Classifying soils at the ultimate stage of weathering: A continuing challenge for sustainable agromanagement practices in the 21st Century

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Abstract
Oxisols cover approximately 23% of the land surface in the tropics and are utilized extensively for agricultural purposes in the tropical countries. Under the variable input types of agricultural systems practiced locally, some of these soils still appear to have problems in terms of proper soil classification and subsequently, hinder attempts to implement sustainable agro-management protocols. Therefore, the objective of this study is to examine the properties of some Oxisols and closely related soils in order to evaluate the classification of these soils.

Soils from several countries in the tropics used in this study. Field observations, water retention differences, apparent CEC of the subsurface horizons, extractable Fe-oxides and external specific surface areas of the clay fractions showed that many kandic horizons have surface properties that are similar to the oxic horizons. Micromorphology indicated that the genetic transition from the argillic to the oxic involves a diminishing expression of the argillic.

It is proposed that the Oxisols be keyed out based only on the presence of an oxic horizon. The proposal provides a better basis for the classification of Malaysian soils and the development of meaningful soil management groups for plantations.

Introduction

Oxisols are known to occupy close to 23% of the land surface in the tropics (Eswaran *et al.*, 1993). Other estimates indicate that these soils occupy approximately 46% (Thomas & Ayarza, 1999), or 38% (Lehane, 2000), if taken into account with the closely related Ultisols. Since the advent of Soil Taxonomy (Soil Survey Staff, 1975), several revisions to the classification of Oxisols had been proposed. However, the classification of transitional soils continued to pose serious problems in many parts of Africa as well as other parts of the tropics. As such, the objective of this study is to reexamine the properties of some Oxisols and closely related soils in order to evaluate the classification of these soils.

Materials and Methods

Soils were selected from Brazil, several countries in Africa and Malaysia for this study (Table 1). The soils were described according to Soil Survey Manual (Soil Survey Staff, 1993). Soils were classified according the Soil Survey Staff (1994). The cation exchange capacity (CEC, pH 7 NH_4OAc method), organic carbon (OC), water retention difference (WRD) and particle-size distribution were carried out according to Soil Survey Laboratory Staff (1992). The data for WRD and CEC of the argillic and cambic horizons were taken from Soil Taxonomy (Soil Survey Staff, 1975). Field descriptions were carried out using the Soil Survey Manual (Soil Survey Staff, 1993) and soil classification according to Keys to Soil Taxonomy (Soil Survey Staff, 1994).

Clay separation was carried out according to Jackson (1969). Mineralogical composition was determined by X-ray diffraction (XRD) technique on oriented specimens using a Phillips diffractometer with an Fe tube. Total elemental analyses on the clay fractions were done according to Jackson (1969). Sequential extraction of the various forms of Fe-oxides was carried out following the recommendation of McKeague *et al.* (1971). External specific surface areas (S.S.A.) were estimated by the N_2-BET method using an Autosorb 1 (Quantachrome Corp., NY). Thin sections of undisturbed soil samples were made according to Jongerius and Heintzberger (1975) and described according to Bullock *et al.* (1985) and Brewer (1964).

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General Properties

Many of the soils studied have finer-textured subsurface horizons (Table 1).

Table 1. The location, classification, texture, soil moisture regime (SMR) and soil temperature regime (STR) of selected soils used in this study.

Soil	Location	Classification	Texture	SMR	STR
		(Soil Survey Staff, 1994)	‡		
P1	Brazil	Typic Eutrustox	c	ustic	isohyperthermic
P2	Zambia	Acrustox	c	ustic	isohyperthermic
P3	Uganda	Kandiudalfic Eutrudox	c	udic	isohyperthermic
P4	Kenya	Typic Kandiustalf	c	ustic	isohyperthermic
P5	Mali	Plinthic Kandiustalf	l	ustic	isohyperthermic
P6	Brazil	Plinthustalf	sl	ustic	isohyperthermic
P7	Zambia	Typic Kandiustult	c	ustic	isohyperthermic
P8	Congo-Kinshasha	Psammentic Paleudult	ls	udic	isohyperthermic
P9	Burundi	Orthoxic Kanhapludult	cl	udic	isothermic
P10	Brazil	Rhodustult	sl	udic	isohyperthermic
P11	Malaysia	Kandiudult	c	udic	isohyperthermic

‡ c=clay, l=loam, scl=sandy clay loam, cl=clay loam, sl=sandy loam, ls=loamy sand.

Many of these soils show a clay increase with depth but do not always have the necessary clay skins on peds faces to support the idea of clay illuviation. The water retention differences expressed on a clay basis and the apparent cation exchange capacities (CEC) of these soils indicate that many of the presently classified kandi-Ultisols and Alfisols are closer to Oxisols, than the true Ultisols or Alfisols.

Mineralo-Chemistry

The X-ray diffraction of clay fractions indicate that the kandic and oxic horizons have similar mineralogical assemblage (Table 2). The similarities of the CEC and external specific surface areas (SSA), and the ratios of the various extractable Fe-oxides also point to the same conclusion.

Table 2 Mineral composition of the oxic and kandic subsurface horizons (from XRD analyses). XRD peak intensity: X=weak, XX=moderate intensity, XXX=intense.

MINERAL	ARGILLIC	KANDIC	OXIC
2:1 phyllosilicates	XXX	---	---
1:1 phyllosilicates	XX	XXX	XXX
Quartz	X	XXX	XXX
Hematite	X	XXX	XXX
Goethite	XXX	X	X
Gibbsite	X	X	X
Short-range order oxides	XXX	X	X
Others	XXX	X	X

Micromorphology

There are highly weathered soils with good evidence of moved clay which have CEC as well as other physical and chemical properties that are closer to the properties of Oxisols than Ultisols or Alfisols. There is a diminishing expression of the argillic horizon as soil formation approaches the oxic stage.

Proposed Classification Criteria for Oxisols

It is proposed that the new definition for Oxisols should read as follows,

D. *Other soils that have an oxic horizon and an iso- soil temperature regime*
Oxisols

The oxic horizon does not have andic soil properties and has all of the following characteristics:

1. A thickness of 30 cm or more, and
2. A particle size of sandy loam or finer in the fine earth fraction, and
3. Less than 10 percent weatherable minerals in the 50- to 200- micrometer fraction, and
4. Rock structure in less than 5 percent of its volume, or sesquioxide coatings on lithorelicts containing weatherable minerals, and
5. A CEC of 16 cmol(+) or less per kg clay (by 1N NH_4OAc pH 7) and an ECEC of 12 cmol(+) or less per kg clay (sum of bases extracted with 1N NH_4OAc pH 7 plus 1N KCl-extractable Al)

Conclusion

As a result of the changes proposed to Soil Taxonomy (Soil Survey Staff, 1999), the Oxisols will now be exclusive to the intertropical belt with an iso- soil temperature regime. The geographic extent of Oxisols in the tropics will increase and conversely, that of kandi- Alfisols and Ultisols will decrease. Testing of the proposed classification on some Malaysian soils showed that the new definition for Oxisols provides a better basis for the classification of the local soils. It is believed that the proposed changes to the Keys to Soil Taxonomy will contribute to a better differentiation of the landscape units in the field as well as permit better interpretations for landuse purposes.

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