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REPORT ON THE CLASSIFICATION EXERCISE OF SOME DEEP WELL DRAINED RED CLAY SOILS OF MOZAMBIQUE

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1. INTRODUCTION

Deep, well drained red clayey soils occupy a considerable part of the northern half of Mozambique and constitute one of the country's most important land reserves. Knowledge of their distribution and variation in properties is essential to guide future agricultural development.

Some of the soils belonging to this group have been described in different soil surveys, but no attempt has been made to study them systematically by correlating the existing information.

Classification of these soils in internationally known soil classification systems like the Soil Taxonomy (ST) and the FAO-Unesco Soil Map of the World Legend (FAO), is difficult because only limited analytical data are available, while the methodology employed is not always exactly the same as prescribed by these systems. Furthermore, special analyses like micromorphology, mineralogy, etc. cannot be realized.

The classification of the red soils in Mozambique and as well in other countries is further hampered by the fact that their characteristics do not correspond well with the central concepts of the diagnostic soil horizons as used in the ST and FAO systems. This applies especially to the definition of the argillic and oxic B horizon, resulting in uncertainty at the highest level of classification.

Twenty locations in northern Mozambique have been selected as reference soils, representative for large areas and covering a wide range in site characteristics, such as altitude, geology, landform and vegetation. Six profiles were selected from these 20 pedons for monolith preparation and additional research. All information is filed, to be used as a reference base. A comprehensive study of this reference base in respect of soil forming processes and factors, soil classification and soil evaluation for agricultural purposes is in preparation (1).

A number of expert soil scientists has been consulted to bring in more expertise in the classification of these soils. The results are presented in this paper.

2. METHODOLOGY

In September 1984 a comprehensive data set for six pedons was sent to an international group consisting of 20 soil experts. Each member was asked to classify the soils in the ST and FAO systems (2) (3).

A short characterization of the six pedons is given here but more data will be found in Annex 2. Pedons MOC 1 to MOC 4 comprise very deep, well drained, dark or dusky red clay soils; having a weak to clear A horizon; a thin, weakly structured to thick, moderately structured textural B horizon, all developed in or on top of a thick massive porous oxic B horizon. Pedon MOC 5 is a deep, well drained, dark reddish brown clay soil; having a thick A horizon, a strongly structured (textural) B horizon and no oxic B horizon. Pedon MOC 6 is a deep, well drained, yellowish red sandy clay, with a loamy sand topsoil; below 150 cm there is a strongly mottled slowly permeable subsoil. The pedon has a thin A horizon, a clear textural B horizon and no oxic B horizon.

The classification round especially aims at the morphologically rather uniform and similar pedons MOC 1 to MOC 4 with both textural and oxic B horizons. Pedons MOC 5 and MOC 6 were included as reference since they offered less problems in classification.

In May 1985 classification results of sixteen experts were available, some classified the soil in one system only. Most of the experts gave comments and observation on their classification.

In annex 1A and 1B results according to ST and FAO systems are given. The ranking number is referring to the expert and is arbitrarily given by the chronology of incoming letters.

3. RESULTS

3.1 Classification according to Soil Taxonomy (1975)

In tables 1A and 2A the results of Annex 1A have been presented according to the main taxonomic levels, i.e. order, suborder, great group and subgroup. The number in brackets refers to the number of experts with similar classification results; no number indicates a single result. A line of dots on the subgroup level refers to the case when no subgroup classification was given. For each pedon an average of 12 responses was obtained.

Classification results show a wide scattering, each pedon receiving 8 different names on the average.

Pedons MOC 1 to MOC 4

The variation in the classification of these pedons originates mainly from the first and fourth taxonomic steps, i.e. order and subgroup level.

The results of the first taxonomic step is showing the problematic decision whether to classify these pedons as Oxi-, Ulti-, or Alfisol. Table 2A shows the overall counts at order level. There is no clear preference visible in the results of pedons MOC 1, 2 and 3; only MOC 4 shows a clear dominance for Alfisols.

The second taxonomic step for all pedons has been executed in a very uniform way. Although only atmospheric climatic data were given the coining in the Ustic regime was not a problematic one. Also the great group level was uniformly classified except for few probably erroneous deviations.

On the fourth taxonomic step, i.e. the subgroup level a second scattering (variation) occurs.

Analysing the Oxisols population of MOC 1 to 4, the "restgroup" Haplustox was most frequently chosen. Only in two cases it ended as Eutrustox (probably caused by a wrong calculation of BS or by a confusion with the BS criteria of Euthrorthox). Typic was most frequently chosen followed by tropeptic and rhodic, the latter not defined in ST but yet given/proposed by the experts.

Tropeptic, referring to a pedal macrostructure, more strongly developed than weak, has been given especially to profile MOC 3. Although MOC 3 does not show so clear the apedal microgranular structure, the structure grade is still weak in the oxic B horizon and as such not really tropeptic.

The Ultisol population shows unanimously Paleustult. No subgroups are defined in ST for the Paleustults. However, half of the participants gave a subgroup classification, mostly oxic, followed by typic, rhodic and orthoxic.

The Alfisol population is showing most frequently Paleustalf. Only twice Rhodustalf was chosen, probably caused by an erroneous rejection of the 'Pale' depth and textural criteria. Subgroup classification for the

Paleustalfs shows equally rhodic, oxic or oxic/rhodic, the latter being the most complete characterization (i.e. no lime, BS < 75%, CEC < 24 me and a colour redder than 5YR).

Pedon MOC 5

This pedon is showing a scattering at all taxonomic levels. At order level there is a preference for the Mollisols, i.e. recognizing the mollic epipedon as main diagnostic horizon. The second and third taxonomy steps were uniformly executed and resulted in Argiustoll.

At subgroup level a clear preference was given to udic as no free calcium carbonate horizon is present in the profile; nevertheless, twice this criterion was not recognized and the pedon was placed as typic.

In a few cases the allocation of pedon MOC 5 in the Mollisol category was rejected and the soil was classified as Alfisol, probably because of the lack of a horizon containing free calcium carbonates. Here the pedon was only in one case classified as Xeralf, the two other cases in the Ustalf. The latter resulted in Rhodic Paleustalf and Typic Rhodustalf. This variation is probably caused by the profile description being not clear whether the CB horizon should be considered as a paralithic contact.

Pedon MOC 6

Because of absence of confusing combinations of diagnostic horizons, this pedon was the easiest to classify at order level, as Alfisol. Only in one case the pedon was allocated to the Mollisols, probably because it was not recognized that the depth and the base saturation did not meet the criteria of the Mollic.

In the Alfisol population scattering originates at the third and fourth taxonomic levels. At great group level the pedon was most frequently allocated in the Paleustalf category followed by Haplustalf and in one case Rhodustalf. At subgroup level the most frequent classification are Oxic and Arenic Oxic, referring to the thick sandy loam epipedon and the low CEC. Probably erroneously, twice the allocation resulted in the Ultic and Typic subgroups.

Table 1A - Classification of 6 Mozambican pedons according to Soil Taxonomy (1975), executed by an international panel

Pedon nr.	Order	Suborder	Great Group	Subgroup
A2/MOC 1	Oxisol	Ustox	Haplustox	Typic (4)
				Rhodic
				Tropeptic
	Ultisol	Ustult	Paleustult	Oxic (2)
				...... (2)
	Alfisol	Ustalf	Paleustalf	Rhodic (2)
				Oxic
L1/MOC 2	Oxisol	Ustox	Haplustox	Typic (2)
				Acric Rhodic
	Ultisol	Ustult	Paleustult	Typic
				Rhodic Orthoxic
				Oxic
				...... (2)
	Alfisol	Ustalf	Paleustalf	Rhodic
				Oxic (2)
				Rhodic Oxic
	Inceptisol	Tropept	Dystropept	Ustoxic
L2/MOC 3	Oxisol	Ustox	Eutrustox	Typic
			Haplustox	Typic
				Tropeptic (3)
	Ultisol	Ustult	Paleustult	Oxic (2)
				Rhodic Oxic (2)
				...... (2)
	Alfisol	Ustalf	Paleustalf	Oxic (2)
			Rhodustalf	......
C1/MOC 4	Oxisol	Ustox	Eutrustox	Typic
	Ultisol	Ustult	Paleustult	Typic
				......
	Alfisol	Ustalf	Paleustalf	Rhodic
				Oxic Rhodic (2)
				Oxic (2)
				Ultic
				...... (2)
			Rhodustalf	Oxic
	Mollisol	Ustoll	Paleustoll	Udic
N2/MOC 5	Mollisol	Ustoll	Argiustoll	Typic (2)
				Udic (6)
				Pachic Vertic
	Alfisol	Ustalf	Paleustalf	Rhodic
			Rhodustalf	Typic
			Haplustalf	Udic
		Xeralf	Haploxeralf	....
N3/MOC 6	Alfisol	Ustalf	Paleustalf	Oxic (4)
				Arenic Oxic (3)
				......
			Rhodustalf	Typic
			Haplustalf	Arenic Oxic
				Ultic
	Mollisol	Ustoll	Paleustoll	Typic

Table 1B - Classification of 6 Mozambican profiles according to the FAO system (1974), executed by an international panel

MOC 1	Ferralsol	rhodic (3)
		orthic
		acrirhodic
	Nitosol	- eutric (2)
	Acrisol	- ferric (3)
MOC 2	Ferralsol	acrirhodic (2)
		rhodic
	Nitosol	dystric
		eutric
	Acrisol	- ferric (3)
	Luvisol	- ferric
	Cambisol	- ferralic
MOC 3	Ferralsol	- rhodic (4)
	Nitosol	dystric (2)
		eutric
	Acrisol	- ferric (3)
MOC 4	Ferralsol	....
		rhodic
	Phaeozem	- luvic (4)
	Nitosol	- humic
	Acrisol	ferric (2)
		humic ferric
		humic
MOC 5	Chernozem	- luvic
	Phaeozem	- luvic (5)
	Luvisol	chromic (2)
		vertic
MOC 6	Arenosol	- cambic
	Acrisol	- ferric (3)
	Luvisol	- ferric (5)

Table 2 A - Overview of first order classification according to the ST system

Pedon	Oxisol	Ultisol	Alfisol	Mollisol	Inceptisol
MOC 1	6	4	3		
MOC 2	3	5	4		1
MOC 3	5	6	3		
MOC 4	1	2	9	1	
MOC 5			4	9	
MOC 6	—	—	11	1	—
sub-total					
MOC 1-4	15	17	19	1	1
(in %)	29	33	37	4	

Table 2B - Overview of "first taxonomic level" classification according to the FAO system

Pedon	Ferral-	Acri-	Nito-	Phaeo.	Luvi-	Areno-	Cherno.	Cambisol
MOC 1	5	3	2					
MOC 2	3	3	2		1			1
MOC 3	4	3	3					
MOC 4	2	4	1	4				
MOC 5				5	3		1	
MOC 6	—	3	—	—	5	1	—	—
subtotal								
MOC 1-4	14	13	8	4	1			1
(in %)	35	33	20	8	5			

3.2 FAO Classification

In tables 1B and 2B results have been presented according to the first and second 'taxonomic' levels, although strictly speaking it is a mono categorical system with 106 units which for logical presentation are organized in 26 groups (FAO, 1974).

For every pedon on the average 10 responses were obtained. Classification results show a wide scattering, each pedon got on the average 5 different names. This scattering originates mainly at the first 'taxonomic' level and only partly at the second.

Pedons MOC 1 to MOC 4

Table 2B shows the overall counts at the first taxonomic level. The variation in results of the first taxonomic step is showing the problematic decision whether to classify these pedons as Ferralsol or non-Ferralsol (i.e. Acri-, Nito-, Luvi-, Phaeo-, or Cambisol). There is no clear preference visible in the results of pedons MOC 1 to 4, however most frequently they were allocated to Ferralsol and Acrisol. The overall allocation percentages for Ferralsol, Acrisol and other categories are 35, 33 and 33% respectively.

Comparing overall allocation percentages of Oxisols versus Ferralsols, 29% for Oxisols to 35% for Ferralsols, a difference which is probably caused by a stricter definition for the Oxisol in the ST key, i.e. "have an oxic horizon, and do not have an argillic horizon that overlies the Oxic horizon". In the FAO key this is not explicitly mentioned and as such a Ferralsol may have an argillic overlying an Oxic horizon.

Analyzing the Ferralsol population of MOC 1 to 4, the rhodic category was most frequently chosen followed by Acri-rhodic, while orthic was only once allocated, probably by an erroneous rejection of the 'rhodic' colour criterion.

The Acrisol population shows quite unanimously the ferric category, only twice humic was allocated due to the darker coloured A horizon in MOC 4.

In the Nitosol population the eutric and dystric categories are most frequently allocated, while humic is only once found. Difference in base saturation calculation, which will be discussed later, are at the base of this variation.

The Luvic Phaeozem category was three times allocated to pedon MOC 4. Ferric Luvisol and ferralic Cambisol were only once allocated to pedon MOC 2.

Pedon MOC 5

This pedon was most frequently allocated as Luvic Phaeozem and if the Mollic A epipedon was rejected, it came out as ferric Luvisol. Only once the pedon was allocated as Chernozem due to the interpretation of the high pH that free calcium carbonate would be present.

Pedon MOC 6

This pedon was most frequently allocated as ferric Luvisol and due to differences in base saturation calculations, it came also out as ferric Acrisol.

Due to the rather sandy texture of the first half metre and the absence of macromorphological visible cutans the pedon was once placed as cambic Arenosol.

4. DISCUSSION

4.1 Argillic and Oxic Horizons

The argillic horizon

The identification of eluvial and illuvial horizons is problematic. A substantial textural difference between topsoil and Bt is present in pedons 1 to 4. It is a clay increase which fulfils the textural requirement of an argillic horizon (AH). However, a clear eluvial horizon, with an abrupt or clear transition towards an illuvial does not exist.

Sheet wash (a very slow process of truncation) is probably the main cause of the textural differentiation. However, even considering lateral clay transport, the occurrence of vertical movement of some clay into the profile is likely as well.

The identification of cutans in the field is a very subjective action. The low correlation between macro- and micromorphology observations - as reported in the literature - is also found in the studied Mozambican pedons.

The upper boundary of the illuvial horizon is set in the profile description at the lower boundary of an A horizon, factually a colour criterion.

The lower boundary of the illuvial horizon is set in the profile description at an objectively observable gradual structure/consistency change towards an oxic B horizon.

In table 3 a summary of properties is given, identifying the argillic horizon. The brackets ( ) in this table are indicating a disputable property classification; in the column of micromorphology it refers to the presence of argillans not enough to fulfill the requirements for an argillic horizon.

Table 3 - Summary of properties diagnostic for an argillic horizon (AH)

	Clay % diff. in top-subsoil	Struc./cons. difference in subsoil	Approx. thickness of the AH (cm)	Cutans			Presence of AH according to ST
				macro	micro	loc.	
MOC 1	22	+	40	(+)	(+)	top Bt	(+)
2	23	+	40	(+)	+	Bt	+
3	32	(+)	80	+	(+)	A+top Bt	(+)
4	34/40	+	95	(+)	+	A,Bt,Bws	+
5	36	-	50?	+	(+)	top B	(+)
6	32/46	-	110	-	+	Bt	+

loc. = location

In the very deep highly weathered pedons MOC 1 to 4 the assumed argillic horizon is deviating from the central concept of an AH in that:
- there is no clear eluvial (E) horizon;
- the upper boundary of the illuvial (Bt) horizon is set at the gradual transition between A and B horizon - based on a colour criterion; however, the textural difference between the A horizon and illuvial horizon is large;
- the illuvial horizon is relatively thin and occuring in the upper part of the subsoil; macro visibility of clay cutans is disputable; micro identification of cutans is in all profiles positive, quantities are variable and only partly fulfilling the requirements of an argillic horizon;
- the lower boundary of the illuvial horizon is mostly set at a gradual or diffuse consistency/structure boundary separating the relatively thin illuvial horizon from a very thick oxic B horizon;
- textural difference between illuvial and the underlying horizon is mostly nil or the decrease is small.

The Oxic horizon

The identification of the oxic horizon for profiles MOC 1 to 4 is relatively easy, due to presence of all typical morphological and analytical properties, diagnostic for the oxic horizon, i.e.:
- very deep solum (4 or more meters)
- vague horizonation and gradual to diffuse boundaries
- (very) weak subangular blocky and/or massive porous structure
- CEC 7 $<$ 16 and ECEC $<$ 10 me/100g clay
- frequently a low negative or positive delta pH value
- very low weatherable mineral content
- absence of argillans

4.2 Summary of diagnostic horizons and properties

In table 4 an overview is given of the diagnostic horizons and properties necessary for classification.

Structure in B horizon

Structure grade is important for the "tropeptic" category. In table 4 the following codes are used: w (weak); m (moderate); s (strong); mp stands for an apedal massive porous structure.

Mollic A horizon

According to definition and criteria in ST and FAO.

Argillic B horizon - See paragraph 4.1

Oxic B horizon - See paragraph 4.1

Base saturation

Base saturation is heavily depending on the analytical method chosen for the determination of the Cation Exchange Capacity and/or the Exchangeable Acidity. Also the depth at which the BS should be calculated is important. For an overview on analytical procedures to determine exchange properties one is referred to Annex 3.

Colour

Determination according to standard Soil Color Charts.

Table 4 - Diagnostic horizons and -properties in Pedons MOC 1 to 6

				structure in		BS (%)[1]			colour
	Mol. A	Argil. B	Oxic B	Arg. B	Oxic B	top	sub[2]	sub[3]	subsoil
MOC 1	-	(+)	+	w/m	mp	38	18	28	2.5YR3-4/6
MOC 2	-	+	+	w	mp	17	16	14	1.5YR3/6
MOC 3	-	(+)	+	m	w	35	40	28	1.25YR3/5
MOC 4	+/-	+	+	w/m	mp	52	42	44	10R 3/5
MOC 5	+	(+)	-	s	.	72	75	53	2.5YR3/4-5
MOC 6	-	+	-	mp	.	50	37	46	5YR4/6

[1] BS (= base saturation) calculated on CEC (NH_4OAc, pH 7) in

[2] "at least some part of the B horizon within 125 cm" (FAO);

[3] BS calculated as "sum of cations pH 8.2" as follows:

BS "sum of cations" = 0.7 x BS "NH_4OAc", at a depth of about 180 cm.

4.3 Trouble points and classification pathways

In this paragraph the 'trouble points' which are causing the variation in the classification will be given. The assumptions, interpretations, observations, doubts and notes which were given by several of the experts are of great help for this listing. With regards to their source, trouble points are originating from the pedon data, or from the definition of diagnostic horizons and properties, or from the classification procedures itself.

Pedon data

Incompleteness, vagueness, etc. in the data set was in a few cases the cause of difficulties. In the environmental data set the lacking of soil temperature has been frequently stated. However, this is a normal situation in many countries

In the profile morphology data set it is the lack of dry/crushed soil colours and the consistency when dry (pedon MOC 4); which are criteria in the mollic definition.

In the analytical data set the following incompletenesses are noted:

- missing of $CaCO_3$ data in pedon MOC 5, while pH is slightly above 7; in one case presence of $CaCO_3$ was assumed which classifies then as Chernozem;
- confusion in textural analysis of topsoil of MOC 6; lab data indicate sandy loam, while field description gives loamy sand, the latter positively for 'arenic' subgroup (ST).
- twice giving clay percentage in the topsoil was disputed, with the arguments: incomplete dispersion, and presence of 'pseudo silt'.
  For the data given, pipette textural analysis is done on H_2O_2 pretreated samples, which are shaked overnight with dispersion agent. Repetition of the textural analyses for all topsoils samples after deferration gives for pedons MOC 1 to 3 an increase of between 5-10% (absolute).
  The presence of 'pseudo' silt and fine sand has been checked microscopically on all fractions resulting from the textural analyses with magnification of about 50X.
  Deviating parts in the depth/clay diagram are originating from pseudo silt forms (e.g. the 'negative' bulge in MOC 2).

n.b.: Although clay percentage may increase after deferration, textural differences between top and subsoil still fulfill the requirements.

- One remark was made about the sand fraction on which mineral counting has been realized. Required is the 20-200μ fraction however for practical reason the 50-500 fraction has been used.
- Incomplete horizon sampling (especially of MOC 1) was disputed because it may hamper the construction of clay% X depth diagrams. Certainly this incomplete slicing is incorrect, but it is mainly restricted to the very deep homogenous subsoil.
- Generally the information on analytical procedures was found to be insufficient.

As regards the micromorphology data set remarks were made on the information related to clay illuviation features, being not always sufficiently quantitatively expressed. It appears that one uses phrases such as 'some isolated clay illuviation features', pro or contra the presence of an argillic horizon.

Diagnostic horizons and properties

Base saturation

Base saturation (BS) is a criterion required in many definitions like the mollic horizon, Ulti-Alfisols and many other categories.
The BS value depends on the CEC method chosen and on the depth at which this value is calculated, see Annex 3 for an overview.
In only some cases the procedure for BS calculation was explicitly stated:

- the use of a BS limit of 50% based on CEC (pH 7, NH_4OAc) to distinguish Alfi- and Ultisols; while ST requires "base saturation by sum of cations of 35%", i.e. based on a calculated CEC (pH 8.2);
- the use of BS derived from unbuffered CEC (=ECEC), because of variable charge character of most pedons;
- the use of the assumed correlation between BS of 35% (pH 8.2, 'sum of cations') = BS of 50% (pH 7, NH_4OAc).

Often the analytical method to determine the BS was not mentioned; in many cases, information on the depth was also lacking. However, it appears from the results of the classification that an important part of the variation is caused by different BS determinations.

The CEC procedure (sum of bases and exchangeable acidity buffered at pH 7) actually in use in the National Soils Laboratory of Mozambique, results in much higher BS values than derived from the standard NH_4OAc procedure of ST. Consequently soils are often classified as Alfi- or Luvisols while they should come out as Ulti- or Acrisol, according to ST or FAO procedures. This will be further discussed in the study of red clayey soils of Mozambique (1).

Argillic and Oxic horizons

The combination of characteristics diagnostic both for the argillic and the oxic horizon is another main trouble point.

Due to the conventional 'mutual exclusivity' of those horizons one is forced to make a choice, although both horizons are present. The identification of a very thick oxic horizon in pedons MOC 1 to 4 is relatively easy due to the presence of all diagnostic properties.

The identification of an argillic horizon overlying the oxic horizon is problematic. As discussed in paragraph 4.1, pedons MOC 1 to 4 are showing a gamma of argillic horizons. From thin (about 40 cm) and weakly developed towards thick (about 100 cm) and more clearly developed.

This difficulty was frequently expressed, below some statements:

- "difficult because of intergrading characteristics";
- "some of the characteristics do not match well with the definitions agreed upon both in FAO Legend and ST";
- "in the field unworkable classification";
- "field morphology is pointing to an argillic horizon while micromorphology is indicating to an oxic";
- "as soon as macro cutans are described it is an argillic horizon, irrespective of micro analyses".

  Insufficiently quantified micro clay illuviation features were used pro or contra the argillic or oxic horizon; even the micro analyses statement "clay illuviation features not enough for the requirements of a AH" is sometimes waived because of other evidences pointing to an argillic (i.e. large textural differentiation, high water dispersable clay content, the large faunal activity destroying the cutans, etc..

- the case of superficial colluvial processes resulting in a coarser textured topsoil was mentioned, especially pedon MOC 6. As indicated before, sheetwash is probably one of the reasons of textural differentiation in all pedons;
- "in many aspect an oxic but intergrading towards an argillic horizon";
- "in all aspects oxic except for the weatherable mineral content and "I assume you have a mineral count error" (MOC 2);
- corrobative properties used for the oxic horizon are: low or negative delta pH values, weak structure and low silt/clay ratio;
- "rejuvenated oxisol due to airborne new material" (MOC 1);
- "the lack of water dispersable clay below 15 cm, the relative high amount of muscovite (more than 6%) and the fairly uniform textural profile, make me classify this soil (MOC 2) into the Inceptisols".

Mollic horizon

Difficulties related to missing information and the base saturation have been mentioned above.

The organic matter content of 1% as lower limit has been recognized as too low, resulting in the identification of a mollic horizon where it is considered not to be corresponding with the underlying central concept. Twice pedon MOC 4 was mentioned as having a mollic horizon, but according to ST it is not a Mollisol due to BS subsoil less than 50%, while in FAO it comes out as Phaeozem (Luvic) because there low subsoil BS values are implicitly allowed (by oversight).

Classification procedures

The classification procedure, referring to the 'keying' procedure or classification pathway, can be problematic due to a combination of diagnostic horizons or properties which are not foreseen in the systems. The use of classification keys in a rigid (automatic) or more flexible way is often disputed among pedologists.

Also interpretation or checking afterwards of the outcome viz. "own central concepts" may result in difficulties. However, remarks on the procedures were mostly given in a general way by the experts.

Below the procedural aspects will be discussed with the FAO system as an example. The possible combinations of diagnostic horizons and properties are listed in table 5, the sequence is taken in accordance with the key of the FAO system.

Table 5 - Possible classification pathways, according to FAO system

Pathway	Presence of diagnostic horizons			classification
	oxic	mollic	argillic	result
1	-	-	-	Cambisol
2	-	-	+	Nito/Acri/Luvisol (pedon MOC 6)
3	-	+	-	Phaeozem
4	-	*+	+	Phaeozem (MOC 5)
5	+	-	-	Ferralsol
6	+	-	+	Nito/Acri/Luvisol or Ferralsol (MOC 1, 2, 3)
7	+	+	-	Ferralsol
8	+	+	+	Ferralsol, Nito/Acri/Luvisol or Phaeozem? (MOC 4)

* the argillic horizon overlies the oxic

Nito-, Acri- and Luvisol pathways

pathway	decrease of clay%	plinthite		ferric		BS% [1]	
a.	< 20	-		-	**Nitosol**		
b.	< 20	+	and/or	+	)	e. < 50	**Acrisol**
c.	> 20	-		-	) no Nitosol	f. < 50	**Acrisol**
d.	> 20	+	and/or	+	)		

1) BS = Base saturation

Some remarks on classification pathways:

ad 6) For pedons MOC 1 to 4 the combination of an argillic and an oxic horizon is a main trouble point. Roughly one third of the classification results are Ferralsols (Oxisols) while 2/3 comes out as non-Ferralsol.

The conventional choice between the two diagnostic horizon is a difficult one as both are important. Some possible reasons for a particular choice are given:

Or prevalence for the argillic B as diagnostic horizon because of:

- classification rule (FAO, 1974, p. 32): "when two or more B horizon occur within 135 cm of the surface, it is the upper B horizon which is determining for the classification."
- rejection of the presence of an oxic B (FAO, 1974, p. 27): "the oxic B horizon is a horizon that is not argillic"

Or prevalence for the oxic B as diagnostic horizon because:

- in the FAO key the use of an oxic horizon 'keys' out earlier than the argillic horizon.
- the argillic B is rejected being relatively too thin in comparison to the oxic B, or too weakly developed, or disputable, viz. central concepts of the argillic horizon.

ad 7) Mollic Ferralsol is not defined

ad 8) - For the choice between oxic or argillic horizon, see ad 6)
- Phaeozem is disputable by definition because Phaeozems should lack an oxic B
- Presence of a mollic in Nito/Acri/Luvisol is excluded by definition

ad a) Twice the lack of a strong (sub)angular blocky structure and clear shiny ped faces in pedons MOC 1 to 4 - when classified as Nitosols - was mentioned. This refers to the original central concept underlying the Nitosols, however these characteristics are not included in the definition.

The rigid application of the few criteria given in the definition of the Nitosols.

The lack of significant diagnostic criteria for the Nitosols has been discussed by Sombroek and Siderius (4).

Generally the structure grade and form is used as checking element for "younger" soils (tropeptic).

General comments

The experts have to rely on the information given without the field contact. This appeared to be not a serious problem as this was only once mentioned. In fact, the pedons were recognized by many experts as "very similar to widespread soils in other countries with similar classification problems, particularly in regard to argillic horizon identification".

Countries mentioned are Australia, Brazil, India and Kenya. One cannot deny that the conventional profile morphology description has still subjective aspects, but this experiment was not designed for testing. It is assumed that this subjectivity will not substantially influence this communal classification experiment, as this assumption is in fact also taken into account for the existing classification systems.

Although profiles have been described twice, with carefully attention by two pedologists, an unknown portion of the variation may be attributed to this phenomenon.

4.4 Kandic horizon

The trouble points for classification with regard to the argillic horizon and to the combination of both argillic and oxic horizon, which have been discussed before are subject of investigation of the international ST committees ICOMLAC and ICOMOX.

The International Committee on Classification of Alfisols and Ultisols with low activity clays (ICOMLAC) was organized in 1975 by the Soil Conservation Service, USDA.

Without being complete a great part of the discussions and the outcoming results of this committee can be found in Isbell (1980) and Moormann and Buol (1981). Below the essentials are given.

The problem of the controversial 'mutual exclusivity' of oxic and argillic horizon has been solved with the introduction of the kandic horizon. The kandic horizon can be considered as a low activity clay containing textural horizon, combining as such 'oxic' and 'argillic' properties, however it differs from 'oxic' and 'argillic' in the following:

- the kandic horizon has an ECEC of less than 12 me per 100 g clay and or a CEC(7) of less than 16 me per 100 g clay.
- the increase of clay percentage (more or less similar to the argillic horizons) must be reached within a vertical distance of 15 cm or less.

Central in the proposed amendments for ST is the introduction of the kandic horizon at the great group level of Alfisols and Ultisols.

Irrespective of having a kandic horizon LAC Alfisols and Ultisols are distinguished from Oxisols by a textural limit, i.e. when a topsoil of 18 cm contains more than 40% clay it is allocated to the Oxisols. This is a rather arbitrarely criterion which may cause that e.g. many Nitosols of the FAO Legend will be classified in the Oxisol order.

5. CONCLUSIONS

The results of classification of a group of experienced soil scientists on some deep, well drained red clayey 'upland' soils of Mozambique show a large variation.

Classification according to ST and FAO systems for the given profiles is still an ambiguous activity. The variation in the results show an acute first order taxonomic problem. Main causes of this variation are the assumed mutual exclusivity of the argillic and oxic horizons by convention and secondly the very confusing situation in the application of cations exchange properties. The argillic and oxic horizons are not mutual exclusive in LAC soils. Argillic horizons may develop on top of or in an oxic horizon.

The newly developed kandic horizon concept seems to be a promising pragmatic solution, which will overcome a part of the problem in respect of the conflicting presence of both argillic and oxic horizons.

The procedures to determine cation exchange properties and derived parameters like base saturation percentage should be reduced to an unambiguous standardized procedure.

ACKNOWLEDGEMENT

This classification experiment entirely depended on the participation of soil scientists with experience in tropical soils. I am greatly indebted to the group of experts who contributed in a very cooperative way.

I should like to express my appreciation for the assistance received from the International Soil Reference and Information Centre (ISRIC), which contributed to this experiment by preparing the monoliths and completing the sample analyses. The stimulating role of director Dr. W.G. Sombroek should be especially mentioned.

LITERATURE

(1) Deep, well drained red clayey soils of Mozambique.
J.H. Kauffman (in prep.)

(2) Soil Taxonomy, 1975. SCS-USDA Agriculture Handbook no. 436

(3) FAO-Unesco Soil map of the World, 1974. Volume I - Legend.

(4) Nitosols, a quest for significant diagnostic criteria.
W.G. Sombroek and W. Siderius. In: Annual Report ISM 1981.

(5) The Kandic horizon as a diagnostic subsurface horizon.
Proc. 4th Intern. Soil Classification Workshop, Rwanda 1981.

(6) Genesis and classification of low activity clay Alfisols and Ultisols: a selective review p. 397-410. In: B.K.G. Theng (et al.) Soils with variable charge. New Zealand Soc. Soil Science Publications.

Annex 1A - Classification of 6 Mozambican profiles according to the Soil Taxonomy (1975) system, executed by an international panel

	A2 MOC1	L1 MOC2	L2 MOC3	C1 MOC4	N2 MOC5	N3 MOC6
1	Paleustult	Paleustult	Paleustult	Paleustalf	Udic Argiustoll	Oxic Paleustalf
2	Oxic Paleustult	Ustoxic Dystropept	Oxic Paleustult	Oxic Rhodic Paleustalf	Udic Argiustoll	Oxic Paleustalf
3	Rhodic Haplustox	Acric / Rhodic Haplustox	Tropeptic Haplustox	--	Rhodic Paleustalf	--
4	Oxic Paleustult	Oxic Paleustult	Oxic Rhodustalf	Oxic Rhodustalf	Udic Argiustoll	Arenic / Oxic Haplustalf
5	Typic Haplustox	Rhodic Paleustalf	Typic Haplustox	Rhodic Paleustalf	Udic Rhodustalf	Oxic Paleustalf
6	--	Typic Paleustult	Paleustult	Paleustalf	Udic Argiustoll	Ultic Haplustalf
7	(Typic) Haplustox	(Rhodic) (Orthoxic) Paleustult	Rhodic Oxic Paleustult	Rhodic Oxic Paleustalf	Typic Argiustoll	Arenic oxic Paleustalf
8	Tropeptic Haplustox	Typic Haplustox	Tropeptic Haplustox	Typic Paleustult	Typic Argiustoll	Typic Paleustoll
9	Paleustult	Paleustult	Paleustalf	Paleustult	Haploxeralf	Paleustalf
10	Rhodic Paleustalf	Oxic Paleustalf	Typic Eutrustox	Typic Eutrustox	Typic Rhodustalf	Typic Rhodustalf
12	Typic Haplustox	--	Tropeptic Haplustox	Ultic Paleustalf	--	--
14	Oxic Paleustalf	Oxic Paleustalf	Oxic Paleustalf	Oxic Paleustalf	Udic Haplustalf	Arenic Oxic Paleustalf
15	Rhodic Oxic Paleustalf	Rhodic Oxic Paleustalf	Rhodic Oxic Paleustalf	Udic Paleustoll	Pachic Vertic Argiustoll	Arenic Oxic Paleustalf
16	Typic Haplustox	Typic Haplustox	Oxic Paleustult	Oxic Paleustalf	Udic Argiustoll	Oxic Paleustalf

Annex 1B - Classification of 6 Mozambican profiles according to the FAO-Unesco Soil Map of the World legend (1974), executed by an international panel

	A2 MOC1	L1 MOC2	L2 MOC3	C1 MOC4	N2 MOC5	N3 MOC6
2	Rhodic Ferralsol	Rhodic Ferralsol	Rhodic Ferralsol	Ferralsol or Humic Acrisol	Chromic Luvisol	Cambic Arenosol
3	Ferric Acrisol	Ferralic Cambisol	Ferric Acrisol	Humic Acrisol	Luvic Phaeozem	Ferric Luvisol
4	Ferric Acrisol	Ferric Acrisol	Ferric Acrisol (Nitosol)	Ferric Acrisol	Luvic Phaeozem	Ferric Acrisol
7	--	--	--	Luvic Phaeozem	--	--
9	Ferric Acrisol	Dystric Nitosol	Ferric Acrisol	Ferric Acrisol	Vertic Luvisol	Ferric Acrisol
10	Eutric Nitosol	Ferric Luvisol	Rhodic Ferralsol	Rhodic Ferralsol	Chromic Luvisol	Chromic Luvisol
11	Acri Rhodic Ferralsol	Acri-Rhodic Ferralsol	Dystric Nitosol	Luvic Phaeozem (ferric Luvisol)	Luvic Phaeozem	Ferric Luvisol
12	Rhodic Ferralsol	Ferric Acrisol	Rhodic Ferralsol	Humic ferric Acrisol	--	--
13	Orthic Ferralsol	Ferric Acrisol	Rhodic Ferralsol	Luvic Phaeozem	Luvic Phaeozem	Ferric Luvisol
15	Eutric Nitosol	Eutric Nitosol	Eutric Nitosol	Luvic Phaeozem	Luvic Chernozem	Ferric Luvisol
20	Rhodic Ferralsol	Rhodic Ferralsol	Dystric Nitosol (Rhodic Ferralsol)	Humic Nitosol (Luvic Phaeozem)	Luvic Phaeozem	Ferric Acrisol

KEY FOR INTERPRETING SOIL PROFILE DESCRIPTIONS

Annex 2

PROFILE : number or code

Date of examination : (season)

Authors :

Higher category classification

- (FAO-UNESCO 1974)
- (Soil Taxonomy 1975)

Environmental information

Location : country, province, district, village/town nearby

Coordinates : S, N

Elevation : m

Landform : general physiography, overall sloperange; land elements

Slope of site : type, shape, length, position of pit

Vegetation : descriptive (for species classification see anex)

Land use : permanency, size+tecnology, main crop(s)

Climate : unimodal, P annual, Ep annual, lenght of dry season, leaching rainfall= $\Sigma(P-Ep)$ (see anex for more details)

General information on the soil

Parent material : general information or rock type (see anex for mineralogy)

Drainage conditions : drainage class SSM

Moisture conditions : dry/moist/wet + depth

Ground water level : depth cm (also indicates perched ground water table, temporarely saturation e

Termitaria : form, size, density

Surface characteristics: sheet wash planes, rill/gully erosion

Miscellaneous

Local soil name : (language name)

Brief description of the profile

always mention depth (of solum =A+B or effective soil depth)
drainage class (SSM)
colour (subsoil)
texture (subsoil)

additionally structure grade(shallow subsoil and the deeper subsoil)
porosity
thickness of a dark topsoil
....
....

KEY FOR INTERPRETING SOIL PROFILE DESCRIPTIONS

HORIZON CODE according guidelines FAO with additionally:

Bt = increase of clay percentage with depth (argillic horizon)
Bt' = weakly structured Bt horizon
Bt" = moderately structured
Bt"' = strongly structured
Btg = Bt with gleying
Bws = porous massive horizon (oxic horizon)
BC = transition horizon

BOUNDARY		TOPOGRAPHY	
a	abrupt	s	smooth
c	clear	w	wavy
g	gradual	i	irregular
d	diffuse	b	broken

COLOUR without indication is moist soil

D dry soil
W wet soil

TEXTURE

S	sand	LS	loamy sand
L	loam	SL	sandy loam
Si	silt	SCL	sandy clay loam
C	clay	SC	sandy clay

sgr = slightly gravelly

PEDAL STRUCTURE

GRADE		SIZE		TYPE	
w	weak	vf	very fine	gr	granular
m	moderate	f	fine	cr	crumb
s	strong	m	medium	ab	angular blocky
		c	coarse	sb	subangular blocky
				pl	platy

APEDAL STRUCTURE

TYPE		COHERENT	
sg	single grain	nc	non coherent
mp	massive porous	wc	weakly coherent
		mc	moderately coherent
		sc	strongly coherent

CONSISTENCY

DRY		MOIST		WET			
dl	loose	ml	loose	ns	non sticky	np	non plastic
s	soft	vfr	very friable	ss	slightly sticky	sp	slightly plastic
sh	slightly hard	fr	friable	s	sticky	p	plastic
h	hard	fi	firm	vs	very sticky	vp	very plastic
vh	very hard	vfi	very firm				
eh	extremely hard	efi	extremely firm				

CUTANS

QUANTITY		VISIBILITY		TYPE	
p	patchy	f	faint	C	clay
b	broken	d	distinct	ir	iron
c	continuous	p	prominent		

POROSITY

QUANTITY		SIZE	
f	few	vf	very fine
c	common	f	fine
m	many	m	medium
vm	very many	c	coarse
a	abundant	vc	very coarse

ROOTS

QUANTITY		SIZE	
f	few	vf	very fine
c	common	f	fine
m	many	m	medium
		c	coarse

MOTTLING

ABUNDANCE		SIZE		CONTRAST		COLOUR
f	few	f	fine	f	faint	in general Munsell notation
c	common	m	medium	d	distinct	
m	many	c	coarse	p	prominent	

NODULES

QUANTITY		SIZE		HARDNESS		SHAPE		TYPE	
vf	very few	s	small	s	soft	s	spherical	ir	iron
f	few	m	medium	h	hard	a	angular	C	clay
fr	frequent	l	large			i	irregular	Mn	manganese
vfr	very frequent								
do	dominant								

/ = to; + = and; . = not described; - = not present

1	= profile number	
2	= sample number	
BEG	= begin sampling depth	
END	= end sampling depth	cm
AVE	= average sampling depth	
CS1	= coarse sand (1000-2000μ)	
CS2	= coarse sand (500-1000μ)	
CS3	= coarse sand (250-500μ)	
FS1	= fine sand (100-250μ)	
FS2	= fine sand (50-100μ)	%
SI1	= coarse silt (20-50μ)	
SI2	= fine silt (2-20μ)	
AG	= clay (<2μ)	
DISP	= water dispersable clay	
H20	= pH-H20	
KCl	= pH-KCl	
H+Al	= exchangeable acidity, unbuffered	me/100g
Al	= exchangeable aluminium, unbuffered	
C	= organic carbon	%
N	= nitrogen	
C/N	= organic carbon/nitrogen quotient	
Ca	= exchangeable calcium	
Mg	= exchangeable magnesium	
K	= exchangeable potassium	me/100g
Na	= exchangeable sodium	
EC	= electrical conductivity	mS/cm
Si/AG	= silt%/Clay%	
DIFPH	= pH(H2O) - pH(KCl)	
ECEC	= sum of cations + exchangeable acidity (H+Al) unbuffered	me/100g
CEC	= cation exchange capacity, pH7 buffered	

PROFILE: A 2 (MOC-1)

Date of examination: 16 October 1982 (end of dry season)
Author : J.H. Kauffman

Higher category classification

- (FAO-UNESCO, 1974)
- (Soil Taxonomy, 1975)

Environmental information

Location : Mozambique, Tete, Angonia, south of Calomué
Coordinates : 14°27' S, 34°22' E
Elevation : 1480 m
Landform : plateau, weakly undulating; smooth interfluves and "dambo's", few bare rock inselbergs
Slope of site: uniform, weakly convex; gradient 2-3%, length > 400 m, upper slope position (see annex)
Vegetation : "Miombo" woodland, recently strongly cut for fuelwood
Land use : shifting cultivation, small farmer, maize
Climate : Unimodal, P = 930, Ep = 1435, 6 months dry season, L.R. = 290 mm ± 300 mm (see annex)

General information on the soil

Parent material : Basement complex; probably felsic to intermediate gneiss
Drainage conditions : well drained
Moisture conditions : 0-200 cm dry, > 200 cm moist
Ground water level : no evidence within 400 cm
Termitaria : dome-shaped mounds, medium, 1 ≤ ha
Surface characteristics: smooth planes indicate superficial lateral flow of water

Miscellaneous

Local soil name : Katonde (Chinhandje/Chichewa)

Brief description of the profile

Very deep, well drained dark red clay soil; weakly to moderately structured up to 62 cm than massive porous.

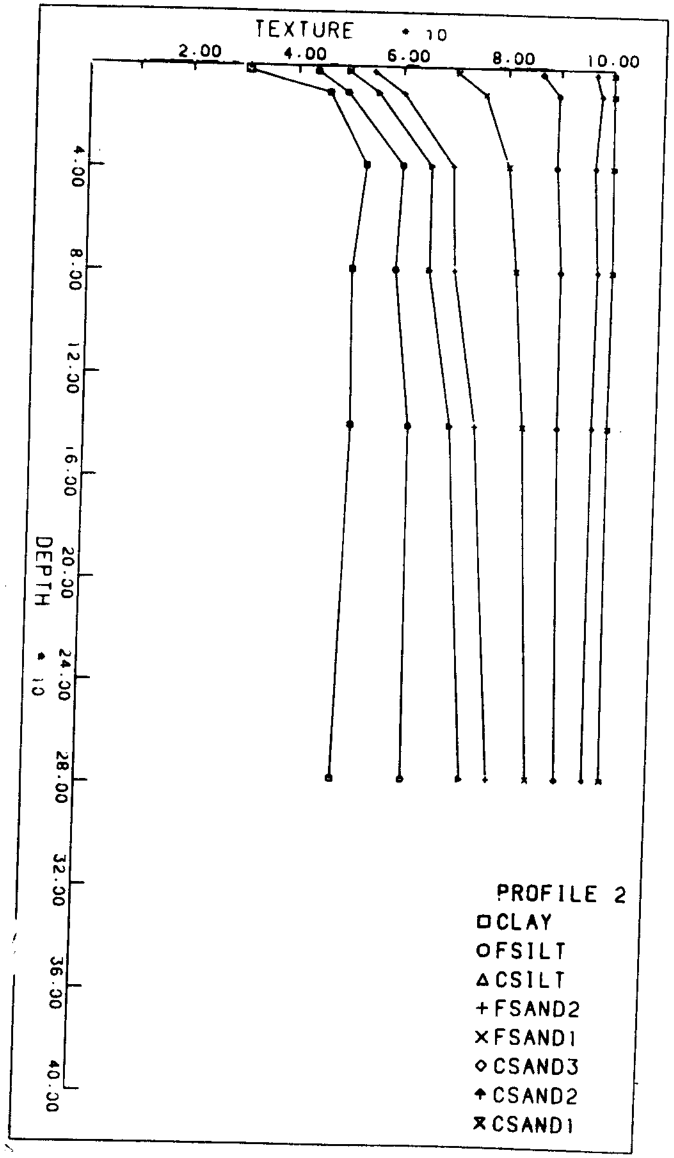
HORIZON DE	DEPTH	BOUND	COLOUR	TEXTURE	STRUCTURE	CONSISTENCY D	M	W	CUTANS	POROSITY	ROOTS	OTHER CHARACTERISTICS
	0-15	g-s	5YR3/3	SC	m vf/f sb+cr	sh	vfr	ss+sp	-	a vf/f	m vf	
	15-25	g-s	2.5YR3/4	C	m vf/f sb	h	fr	ss+sp	-	vm vf/f	c vf/f	
	25-62	g-s	2.5YR3/6	C	w vf/f sb	h	fr	ss+sp	b d C	vm vf/f	c vf/f	
	62-170+		2.5YR3-4/6	C	mp-wc[1]	sh	vfr	ss+sp	b d C	vm vf/f	f vf/f	very few, medium, soft to hard spherical iron cemented clay nodules
	augering 170-400	d-.	2.5YR4/6	C	.		.		.	.	.	very few medium to large, hard, iron cemented clay nodules
	400-600		2.5YR4/6	C	.		.		.	.	.	few medium, hard, spherical, iron/mn concretions

es

tructure is difficult to describe, no clear ped visible, in fact every "ped" size can be made with a slight force; massive porous-
eakly coherent can also be described as very weak, very fine to fine subangular blocky ('coffee granules structure').
he nodules have the same colour as the soil matrix. They differ from the soil by their coherency and the absence of pores. Their
ature is probably clay indurated with iron.
pherical termite holes with flat bottom and Ø of about 8 cm are visible in the whole soil profile with a density of 1 to 2/m^2;
ainly empty but sometimes filled with fungus combs.

1	2	BEG	END	AVE	CS1	CS2	CS3	FS1	FS2	SI1	SI2	AG	DISP	H2O	KCl	H+Al	Al	C	N	C/N	Ca	Mg	K	Na	EC	S bases
2	1	0	4	2.0	3.4	10.0	16.2	16.0	4.9	5.9	12.6	31.0	8.5	5.7	5.0	0.10	0.00	1.70	0.11	15.5	2.6	1.5	0.5	0.0	0.08	4.6
2	2	5	15	10.0	2.4	8.0	14.1	15.5	4.8	6.0	3.4	45.9	9.9	5.5	4.8	0.11	0.00	1.26	0.07	18.0	1.8	0.9	0.4	0.0	0.08	3.1
2	3	30	45	37.5	3.5	7.2	9.1	10.7	4.1	5.4	7.1	53.1	0.5	5.1	4.6	0.18	0.00	0.30	0.03	10.0	0.8	0.4	0.3	0.0	0.03	1.5
2	4	70	85	77.5	2.9	6.9	8.5	11.9	4.7	6.4	8.4	50.7	0.0	5.6	5.6	0.00	0.00	0.17	0.01	17.0	0.8	0.5	0.2	0.0	0.01	1.5
2	5	130	145	137.5	3.0	6.5	6.6	9.3	4.7	7.9	11.2	50.8	0.0	5.5	5.6	0.00	0.00	0.16	0.01	16.0	1.8	1.0	0.2	0.0	0.01	3.0
2	6	260	290	275.0	3.3	5.2	5.5	7.7	5.1	11.1	13.6	48.5	0.0	5.4	5.7	0.02	0.00	0.08	0.01	8.0	1.6	0.8	0.1	0.0	0.01	2.5

Si/AG	DIFPH	ECEC	CEC	V%
.60	.7	4.7	1.[illegible]	98
.20	.7	3.2	8.4	97
.24	.5	1.7	8.3	88
.29	.0	1.5	6.7	100
.38	-.1	3.0	7.4	100
.51	-.3	2.5	7.5	100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32.00
36.00
40.00
PROFILE 2
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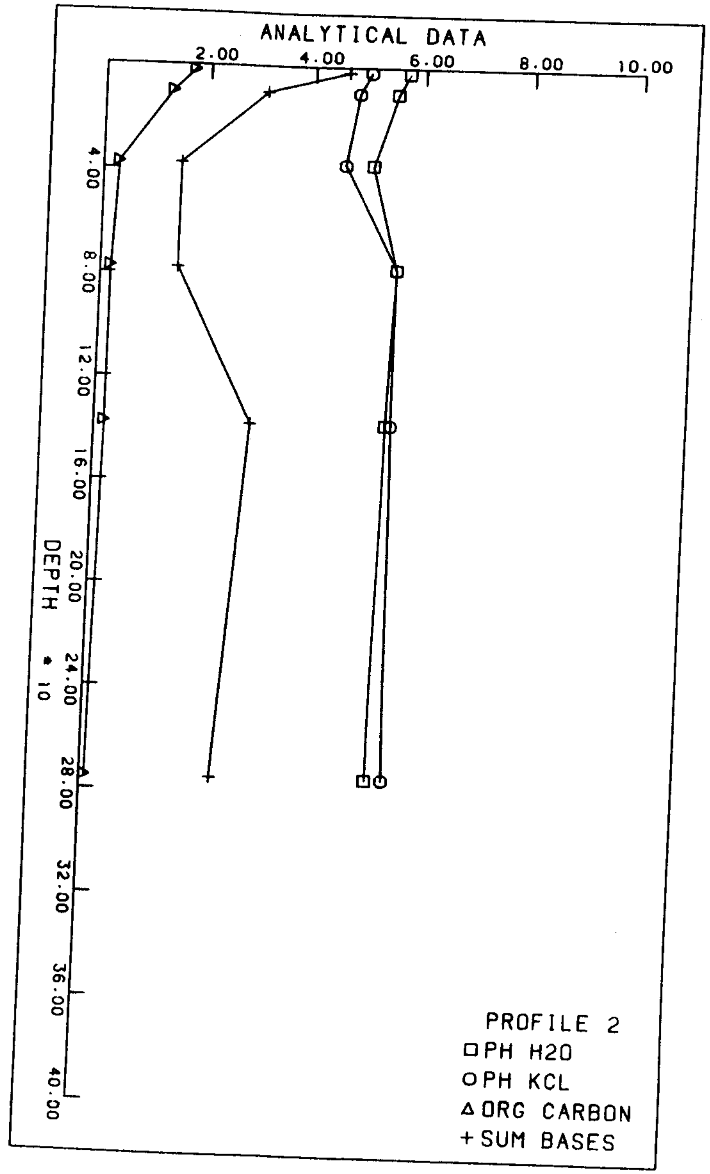
○FSILT
△CSILT
+FSAND2
×FSAND1
◇CSAND3
✦CSAND2
⌘CSAND1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DEPTH * 10
4.00
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12.00
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20.00
24.00
28.00
32.00
36.00
40.00
PROFILE 2
□PH H2O
○PH KCL
△ORG CARBON
+SUM BASES

- Interpretation of the micromorphological data. Profile <u>no. A2 MOC-1</u>), Sul de Calomué.

- In the studied pedon clay illuviation has occureed, but the scope cannot be traced. Only in the top of the B horizon (2) isolated clay illuviation features are observed. Deeper in the B horizon they are not observed and most problably never occurred as here only sepic plasmic fabrics are present in the undisturbed groundmass zones.
- The soil fauna plays the dominant role is this pedon. The structure and porosity is determined by the animal activity viz. the large extent of interconnected infillings, consisting of shaped mineral excrements also responsible for the enaulic coarse/fine related distribution.
  Several species are responsible. One, most probably a species of the Vermes, produces shapeless excreta in which the organic material is inseparable mixed with mineral material, including a few recognizable larger organic fragments, giving the groundmass a darker colour. The mull humusform in the A horizon consists of this material and it occurs in a few massive infillings, which locally tend to striotubules, in the upper part of the B horizon*. The coatings along faunal voids and infillings are produced by the soil fauna by plastering with excrements or by compaction of infilling material adjoining the void. These coatings and compactions give the soil material a higher coherence than expected from the extent of infillings with mineral aggregates. These coatings and compactions are the reason that the soil material under slight pressure breaks into any "ped size".

* Described as mottles in the profile description.

Code ISM MOC 1 /A2 Year 83 Country Mozambique

Lab. no.	depth cm	SiO_2	Al_2O_3	Fe_2O_3		CaO	MgO	K_2O	Na_2O	TiO_2	MnO	P_2O_5	BaO	ign. loss	∑	SiO_2/Al_2O_3	SiO_2/Fe_2O_3	SiO_2/R_2O_3	Al_2O_3/Fe_2O_3
		elemental composition of the total soil (weight %)														Molar ratios			
83001	0-4	63.37	15.06	9.32		0.10	0.10	0.29		3.61	0.13	0.32	0.01	8.45	100.77				
2	4-15	60.15	17.19	9.65		0.07	0.06	0.30		3.54	0.12	0.28	0.02	8.80	100.17				
3	30-45	57.48	22.04	9.81		0.03	0.07	0.24		2.77	0.08	0.33	0.01	8.85	101.70				
4	70-85	55.91	21.70	10.21		0.03	0.06	0.23		2.99	0.06	0.17	0.01	8.92	100.29				
5	130-145	53.19	23.37	10.38		0.03	0.07	0.23		2.78	0.06	0.17	0.01	9.55	99.84				
6	260-290	51.96	25.37	10.59		0.04	0.07	0.16		2.38	0.06	0.14	0.01	9.86	100.64				
7	400-460	-Rock-																	

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Lab. no.		SiO_2	Al_2O_3	Fe_2O_3		CaO	MgO	K_2O	Na_2O	TiO_2	MnO	P_2O_5	BaO	ign. loss	∑	SiO_2/Al_2O_3	SiO_2/Fe_2O_3	SiO_2/R_2O_3	Al_2O_3/Fe_2O_3
		elemental composition of the clay fraction (weight %)														Molar rations			

Code ISM MOC-1 Year 1983 Country Mozambique

Lab. no.	Depth cm	Kaol	Mi/Ill	Verm	Chlor	Smec	Mix			Quar	Feld	Gibb	Goeth	Hem
83001		+++								0-tr.		tr.	X	tr.-X
2		+++								0-tr.		tr.	X	tr.-X
3		+++								0-tr.		tr.	X	tr.-X
4		+++								0-tr.		tr.-X	X	tr.-X
5		+++								0-tr.		tr.	X	tr.-X
6		+++								0-tr.		tr.	X	tr.-X
										0-tr.		tr.	X	tr.-X

MON. NO	CEC 1 +	gebufferd pH=7 CEC 2 ++	CEC gem.	ongebufferd CEC +++	AEC *
83-1	11.4	12.6	12.0	6.8	
-2	8.4	9.2	8.8	4.3	0.36
-3	8.3	7.5	7.9	3.2	
-4	6.7	6.5	6.6	3.8	
-5	7.4	6.0	6.7	5.0	
-6	7.5	7.4	7.5	3.5	

* bepaald door meting in percolaat van ongebufferde CEC } alles uitgedrukt in meq/

\+ 20.2

ignored

PROFILE: L1 (MOC 2)

Date of examination: 25 October 1982 (end of dry season); rep.: 5 April 1983 (end of rainy season)

Authors : J.H. Kaufman/M. Vilanculos

Higher category classification

- (FAO-UNESCO, 1974)
- (Soil Taxonomy, 1975)

Environmental information

Location : Mozambique, Niassa, Lichinga, Lichinga
Coordinates : 13°18' S, 35°16' E
Elevation : 1325 m
Landform : Plateau, (weakly) undulating; smooth interfluves and dambo's
Slope of site: uniform, convex, gradient 1-2%, length ± 500 m; position: top of interfluves
Vegetation : fallow grass/herb
Land use : shifting cultivation, small farmer, maize
Climate : Unimodal, P = 1060, Ep = 1260, 6 months dry season, L.R. = 480 mm 500 mm (see annex)

General information on the soil

Parent material : Basement complex; diorite (see annex)
Drainage conditions : well drained
Moisture conditions : 0-130 cm dry, > 130 cm moist
Ground water level : no evidence within 500 cm
Termitaria : dome-shaped mounds, very large, 1-2/ha
Surface characteristics: surface smooth by superficial lateral flow of water

Miscellaneous

Local soil name : Chicunja (Jaua language)

Brief description of the profile

A very deep, well drained dark red clay soil, weakly structured up to 58 cm then porous massive, topsoil is weakly developed.

E	HORIZON DEPTH	BOUND	COLOUR	TEXTURE	STRUCTURE	CONSISTENCY D M W	CUTANS	POROSITY	ROOTS	OTHER CHARACTERISTICS
	0-15	a-s	2.5YR3/4	SC	m vf/f	sh vfr ss+sp		a vf/f	m f	
'	15-58	d-s	1.25YR3/6	C	m/w vf/f	h fr ss+sp	b d C	vm vf/f	m f	
s	58-180		1.25YR3/6	C	pm-wc	sh vfr ss+sp	p f C	vm vf/f	c f	very few, medium, soft spherical and irregular iron cemented clay nodules
	augering									
s	180-400		1.25YR3/6	C						
	400-650		idem but with increasing percentage of minerals (rotten rock)							

es

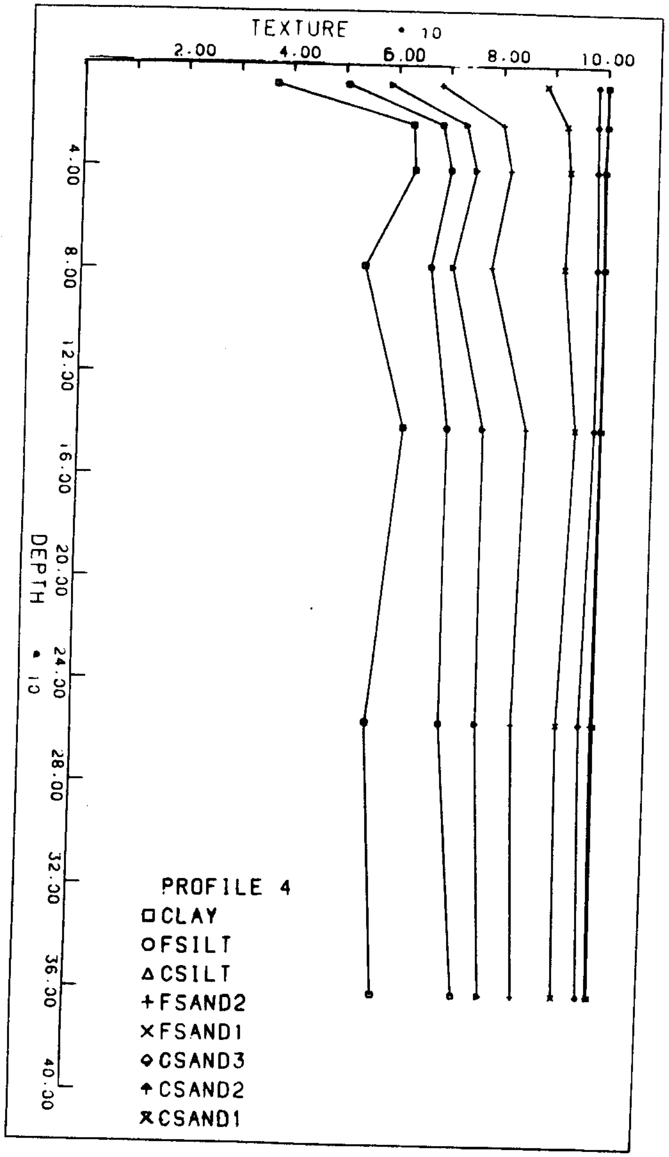
:ructure is difficult to describe; every "ped" size can be formed with little force!
.ear natural ped surfaces are not present in the subsoil > 58 cm.
ırizon differentiation is a combined effect of structure and consistency.
.e subsoil > 58 cm can be described in term of "floury", "coffee granules".
e massive soft, probably iron cemented clay nodules with same colour as soil matrix are present from about 100 cm and deeper.
few fine vertical cracks are visible in the profile.
gnetite is present in the whole profile; weatherable minerals are visible from 200 cm and deeper.
esence of cutans in deeper subsoil is disputable.

1	2	BEG	END	AVE	CS1	CS2	CS3	FS1	FS2	SI1	SI2	AG	DISP	H2O	KCl	H+Al	Al	C	N	C/N	Ca	Mg	K	Na	EC
4	1	0	15	7.5	0.1	1.7	9.8	20.1	9.7	8.2	13.6	36.9	11.6	5.2	4.5	0.28	0.00	1.19	0.08	14.9	0.6	0.8	0.2	0.0	0.03
4	2	15	30	22.5	0.1	1.7	5.8	12.4	6.9	4.6	5.6	63.0	0.0	5.0	4.7	0.16	0.00	0.46	0.04	11.5	0.2	0.8	0.1	0.0	0.01
4	3	30	50	40.0	0.2	1.3	5.2	11.5	6.5	4.8	6.9	63.5	0.0	5.1	4.9	0.06	0.00	0.32	0.04	8.0	0.2	0.8	0.1	0.0	0.02
4	4	65	90	77.5	0.1	1.3	6.2	14.1	7.3	4.2	12.6	54.3	0.0	5.5	5.7	0.02	0.00	0.15	0.03	5.0	0.6	0.9	0.1	0.0	0.01
4	5	130	150	140.0	0.2	1.1	3.6	9.6	8.2	6.8	8.5	62.[illegible]	0.0	5.5	5.7	0.03	0.00	0.14	0.03	4.7	0.2	0.1	0.7	0.1	0.00
4	6	240	270	255.0	0.4	2.3	4.4	8.7	6.7	7.0	14.2	56.2	0.0	5.5	5.1	0.15	0.00	0.05	0.02	2.5	0.6	0.4	0.2	0.1	0.01
4	7	350	370	360.0	0.2	1.9	4.7	7.8	6.1	5.1	15.6	58.[illegible]	0.0	5.6	4.5	0.62	0.00	0.05	0.00	-.1	0.0	0.1	0.2	0.2	0.01
4	8	550	600	575.0	0.1	2.7	9.4	16.0	9.1	6.8	33.5	22.3	0.0	5.5	4.2	2.08	1.80	0.04	0.02	2.0	0.2	0.0	0.1	0.1	0.01

1.6
1.1
1.1
1.6
1.0
0.3
0.3
0.2

Si/AG	DIFPH	ECEC	CEC	
.59	.7	1.9	9.1	84
.16	.3	1.3	8.1	85
.18	.2	1.2	6.7	92
.3	-.2	1.6	5.2	100
.2	-.2	1.1	5.4	91

→ better rerun analysis
or might be a clue for discontinuity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36.00
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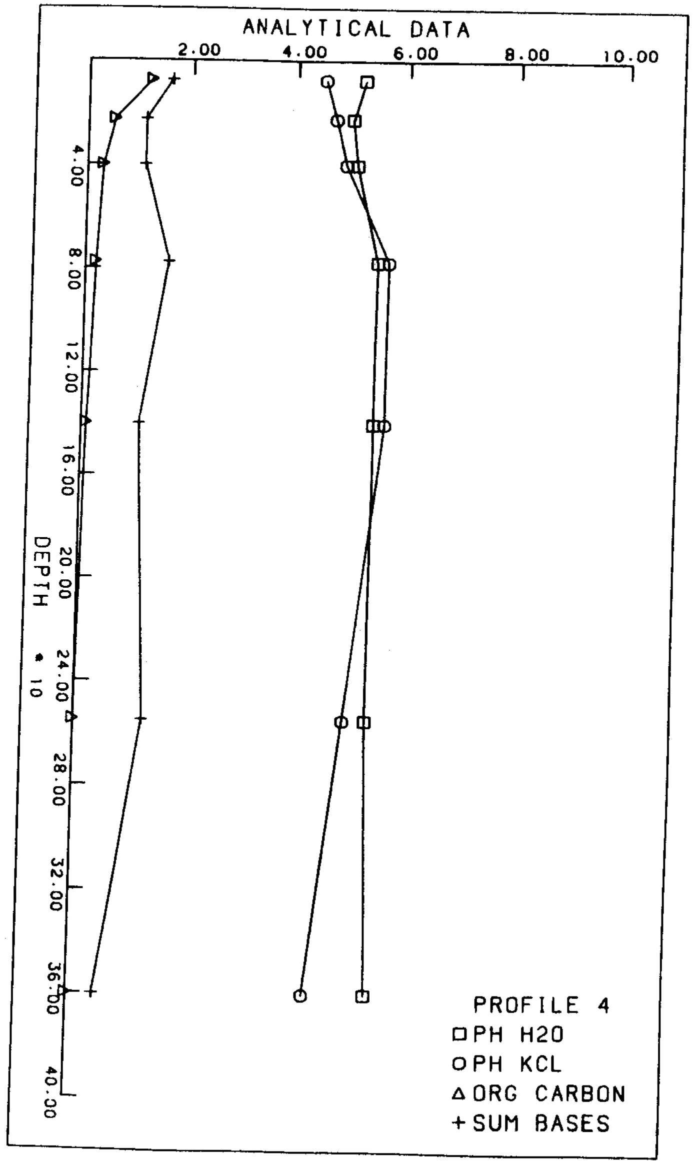
PROFILE 4
□CLAY
OFSILT
ΔCSILT
+FSAND2
×FSAND1
◊CSAND3
↑CSAND2
⌅CSAND1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PROFILE 4
□PH H20
OPH KCL
ΔORG CARBON
+SUM BASES

Code ISM *MOC 2 L1* Year *1983*

Country *Mozambique*

elemental composition of the total soil (weight %)

Lab. no.	depth cm	SiO_2	Al_2O_3	Fe_2O_3		CaO	MgO	K_2O	Na_2O	TiO_2	MnO	P_2O_5	BaO	ign. loss	∑	Molar ratios SiO_2/Al_2O_3	SiO_2/Fe_2O_3	SiO_2/R_2O_3	Al_2O_3/Fe_2O_3
83-008	0-15	58.23	18.70	10.85		0.03	0.05	0.10		2.98	0.12	0.18	–	9.61	100.86				
9	15-30	47.52	25.78	11.87		0.01	0.04	0.08		2.44	0.09	0.18	–	11.39	99.39				
10	30-50	45.96	27.03	12.11		0.02	0.06	0.07		2.40	0.08	0.16	–	11.76	99.67				
11	65-90	47.89	25.26	12.14		0.00	0.06	0.08		2.66	0.07	0.08	–	11.36	99.60				
12	130-150	43.83	27.70	12.93		0.00	0.07	0.08		2.67	0.07	0.07		11.70	99.11				
13		46.80	27.49	12.45		0.00	0.02	0.07		2.35	0.09	0.06		10.96	100.28				
14	240-280	47.70	27.70	12.44		0.00	0.03	0.07		2.32	0.09	0.06		10.83	101.23				
15	350-370	46.98	27.26	12.18		0.00	0.02	0.06		2.06	0.06	0.05		10.73	99.38				
16	550-560	50.14	26.19	11.47		0.00	0.08	0.05		1.57	0.05	0.03		10.32	99.81				

elemental composition of the clay fraction (weight %)

Lab. no.		SiO_2	Al_2O_3	Fe_2O_3		CaO	MgO	K_2O	Na_2O	TiO_2	MnO	P_2O_5	BaO	ign. loss	∑	Molar rations SiO_2/Al_2O_3	SiO_2/Fe_2O_3	SiO_2/R_2O_3	Al_2O_3/Fe_2O_3

Code ISM *MOC 2* Year *1983*

Country *Mozambique*

Lab. no.	Depth cm	Kaol	Mi/Ill	Verm	Chlor	Smec	Mix		Quar	Feld	Gibb	Goeth	Hem
83-008		+++							0-tr.		X	X	tr.-X
9		+++							0-tr.		X	X	tr.-X
10		+++							0-tr.		X	X	tr.-X
11		+++							0-tr.		X	X	tr.-X
12		+++							0-tr.		X	X	tr.-X
13		+++							0-tr.		X	X	tr.-X
14		+++							0-tr.		tr.-X	X	tr.-X
15		+++							0-tr.		tr.	X	tr.-X
16		+++							0-tr.		–	X	tr.-X
		+++							0-tr.		tr.	X	tr.-X

MON. NO	CEC 1 +	gebufferd pH=7 CEC 2 ++	CEC gem.	ongebufferd CEC +++	AEC *
83-8	9.1	9.3	9.2	2.5	
-9	8.1	6.9	7.5	3.1	.67
-10	5.7	6.2	6.5	2.6	
-11	5.2	4.6	4.9	2.5	
-12	5.4	4.8	5.1	2.2	
-14	5.8	6.7	6.3	3.6	
-15	6.0	6.4	6.4	3.1	
-16	4.6	6.2	4.9	2.6	

*	bepaald door chloride meting in percolaat van ongebufferde CEC
+	202
++	2.02
+++	2.02

} uitgedrukt in meq/100 gr grond

- A few black rounded nodules including coarse mineral grains are present from 70 cm depth onwards. Diam. up to 3 mm, randomly distributed.
- One large, 12 mm Ø, rounded nodule or different soil fragment occurs at 170 cm depth, with different colour, coated with a patchy ferri-argillan and in the interior small voids occur with the same kind of ferri-argillans.

Interpretation of the micromorphological data profile No. L1 (moc-2) Lichinga.

- Clay illuviation has occurred in the studied pedon. In the small areas (<30% of the groundmass) undisturbed by faunal activity in the first two thin sections (1,2) the abundance fulfills the requirements of an argillic horizon. The animal activity is of such a type that after disturbance and production of excrements only a few fragments of the clay illuviation features can be detected.
- The influence of the soil fauna is large. The structure and porosity is determined by the animal activity viz. the large extent of inter-connected infillings dominantly consisting of shaped mineral excrements. Along faunal voids, as result of faunal activity, compacted zones occur increasing the coherence of the soil material. Several species are responsible of which one producing small excrements and soil aggregates with diameters varying between 40-100 µm, most probably a kind of termite and a larger species producing ellipsoidal to bacillocylindrical excrements, have most impact. The latter species is also responsible for the infilled voids with compact clay-rich groundmass-material occurring over the whole studied depth.
- The incorporated charchal fragments are indicative for burning practises of men. The incorporation till 70 cm depth is most probably a consequence of the high biological activity.

PROFILE: L 2 (MOC 3)

Date of examination: 26 October 1982 (end of dry season); re.: 7 April 1983 (end of rainy season)

Authors : J.H. Kauffman, M. Vilanculos

__Higher category classification__

- (FAO-UNESCO, 1974)
- (Soil Taxonomy, 1975)

__Environmental information__

Location : Mozambique, Niassa, Sanga, Unango

Coordinates : 12°57' S, 35°23' E

Elevation : 1075 m

Landform : Plateau, weakly undulating; smooth interfluves and dambo's, few rocks, outcrops/inselbergs

Slope of site: uniform, weakly convex, gradient 1-2%, > 500 m; position: upper slope

Vegetation : Brachystegia Woodland (see annex)

Land use : recently cleared for permanent mechanized farming, maize

Climate : Unimodal, P = , Ep = , 6 months dry, L.R. = (see annex)

__General information on the soil__

Parent material : Basement complex, diorite (see annex)

Drainage conditions : well drained

Moisture conditions : 0-17 moist, 17-200 dry, > 200 cm moist

Ground water level : no evidence within 600 cm

Termitaria : dome-shaped mounds, very large, < 1/ha

Surface characteristics: ± 2 cm dry litter present

__Miscellaneous__

Local soil name : Chicunja (Jaua language)

__Brief description of the profile__

A very deep, well drained, dark red clay soil, moderately structured.

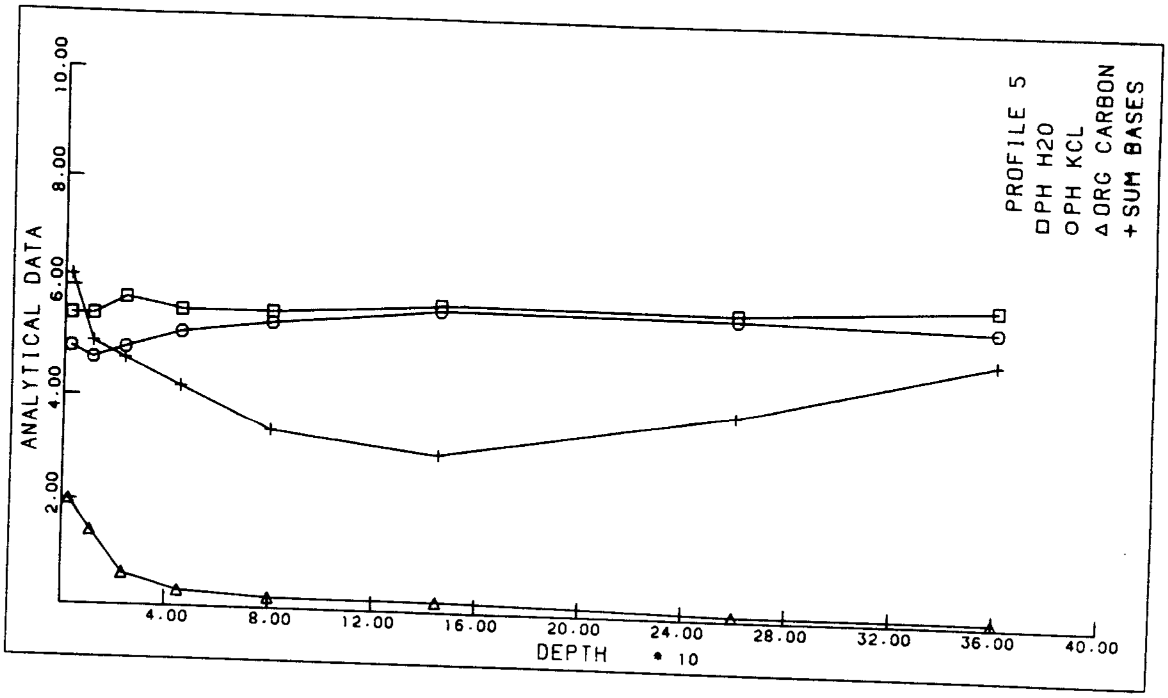
DE	HORIZON DEPTH	BOUND	COLOUR	TEXTURE	STRUCTURE	CONSISTENCY D	M	W	CUTANS	POROSITY	ROOTS	OTHER CHARACTERISTICS
h	0-15	c-s	2.5YR3/3	C	m vf/f sb+cr	.	fr		–	vm vf/f	m f+m	
B	15-25	g-s	2.5YR3/4	C	m vf/m sb	h	fr		b f C	vm vf/f	m f+m	
t''	25-70	d-s	1.25YR3/4	C	m vf/m sb	h	fr		c p C	m vf/f	m f	...... few faint black mottling
t'	70-105	d-s	1.25YR3/5	C	m/w vf/f sb	(s)h	vfr		b d C	m vf/f	m f	very few medium soft iron cemented clay nodules
ws	105-185+		1.25YR3/5	C	w vf/f sb	sh	vfr		p d C	m vf/f	c f	
	augering											
ws	185-400		idem with few weatherable minerals visible									
:	400-600		idem with increasing percentage of weatherable minerals									
	600-670+		rotten rock									

__:es__

lagnetite is present in whole profile.
ioft nodules has same colour as soil matrix, inner side of nodules is massive.
lorizon boundaries in subsoil are very diffuse.

1	2	BEG	END	AVE	CS1	CS2	CS3	FS1	FS2	SI1	SI2	AG	DISP	H2O	KCl	H+Al	Al	C	N	C/N	Ca	Mg	K	Na	EC	
5	1	0	5	2.5	0.4	2.9	8.3	14.6	7.8	7.2	19.1	39.8	28.5	5.5	4.9	0.13	0.00	1.98	0.14	14.1	2.9	2.5	0.7	0.1	0.09	6.2
5	2	5	17	11.0	0.4	2.7	7.3	12.6	6.7	4.3	12.2	53.7	17.4	5.5	4.7	0.12	0.00	1.36	0.11	12.4	2.5	1.8	0.6	0.1	0.05	5.0
5	3	17	30	23.5	0.4	2.3	5.4	8.8	5.2	4.5	6.2	67.2	21.8	5.8	4.9	0.04	0.00	0.64	0.06	10.7	2.5	1.6	0.5	0.1	0.03	4.7
5	4	30	60	45.0	0.3	1.8	4.0	6.7	3.8	4.5	6.3	72.6	1.5	5.6	5.2	0.00	0.00	0.29	0.05	5.8	2.1	1.4	0.6	0.1	0.02	4.2
5	5	65	95	80.0	0.4	1.9	4.4	7.5	4.3	5.4	14.3	61.8	0.0	5.6	5.4	0.00	0.00	0.19	0.03	6.3	1.6	1.1	0.5	0.2	0.01	3.4
5	6	130	160	145.0	0.4	1.6	3.0	6.0	4.5	7.1	15.3	62.1	0.0	5.8	5.7	0.00	0.00	0.15	0.02	7.5	1.4	1.2	0.3	0.1	0.01	3.0
5	7	230	290	260.0	1.9	4.0	4.3	5.6	4.2	8.6	15.4	56.0	0.0	5.8	5.7	0.02	0.00	0.07	0.04	2.0	1.9	1.3	0.5	0.2	0.01	3.9
5	8	330	390	360.0	0.5	2.2	3.5	5.7	4.9	9.8	23.8	49.5	0.0	6.0	5.6	0.02	0.00	0.06	0.03	2.0	2.3	2.1	0.4	0.2	0.01	5.0

Si/AG	DIFPH	ECEC	CEC	
.66	.6	6.3	16.2	98
.31	.8	5.1	14.0	98
.16	.9	4.7	12.3	100
.15	.4	4.2	9.8	100
.32	.2	3.4	7.9	100
.36	.1	3.0	7.5	100
.43	.1	3.9	9.0	100
.68	.4	5.0	10.1	100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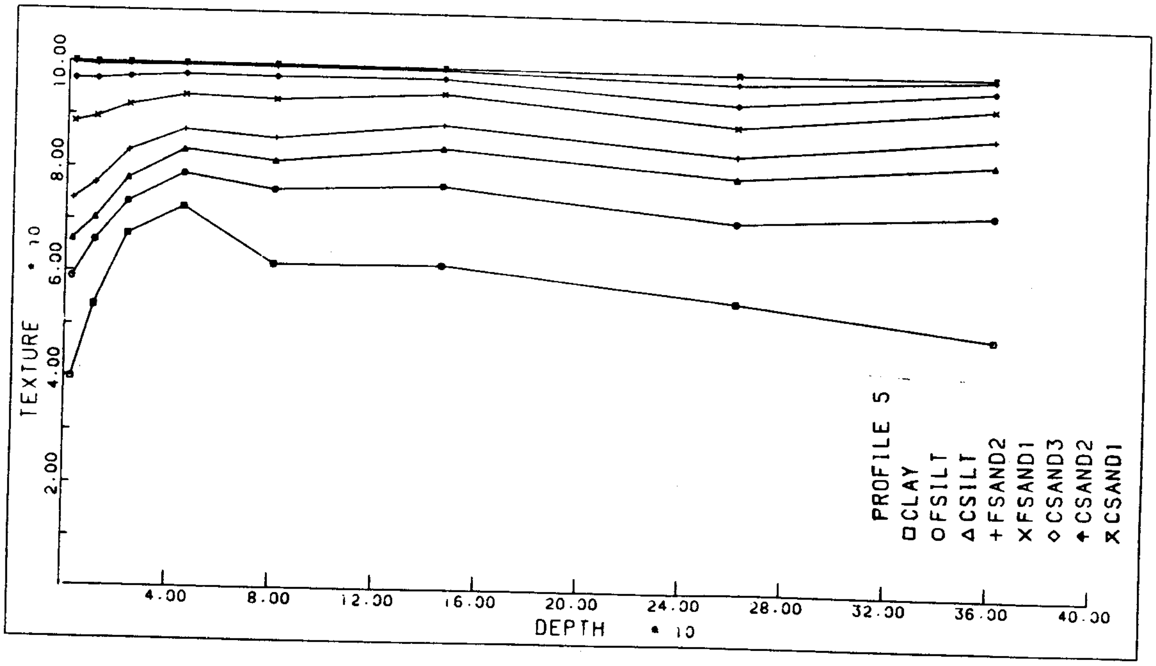
PROFILE 5
□PH H20
○PH KCL
△ORG CARBON
+SUM BASES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PROFILE 5
□CLAY
○FSILT
△CSILT
+FSAND2
×FSAND1
◇CSAND3
CSAND2
CSAND1

Code ISM MOC 3/L2 Year 1983

Country Mozambique

Lab. no.	depth cm	SiO_2	Al_2O_3	Fe_2O_3		CaO	MgO	K_2O	Na_2O	TiO_2	MnO	P_2O_5	BaO	ign. loss	Σ	$\frac{SiO_2}{Al_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$	$\frac{SiO_2}{R_2O_3}$	$\frac{Al_2O_3}{Fe_2O_3}$
		elemental composition of the total soil (weight %)														Molar ratios			
83017	0-5	44.35	20.44	18.25		0.16	0.19	0.34		5.34	0.22	0.29	0.03	10.83	100.43				
18	5-17	43.30	22.38	17.57		0.13	0.17	0.32		4.75	0.20	0.24	0.02	10.73	99.80				
19	17-30	42.43	25.82	16.22		0.10	0.13	0.25		3.78	0.17	0.23	0.01	11.02	100.15				
20	30-60	40.81	28.52	14.96		0.07	0.11	0.21		3.07	0.14	0.16	0.00	11.76	99.81				
21	65-95	41.83	28.43	15.67		0.06	0.09	0.21		3.40	0.11	0.08	0.00	11.19	101.07				
22	130-160	40.24	29.44	15.92		0.05	0.11	0.16		3.33	0.09	0.08	0.00	11.57	101.00				
23	230-260	42.38	29.06	15.74		0.06	0.13	0.09		2.63	0.29	0.09	0.06	10.97	101.50				
24	330-390	42.13	29.36	14.33		0.07	0.11	0.07		2.31	0.09	0.07	0.00	11.37	99.90				

elemental composition of the clay fraction (weight %) — Molar rations

Lab. no.		SiO_2	Al_2O_3	Fe_2O_3		CaO	MgO	K_2O	Na_2O	TiO_2	MnO	P_2O_5	BaO	ign. loss	Σ	$\frac{SiO_2}{Al_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$	$\frac{SiO_2}{R_2O_3}$	$\frac{Al_2O_3}{Fe_2O_3}$

Code ISM MOC-3 Year 83 Country Mozambique

Lab. no.	Depth cm	Kaol	Mi/Ill	Verm	Chlor	Smec	Mix			Quar	Feld	Gibb	Goeth	Hem
83-17		+++								[illegible]		X	X	tr-X
18		+++								0-tr		tr-X	X	tr-X
19		+++								0-tr		X	X	tr-X
20		+++								0-tr		X	X	tr-X
21		+++								0-tr		X	X	tr-X
22		+++								0-tr		X	X	tr-X
23		+++								0-tr		tr	X	tr-X
24		+++								0-tr		—	X	tr-X

MON. NO	CEC 1 +	gebufferd pH=7 CEC 2 ++	CEC gem.	ongebufferd CEC +++	AEC *
83-17	16.[illegible]	15.[illegible]	15.8	5.6	
-18	14.6	13.9	14.0	5.7	0.46
-19	[illegible]	[illegible]	[illegible]	5.8	
-20	[illegible]	[illegible]	[illegible]	[illegible]	
-21	[illegible]	[illegible]	[illegible]	[illegible]	
-22	[illegible]	[illegible]	[illegible]	[illegible]	
-23	9.[illegible]	10.[illegible]	[illegible]	[illegible]	
-24	10.1	[illegible]	9.5	[illegible]	

*	bepaald door chloride-meting in percolaat van ongebufferde CEC
+	202
++	202
+++	202

} uitgedrukt in meq/100 gr grond.

Interpretation of the micromorphological data Profile No. L2 (MOC3), Unango, Mozambique.

- Clay illuviation has occurred in the present A horizon and top of the B horizon. In undisturbed zones in the groundmass the abundance of ferri argillans and infilled voids, especially in the top of the B horizon (32-47 cm) is enough for an argillic horizon. Theze zones, however, cover too small an area to fulfill the requirements. Indicative for the disturbance are the papules, which are common in the zone where most undisturbed remnants of clay illuviation are present.
- The occurrence of clay illuviation features in the A horizon indicates that the topsoil is eroded. In the A horizon the quantity of coarse autochtoneous mineral grains is higher than in the B horizon supporting disappearance of fine-grained material. As not any indication is observed of illuviation of fine-grained material in the B horizon, lateral erosion has to be taken place.
- In the A horizon, strongly decreasing in quantity with depth in the B horizon, charcoal is present, as large fragments up to 3 mm Ø, as part of the coarse material and as small black particles in the fine grained material. The charcoal is formed by burning of the vegetation at the surface and incorporated in the soil material, whereby the fauna has played an important role. The incorporation of charcoal particles resulted in a darker colour of the A horizon, and is not related to a mollic epipedon.
- The colour of the fine material in the A horizon is not homogeneous. Material of the B horizon is incorporated, indicating an impact of cultivation practices.
- The influence of the fauna is dominant in the studied zones and mainly results in homogenisation. Soil animals produce void systems, many of which are partly or completely infilled with loosely packed, shaped mineral excrements. These void systems are often interconnected. Locally zones of the groundmass only consists of these loosely packed mineral excrements. In the horizon and top of the B horizon common distinct void systems have a compact coating of mainly fine-grained material. These are also a product of faunal activity, generally formed by compaction of excrements along the walls. Deeper in the pedon they hardly occur.

- Roots occur over the whole studied depth and produced a part of the voids.
- In the deepest section (125 - 140 cm) a few less weathered minerals and rock fragments occur and also some larger grains up to 3 mm Ø are found, marking the zone where weathering has been less.

Note: The micromorphology of this pedon very much resembles the one of the Indian Benchmark Soil Thekadi. Pedon no. 57. Micromorphological analyses and characterisation of 70 Benchmark Soils of India by M.J. Kooistra, 1982, Netherlands Soil Survey Institute, p. 622-630.

PROFILE: C 1 (MOC 4)

Date of examination: 12 November 1982 (start of rainy season);
repeat: 30 March 1983 (end of rainy season)

Authors : J.H. Kauffman, M. Vilanculos

Higher category classification

- (FAO-UNESCO, 1974)
- (Soil Taxonomy, 1975)

Environmental information

Location : Mozambique, Cabo Delgado, Montepuez, Chipembe
Coordinates : 13°09' S, 38°37' E
Elevation : 500 m
Landform : Planation surface, weakly undulating; very broad smooth interfluves
Slope of site: uniform, straight, gradient about 1%, length about 2 km, position: on upper slope or top of interfluve
Vegetation : closed Bambu forest with scattered high trees (see annex)
Land use : nearby permanent mechanized farming, maize and cotton
Climate : Unimodal, P = 930, Ep = 1445, 6 months dry, L.R. = 300 mm (see annex)

General information on the soil

Parent material : Basement; probably gabro norite (see annex)
Drainage conditions : well drained
Moisture conditions : 0-25 cm moist, 25-30 cm dry
Ground water level : no evidence within 300 cm
Termitaria : dome-shaped mounds, medium/large, about 1/5 ha
Surface characteristics: about 1 cm litter (in the agricultural field few signs of sheet erosion)

Miscellaneous

Local soil name : Ithaya yoquilla (Macau language)

Brief description of the profile

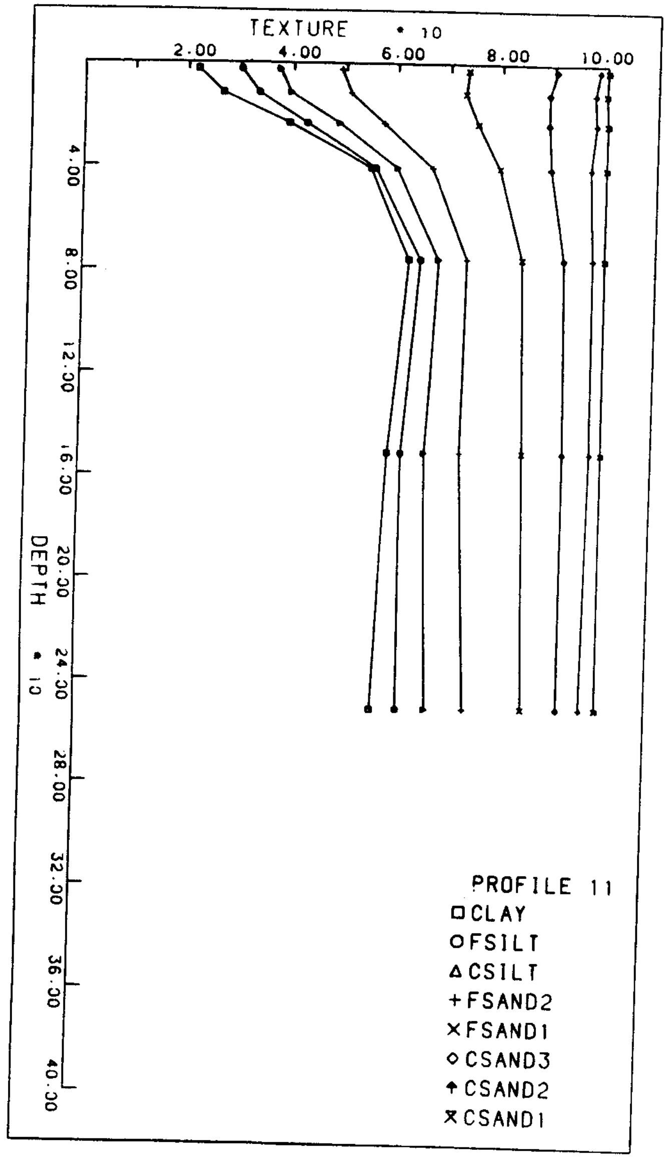
A very deep, well drained, dusky red clay soil, weakly to moderately structured up to 125 cm than porous massive, with a dark coloured topsoil.

HORIZON DEPTH	BOUND	COLOUR	TEXTURE	STRUCTURE	CONSISTENCY D	M	W	CUTANS	POROSITY	ROOTS	OTHER CHARACTERISTICS
0-18	c-s	5YR2.5/2	SCL	w vf/f cr	.	vfr	ns+sp	-	vm vf/m	m f/m	
18-30	g-s	2.5YR3/2	SC	w vf/f sb	.	vfr	ss+sp	-	vm vf/f	m f/m	
30-60	d-s	1.25YR3/4	C	w/m vf/f sb	h	vfr	ss+sp	b d C	m vf/f	m f	
60-125	d-s	10 R3/5	C	w vf/f sb	sh	vfr	ss+sp	p f C	m vf/f	c f	
125-175+		10 R3/5	C	pm-wc	sh	vfr	ss+sp	p f C	m vf	c f	very few medium soft iron cemented clay nodules
augering											
175-320		10 R3/5	C	.		.		.	.	.	
320-400		10 R3/5		.		.		.	.	.	few medium soft/hard spherical iron/mn concretions
400-430				.		.		.	.	.	frequent medium soft/hard spherical iron/mn concretions
430+		abrupt to hard rock or stone									

ie upper horizon has few holes filled with reddish subsoil; the subsoil has few holes filled with dark coloured topsoil.
'aces of magnetite are present from 30 cm and deeper.
'herical termite holes with flat botton and with a diameter of 4 to 8 cm are visible in the whole soil profile, density is
out $4/m^2$.

1	2	BEG	END	AVE	CS1	CS2	CS3	FS1	FS2	SI1	SI2	AG	DISP	H2O	KCL	H+Al	Al	C	N	C/N	Ca	Mg	K	Na	EC	
11	1	0	5	2.5	1.7	8.1	16.9	24.3	11.6	7.3	8.3	21.9	7.0	5.9	5.3	0.02	0.00	2.29	0.13	17.6	4.7	4.2	0.3	0.1	0.06	9.3
11	2	5	18	11.5	2.2	8.6	16.1	22.0	11.3	6.0	6.9	26.7	9.5	5.7	4.8	0.02	0.00	1.77	0.10	17.7	3.3	2.8	0.1	0.1	0.03	6.3
11	3	18	28	23.0	2.2	8.9	13.6	17.9	8.7	6.1	3.3	39.4	14.4	5.6	4.7	0.07	0.00	1.10	0.07	15.7	2.4	2.0	0.1	0.1	0.03	4.6
11	4	30	50	40.0	3.0	7.5	9.7	12.9	6.7	4.1	1.0	55.1	15.2	5.5	4.5	0.15	0.00	0.73	0.07	10.4	1.9	1.7	0.1	0.1	0.02	3.3
11	5	60	90	75.0	2.3	5.4	7.8	10.7	5.4	3.4	2.2	62.7	10.2	5.9	4.9	0.04	0.00	0.42	0.04	10.5	2.1	1.5	0.1	0.1	0.01	3.3
11	6	125	175	150.0	2.2	5.1	7.7	12.1	6.7	4.4	2.6	59.2	0.5	6.4	5.5	0.00	0.00	0.00	0.05	0.0	2.1	1.7	0.1	0.1	0.01	4.0
11	7	225	275	250.0	3.1	4.3	6.8	11.4	7.2	5.5	5.0	56.8	0.0	6.4	5.6	0.02	0.00	0.00	0.03	0.0	2.5	1.8	0.1	0.1	0.02	4.5

Si/AG	DIFPH	ECEC	CEC	
.71	.6	9.3	15.9	100
.48	.9	6.3	12.9	100
.24	.9	4.7	9.7	98
.09	1.0	3.9	9.1	97
.09	1.0	3.8	8.2	100
.12	.9	4.0	7.2	100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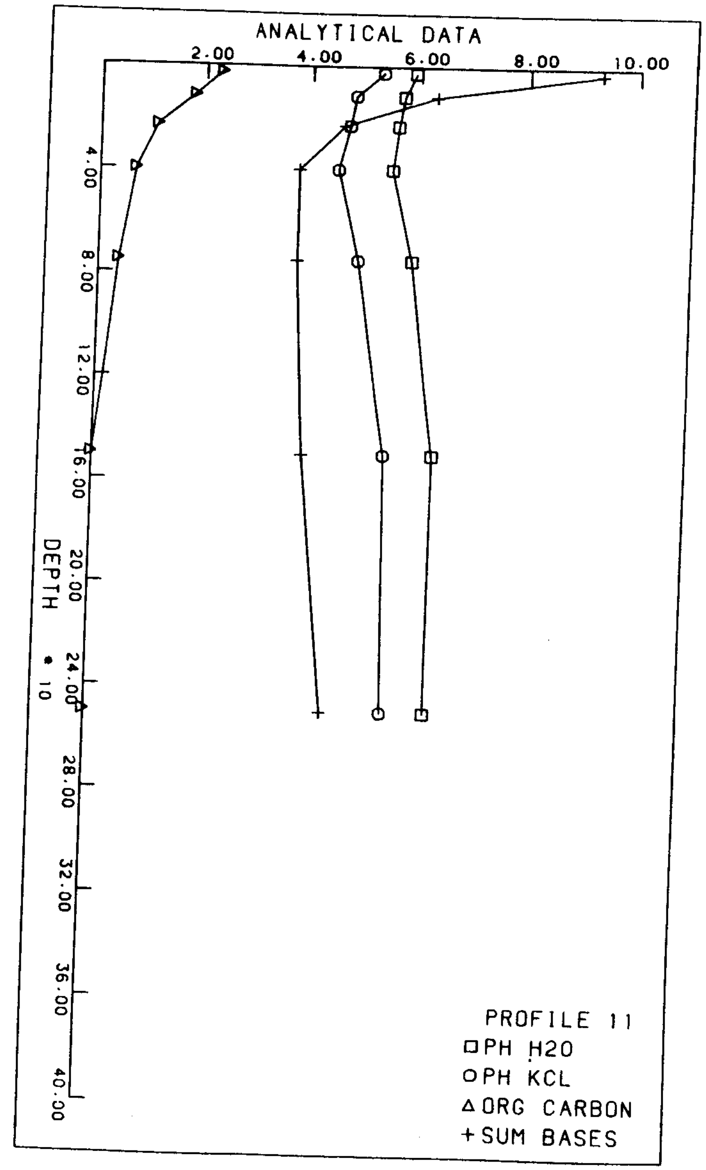
DEPTH * 10
PROFILE 11
CLAY
FSILT
CSILT
FSAND2
FSAND1
CSAND3
CSAND2
CSAND1


ANALYTICAL DATA
DEPTH * 10
PROFILE 11
PH H2O
PH KCL
ORG CARBON
SUM BASES

Code ISM MOC 4/C1 Year 1983 Country Mozambique

Lab. no.	depth cm	SiO_2	Al_2O_3	Fe_2O_3		CaO	MgO	K_2O	Na_2O	TiO_2	MnO	P_2O_5	BaO	ign. loss	Σ	$\frac{SiO_2}{Al_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$	$\frac{SiO_2}{R_2O_3}$	$\frac{Al_2O_3}{Fe_2O_3}$
		elemental composition of the total soil (weight %)														Molar ratios			
83026	0-5	76.82	7.13	6.96		0.27	0.16	0.05		2.74	0.13	0.03	0.00	6.25	100.53				
27	5-18	75.36	8.80	7.72		0.20	0.16	0.03		2.67	0.12	0.03	0.00	6.06	101.16				
28	18-28	69.92	12.21	8.84		0.14	0.09	0.02		2.29	0.11	0.03	0.00	6.58	100.21				
29	30-50	63.48	16.59	10.20		0.10	0.10	0.02		1.77	0.09	0.03	0.00	7.48	99.86				
30	60-90	59.54	19.86	11.39		0.08	0.09	0.02		1.69	0.08	0.03	0.00	8.25	101.04				
31	125-170	59.16	18.30	11.32		0.08	0.07	0.02		1.88	0.10	0.02	0.00	7.46	98.36				
32	225-275	60.01	19.25	11.94		0.09	0.09	0.02		1.84	0.11	0.01	0.00	7.53	100.89				

Lab. no.		SiO_2	Al_2O_3	Fe_2O_3		CaO	MgO	K_2O	Na_2O	TiO_2	MnO	P_2O_5	BaO	ign. loss	Σ	$\frac{SiO_2}{Al_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$	$\frac{SiO_2}{R_2O_3}$	$\frac{Al_2O_3}{Fe_2O_3}$
		elemental composition of the clay fraction (weight %)														Molar rations			

Code ISM MOC-4 Year 1983 Country Mozambique

Lab. no.	Depth cm	Kaol	Mi/Ill	Verm	Chlor	Smec	Mix			Quar	Feld	Gibb	Goeth	Hem
83026		+++								0-Tr			Tr - X	Tr - X
27		+++								0-Tr			Tr - X	Tr - X
28		+++								0-Tr			Tr X	Tr - X
29		+++								0-Tr			Tr - X	Tr - X
30		+++								0-Tr			Tr - X	Tr - X
31		+++								0-Tr			Tr - X	Tr - X
32		+++								0-Tr			Tr - X	Tr - X

MON. NO	CEC 1 +	gebufferd pH=7 CEC 2 ++	CEC som.	ongebufferd CEC +++
83-26	[illegible]	[illegible]	[illegible]	[illegible]
-27	[illegible]	[illegible]	[illegible]	[illegible]
-28	[illegible]	[illegible]	[illegible]	[illegible]
-29	[illegible]	[illegible]	[illegible]	[illegible]
-30	[illegible]	[illegible]	[illegible]	5.6
-31	[illegible]	[illegible]	[illegible]	[illegible]
-32	[illegible]	[illegible]	8.0	6.2

+	202	} uitgedrukt in meq/100 gr grond
++	202	
+++	202	

Interpretation of the micromorphological data Profile No. C1 (MOC-4), Chipembe, Mozambique.

- Clay illuviation occurred over the whole studied zone, in the actual A as well as the B horizon. The quantities fulfill the requirements for an argillic horizon. In the first 12 cm of the A horizon and deep in the B horizon papules are common indicating disturbances by other processes.

- The topsoil of the studied pedon is eroded. Clay illuviation features are present in the A horizon and the quantity of coarse mineral material is higher than deeper in the pedon (resulting in a dense porphyric packing contrary to the open porphyric packing in the B horizon) as result of lateral erosion of fine mineral material. Moreover, the mineralogy of the coarse mineral material in the A horizon is more varied (includes pyroxenes and feldspars) than deeper in the pedon, which may be indicative for a kind of transport of coarse mineral material over the surface placing the profile in a lower position in the landscape or they are brought in by human activities.

- Soil fauna plays an important role. Large void systems are produced, often interconnected, which are partly or completely infilled with open packed to slightly welded shaped mineral excrements. Over the whole depth some of these voids have plastered walls, consisting of compact fine-grained mineral material, produced by soil fauna. In the B horizon the animal activity is responsible for the disturbance of clay illuviation features.

- In the A horizon occurs a relatively high quantity on dead organic matter as coarse, dark coloured fragments. The dark colour is an evidence of decomposition by fungal and microfloral attack. Due to the presence of this organic material the A horizon is darker coloured. The occurrence can be a result of animal activity under a shrub vegetation or woodland and/or a result of cultivation practices.

PROFILE: N 2 (MOC 5)

Date of examination: 23 November 1982 (start of rains); repeat: 13 April 1983 (end of rains)

Authors : J.H. Kauffman, M. Vilanculos

Higher category classification

- (FAO-UNESCO, 1974)
- (Soil Taxonomy, 1975)

Environmental information

Location : Mozambique, Nampula, Monapo, Metochéria

Coordinates : 14°49' S, 40°05' E

Elevation : 180 m

Landform : planation surface, nearly flat to weakly undulating; dissected interfluves

Slope of site: complex, weakly convex, length < 300 m, gradient 1-2%; position: nearly on top of interfluve

Vegetation : dense grass cover with few trees (originally probably dense rich forest)

Land use : at site nearly permanently cultivated plots of small farmers, nearby large cotton estates

Climate : Unimodal, P = 935, Ep = 1425, ± 6 months dry, L.R. = 275 mm (see annex)

General information on the soil

Parent material : mafic rock type, probably gabro (see annex)

Drainage conditions : well drained

Moisture conditions : 0-85 moist, > 85 cm dry

Ground water level : no evidence

Termitaria : dome-shaped mounds, density about < 1/ha

Surface characteristics: in the cultivated land rill erosion is common, mainly on the more sloping terrain towards natural drainage channels

Miscellaneous

Local soil name : -

Brief description of the profile

A deep, well drained, dark reddish brown clay soil, strongly or moderately structured; with a thick dark coloured topsoil; subsoil aggregates fall apart when wetted.

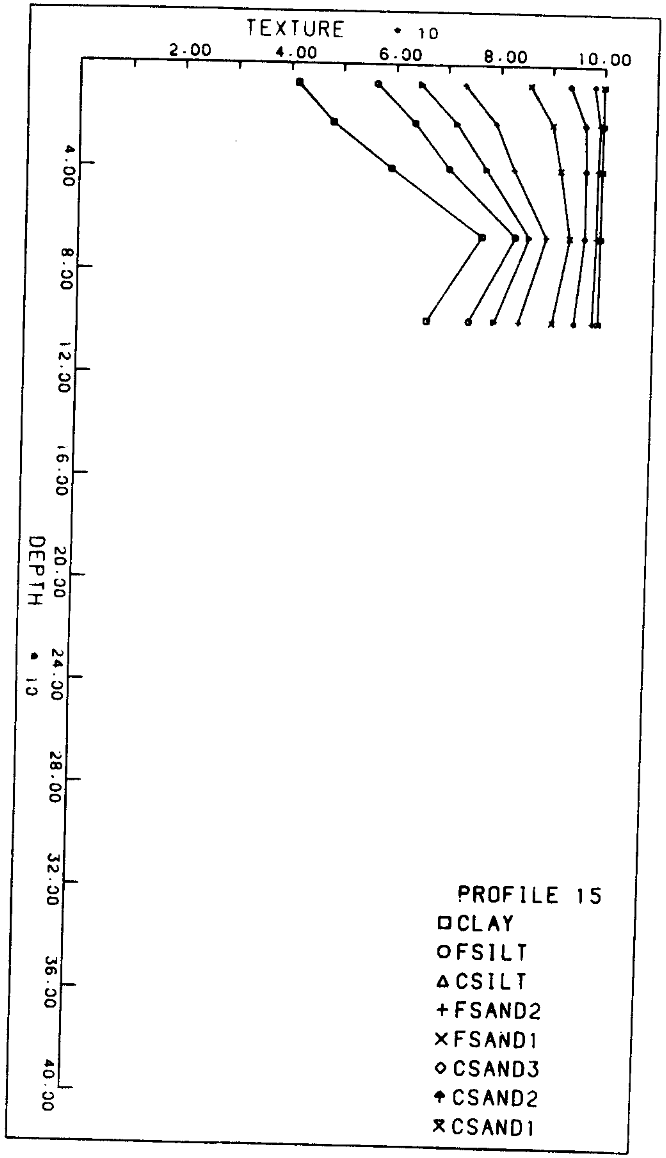
CODE	HORIZON DEPTH	BOUND	COLOUR	TEXTURE	STRUCTURE	CONSISTENCY D	M	W	CUTANS	POROSITY	ROOTS	OTHER CHARACTERISTICS
Ah	0-30	c-s	5YR3/1	C	m vf/f sb+cr	(s)h	vfr	ss/p	-	vm vf/m	m f/m	
AB	30-50	g-s	5YR3/2	C	s/m vf/m sb+ab	h	fr	s/p	c/b p C	m vf	m f	
Bt'''	50-95	g-s	2.5YR3/4	C	s/m f/m sb+ab	h	fr	s/p	c p C	c vf/f	c f	
BC	95-140	d-w	±2.5YR3/5	C	m f sb+ab	h	fr	s/p	c p C	c f	c f	very few to few fine to medium strongly weathered rock
CB	140-160+		7.5YR5/8 + 2.5YR3/4	mainly rotten rock								

ote

Soil when dry has a few cracks, width is less than ½ cm.
Soils clods falls apart in very fine angular aggregates when saturated with water.
At a depth of about 70-100 cm is present a "stone layer" with a thickness of 5 to 15 cm containing few, fine to medium iron rich, angular concretions and few quartz gravels; the layer forms no limitation for root development.

1	2	BEG	END	AVE	CS1	CS2	CS3	FS1	FS2	SI1	SI2	AG	DISP	H2O	KCl	H+Al	Al	C	N	C/N	Ca	Mg	K	Na	EC	
15	1	0	15	7.5	1.8	4.6	7.8	12.4	8.5	8.4	15.0	41.4	16.2	7.1	6.0	0.06	0.00	2.81	0.19	14.8	20.5	3.5	1.2	0.1	0.13	25.3
15	2	15	30	22.5	0.6	2.8	6.4	10.8	7.5	8.1	15.5	48.3	19.8	7.9	6.6	0.06	0.00	1.92	0.14	13.7	20.9	2.5	1.2	0.1	0.13	24.7
15	3	30	50	40.0	0.8	2.3	4.9	9.0	5.2	7.1	11.2	59.5	25.1	7.9	6.3	0.03	0.00	1.18	0.10	11.8	15.1	5.0	0.2	0.1	0.09	20.4
15	4	50	82	66.0	0.8	2.2	2.9	4.6	3.3	2.6	6.3	77.3	21.9	7.8	6.1	0.03	0.00	0.74	0.09	8.2	12.5	7.0	0.3	0.1	0.08	19.7
15	5	82	125	99.0	1.2	3.5	4.3	6.4	4.6	4.8	8.1	67.1	22.1	8.0	6.0	0.02	0.00	0.51	0.08	6.4	11.4	7.5	0.2	0.1	0.06	19.2

Si/AG	DIFPH	ECEC	CEC	
.57	1.1	25.4	35.3	100
.49	1.3	24.8	31.6	100
.31	1.6	20.4	27.2	100
.12	1.7	19.9	25.6	100
.19	2.0	19.2	25.0	100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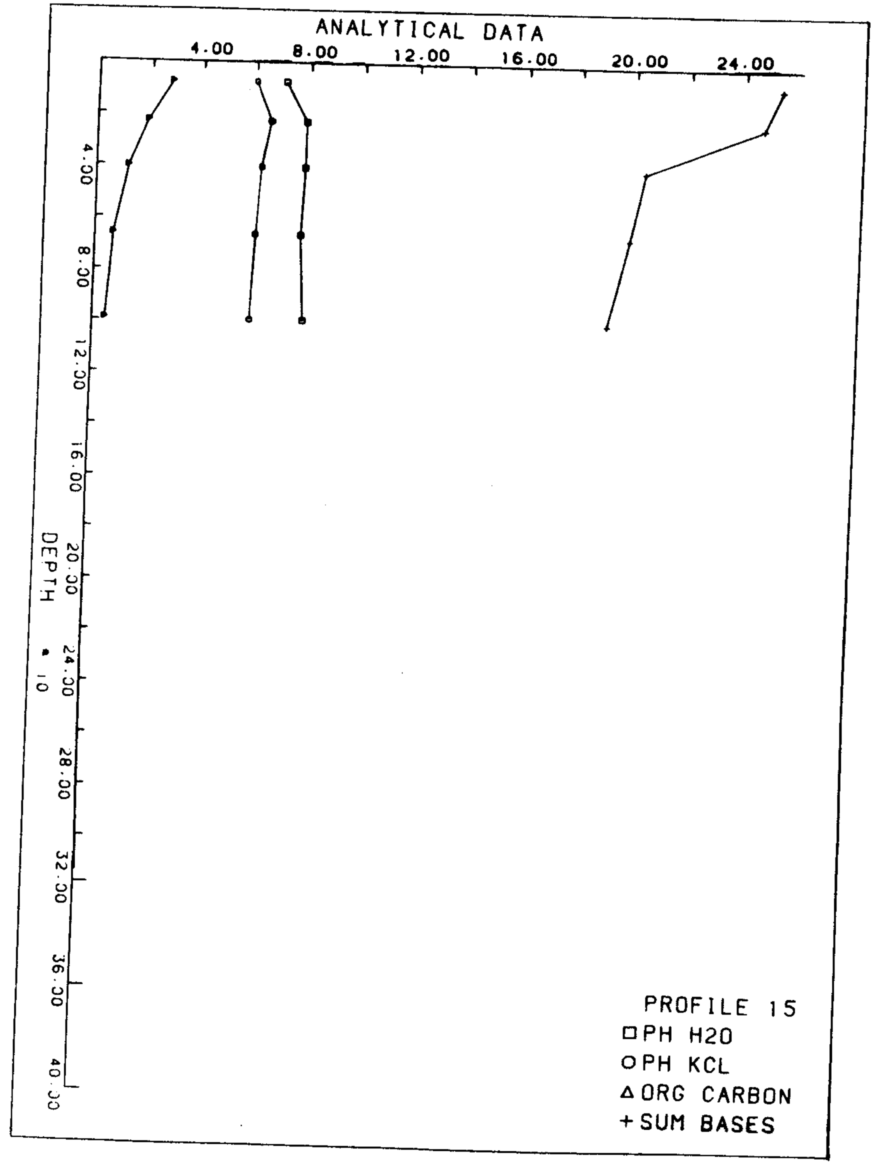
12.00
16.00
20.00
24.00
28.00
32.00
36.00
40.00
PROFILE 15
CLAY
FSILT
CSILT
FSAND2
FSAND1
CSAND3
CSAND2
CSAND1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DEPTH * 10
4.00
8.00
12.00
16.00
20.00
24.00
28.00
32.00
36.00
40.00
PROFILE 15
PH H20
PH KCL
ORG CARBON
SUM BASES

Code ISM MOÇ5/N2 Year 1983 Country Moçambique

Lab. no.	depth cm	SiO_2	Al_2O_3	Fe_2O_3		CaO	MgO	K_2O	Na_2O	TiO_2	MnO	P_2O_5	BaO	ign. loss	∑	SiO_2/Al_2O_3	SiO_2/Fe_2O_3	SiO_2/R_2O_3	Al_2O_3/Fe_2O_3
		elemental composition of the total soil (weight %)														Molar ratios			
3033	0-15	50.30	20.80	10.27		3.61	1.96	0.91		0.81	0.13	0.11	0.04	10.77	99.71				
34	15-30	49.44	21.53	11.09		3.31	1.84	0.75		0.81	0.14	0.04	0.03	10.12	99.10				
35	30-50	47.10	23.77	11.47		2.29	1.49	0.65		0.85	0.12	0.02	0.02	11.95	99.73				
36	50-82	44.75	27.94	11.82		1.37	1.11	0.45		0.73	0.09	0.01	0.01	11.70	100.00				
37	82-125	44.17	26.90	12.67		2.19	1.70	0.33		0.70	0.11	0.02	0.01	10.80	99.60				
38																			

elemental composition of the clay fraction (weight %) — Molar rations

Lab. no.		SiO_2	Al_2O_3	Fe_2O_3		CaO	MgO	K_2O	Na_2O	TiO_2	MnO	P_2O_5	BaO	ign. loss	∑	SiO_2/Al_2O_3	SiO_2/Fe_2O_3	SiO_2/R_2O_3	Al_2O_3/Fe_2O_3

Code ISM MOÇ-5 Year 1983 Country Moçambique

Lab. no.	Depth cm	Kaol	Mi/Ill	Verm	Chlor	Smec	Mix			Quar	Feld	Gibb	Goeth	Hem
3-33		++				+				0-tr.			tr.	tr.
34		++				+				0-tr.			tr.	tr.
35		++				+				0-tr.			tr.	tr.
36		+++				tr-+				0-tr.			tr.	tr.
37		+++				tr-+				0-tr.			tr.	tr.

MON. NO	CEC 1*	CEC 2** (gebufferd pH=7)	CEC gem.***	CEC (ongebufferd)
83-33	35.3	36.8	36.1	33.1
-34	31.6	33.1	32.4	30.5
-35	27.2	28.0	27.6	26.2
-36	25.6	25.7	25.7	23.0
-37	25.0	23.1	24.1	21.9

\+ 202 } uitgedrukt in meq/100 gr grond
++ 202
+++ 202

PROFILE: N 3 (MOC 6)

Date of examination: 28 November 1982 (start of rainy season);
repeat: 27 April 1983 (end of rainy season)

Authors : J.H. Kauffman, M. Vilanculos

<u>Higher category classification</u>

- (FAO-UNESCO, 1974)
- (Soil Taxonomy, 1975)

<u>Environmental information</u>

Location : Mozambique, Nampula, Nampula, Nova Chaves
Coordinates : 15°18' S, 39°07' E
Elevation : 450 m
Landform : middle planation surface, (weakly) undulating; irregular interfluves, bare rock inselbergs frequent
Slope of site: straight/irregular, gradient %, length m; position: upper slope
Vegetation : fallow grasses + herbs (see annex)
Land use : shifting cultivation, small farmer, cassave/cashew
Climate : Unimodal, P = , Ep = , about 6 months dry; L.R. = 350 mm (see annex)

<u>General information on the soil</u>

Parent material : Basement; granite (see annex)
Drainage conditions : well drained, 0-120 cm, > 120 cm imperfectly
Moisture conditions : 0-165 cm moist
Ground water level : probably deep subsoil > 150 cm is saturated during some period in rainy season
Termitaria : dome-shaped mounds, medium/large, < 1/ha; also few chimney-shaped mounds present
Surface characteristics: -

<u>Miscellaneous</u>

Local soil name : -

<u>Brief description of the profile</u>

A deep, well drained, yellowish red sandy clay (loam), with a loamy sand topsoil and deeper than 150 cm having a strongly mottled low permeable subsoil.

DE	HORIZON DEPTH	BOUND	COLOUR	TEXTURE	STRUCTURE	CONSISTENCY D	M	W	CUTANS	POROSITY	ROOTS	OTHER CHARACTERISTICS
ı	0-21	c-s	10YR3/1	LS	w f/m sb	.	l	ns+np	-	vm f	m vf	
	21-52	c-s	7.5YR3.5/2	LS	w m[1] sb	.	l	ns+np	-	vm f	m vf	
:	52-121	g-s(w)	5YR4/6	SCL/SC	pm-wc	.	vfr	ss+sp	p f C(?)	m vf/f	c vf/f	
:g	121-165+		2.5YR4/6	SC	w m ab	vh	fr	s+sp	-	m vf/f	f vf/f	many 10YR7/1 + 10YR6/6 mottling

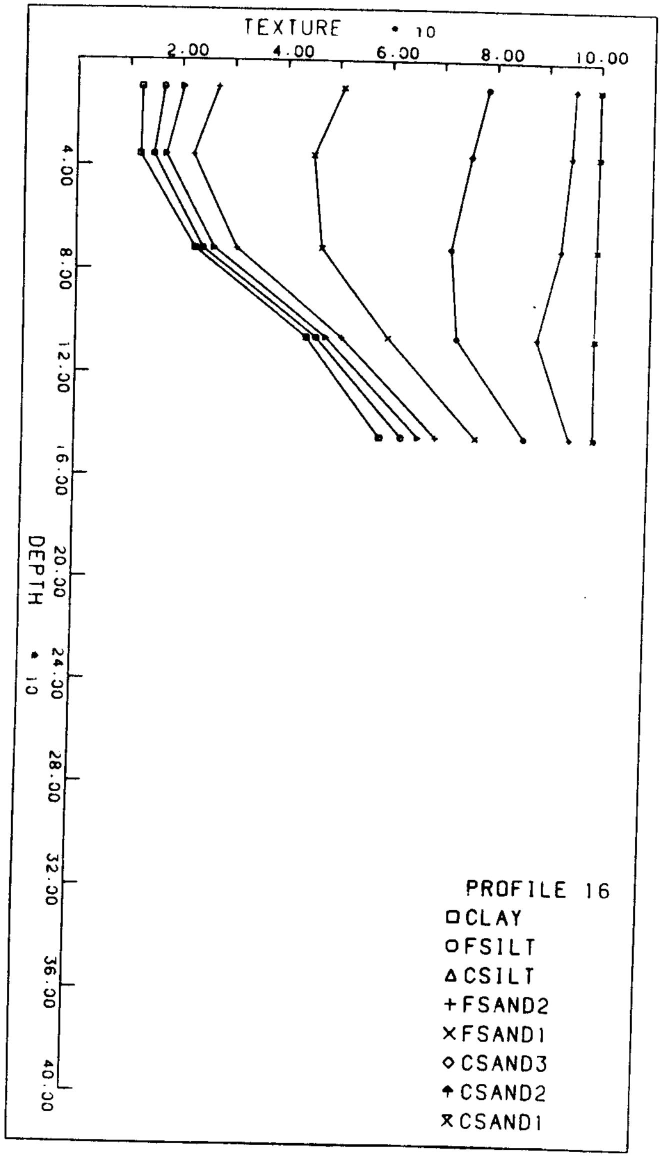
<u>e</u>

'tructure of topsoil can be also described as single grain or massive porous/weakly coherent.
n topsoil are holes filled with redder coloured subsoil; in subsoil are holes filled with darker coloured topsoil.
.t 90 cm one can observe a slight increase in clay content.
'ermite holes are present, density about $2/m^2$.
'he strongly mottled subsoil is caused by temporarily stagnant water.

1	2	BEG	END	AVE	CS1	CS2	CS3	FS1	FS2	SI1	SI2	[illegible]	~~DISP~~	H2O	KCl	H+Al	Al	C	N	C/N	Ca	Mg	K	Na	EC	
16	1	0	21	10.5	4.7	16.7	27.6	23.9	6.7	3.7	4.3	12.3	10.2	6.3	5.7	0.00	0.00	1.03	-.10	-.10	2.2	0.4	0.1	0.0	0.05	2.7
16	2	21	52	36.5	5.4	19.0	30.2	22.9	5.3	2.4	2.6	12.2	12.4	6.2	4.8	0.10	0.00	0.22	-.10	-.10	0.8	0.2	0.1	0.0	0.04	1.1
16	3	52	93	72.5	7.0	21.0	24.7	16.3	4.2	2.2	1.5	23.1	3.4	6.0	4.7	0.10	0.00	0.49	-.10	-.10	1.2	0.2	0.1	0.0	0.04	1.5
16	4	93	121	107.0	11.2	15.3	13.2	8.8	3.0	1.9	1.9	44.6	10.8	5.9	5.1	0.10	0.00	0.45	-.10	-.10	1.8	0.3	0.1	0.0	0.04	2.2
16	5	131	160	145.5	4.6	8.8	9.2	7.7	3.4	3.3	4.1	58.9	2.3	6.2	5.6	0.00	0.00	0.27	-.10	-.10	3.1	0.5	0.0	0.0	0.03	3.6
16	6	275	310	292.5	12.8	15.2	11.7	8.9	4.5	7.0	9.0	30.8	2.5	5.5	5.4	0.00	0.10	0.22	-.10	-.10	0.2	0.8	0.1	0.0	0.03	1.1
16	7	325	375	350.0	12.8	12.4	7.7	4.9	2.6	5.3	8.3	46.0	2.0	5.4	4.7	0.20	0.20	0.25	-.10	-.10	0.3	1.1	0.1	0.0	0.04	1.5

Si/AG	DIFPG	ECEC	CEC	
.65	.6	2.7	5.4	100
.41	1.4	1.2	2.5	92
.16	1.3	1.6	4.0	94
.09	.8	2.3	4.3	96
.13	.6	3.6	5.5	100

→ better have rerun analysis or might be a clue for discontinuity. Perhaps ineffective dispersion due to narrow ΔpH in sample before the last - rather probability of dispersed with hexametaphosphate.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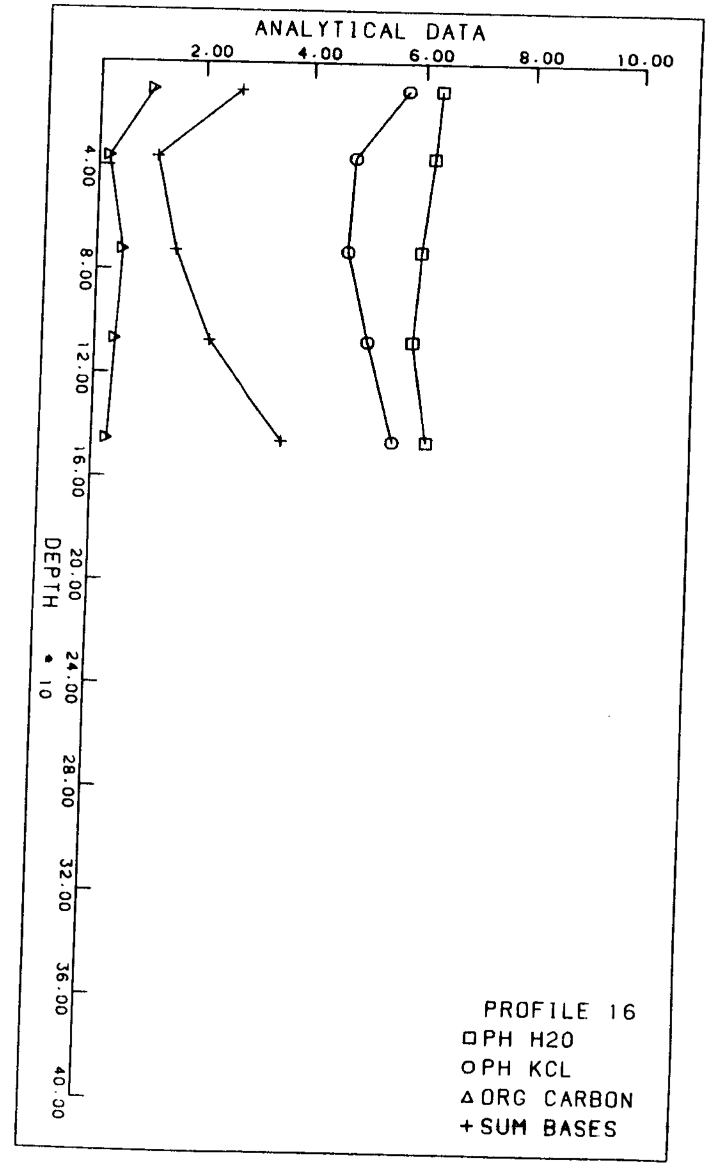
2.00
4.00
6.00
8.00
10.00
DEPTH * 10
4.00
8.00
12.00
16.00
20.00
24.00
28.00
32.00
36.00
40.00
PROFILE 16
□CLAY
○FSILT
△CSILT
+FSAND2
×FSAND1
◇CSAND3
CSAND2
CSAND1


ANALYTICAL DATA
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4.00
6.00
8.00
10.00
DEPTH * 10
4.00
8.00
12.00
16.00
20.00
24.00
28.00
32.00
36.00
40.00
PROFILE 16
□PH H20
○PH KCL
△ORG CARBON
+SUM BASES

Code ISM *MOC-6* Year Country *MOÇAMBIQUE* D

Lab. no.	Depth cm	Kaol	Mi/Ill	Verm	Chlor	Smec	Mix			Quar	Feld	Gibb	Goeth	Hem
83-449		+++	tr.							tr.	tr.		tr-x	
450		+++	tr							tr	o-tr		tr-x	
451		+++	o-tr							tr	o-tr		tr-x	
452		+++	-							a	o-tr		tr-x	
453		+++	-							o-tr	-		tr-x	
454		+++	-							o-tr	-		X	
455		+++	-							o-tr	-		X	

Lab. no	Sand mineralogy

Annex 3 - Exchange properties

Overview of analytical procedures to determine exchange properties

Solution (extractant)		Elements to calculate CEC	Measured CEC	NH_4^+-ions
pH	salt	Extracted cations	Exchanged cations	retained
"soil"	KCl/NH_4Cl	Aluminium (Al)f or NH_4 retained	all cations = CEC(f); NH_4Cl	$(NH_4^+)f$
7	NH_4OAc	Ca, Mg, Na, K (Bases)7	all cations = CEC(7); NH_4OAc	
8.2	BaCl	(H + Al) 8.2		

Terminology for Cation Exchange Capacities

ECEC = (Bases)7 + (Al)f = "effective CEC" or "sum of bases plus extractable Al"

ECEC = $(NH_4^+)f$ = "me of NH_4-ions retained by unbuffered NH_4Cl solution"

CEC(7) = "cation exchange capacity"

CEC(8.2) = (Bases)7 + (H + Al) 8.2 = "sum of cations"

Terminology for Base Saturation Percentages

$$BS\ (7) = \frac{(bases)7}{CEC\ 7} \times 100$$

$$BS\ (8.2) = \frac{(bases)7}{CEC\ 8.2} \times 100$$

$$BS\ (f) = \frac{(bases)7}{ECEC} \times 100$$

Overview of the exchange properties criteria used in ST and FAO

SOIL TAXONOMY

Oxic horizon

- ECEC $\leqslant 10$ me/100 g clay (for both analytical procedures)
- CEC(7) $\leqslant 16$ me/100 g clay

Ultisol

- BS (8.2) < 35% at a depth of (about) 180 cm
- Often used in the assumed correlation: 35% BS (8.2) ≈ 50% BS (7)

Mollic epipedon

- BS (7) > 50%

Oxic subgroup

- CEC(7) $\leqslant 24$ me/100 g clay in the major part of the argillic horizon

Acri (sub)group

- CEC < 1.5 me/100 g clay (for both analytical procedures)

Haplustox

- BS (7) < 50% when clayey
- BS (7) < 35% when loamy

FAO

Mollic horizon

- BS (7) > 50%

Oxic horizon

- ECEC < 10 me (for both analytical procedures)
- CEC(7) < 16 me

Acrisols and dystric subgroups

- BS (7) < 50% in at least a part of the B horizon within 125 cm of the surface

Annex 4 - List of participants

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Mr. F.N. Muchena, Kenya
Mr. R. Sant'Anna and colleague, Ghana
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Drs. R. Voortman, Mozambique
Drs. J. van Wambeke, Mozambique