estimate of clay content (%clay = 3.5 x 15 bar water) in the classification of selected oxic subgroups of Inceptisols.

Depth (cm)	Horizon	CEC meq/100 g soil	CEC meq/ 100 g clay	CEC meq/100 g clay	Horizon Boundary	Mica (%)
Hoolehua series, Oxic Ustropept, Hawaii. Source: SSIR No. 29, 1976, p 86.						
0-23	Ap1	15.6	29.16	20.83	CS	15
23-38	Ap2	14.6	25.39	18.13	CW	
38-53	B11	11.2	20.00	14.29	CW	15
53-68	B12	10.4	19.17	13.69	CW	
68-123	B21	10.1	19.42	13.87	GW	15
123-160	B22	9.8	19.40	13.86		
Uwala series, Oxic Ustropept, Hawaii. Source: SSIR No. 29, 1976, p 92.						
0-18	Ap1	11.9	20.9	14.9	CW	
18-38	Ap2	10.7	16.9	12.1	AW	
38-75	B2	12.0	16.4	*	CW	
75-110	B3	12.4	15.5	*	CW	
110-150	C	11.8	16.2	*		

* Percent clay content greater than 100 when estimated with the factor 3.5.

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