EXCHANGE CHARACTERISTICS, CLAY-SILT MINERALOGY AND CLASSIFICATION OF SOME YELLOWISH SEDIMENTARY SOILS IN THE TIKO PLAIN AREA, SOUTH-WEST CAMEROON

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ABSTRACT

The rather flat and monotonous landscape of the Tiko plain area in South-West Province, Cameroon, suggests an equally uniform soil pattern at first sight, but a recent detailed soil survey in the area revealed a wide variety in soils. Though most of the soils have pale yellowish brown colours, they differ in texture, effective depth to laterite crust, gravel content, drainage and mineralogical and chemical properties. We discuss the soil conditions in Tiko plain on the basis of seven profiles. Emphasis is put on the exchange characteristics of the soils and the mineralogy of their silt and clay fractions. Based on these data the soils are classified in three classification systems ; the US Soil Taxonomy, the FAO World Soil Map Legend System and the French CPCS System.

RESUME

A première vue le paysage assez plat et monotone de l'aire de la plaine de Tiko dans la province du Sud-Ouest, Cameroun, suggère une répartition de sols assez uniforme. Cependant une prospection détaillée dans la région a révélé une grande variété de sols. Bien que la plupart des sols sont de couleur brun jaunâtre pâle, ils montrent une diversité en texture, profondeur effective jusqu'à la cuirasse, teneur en gravillons, drainage et propriétés minéralogiques et chimiques. On discute des conditions pédologiques dans la plaine de Tiko à partir de sept profils. L'accent est mis sur les caractéristiques d'échange des sols et sur la minéralogie des limons et des argiles. Ensuite les sols sont classés, par référence à la Soil Taxonomy, à la Carte Mondiale FAO et à la Classification Française CPCS.

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INTRODUCTION

Tiko plain is an old, slightly uplifted, tilted and dissected coastal plain of low relief stretching out at the southeastern foot of the Cameroon volcano (4070m). The plain is built up of thick layers of marine and deltaic deposits. According to Dumort (1968) these were laid down during the Tertiary (Mio-Pliocene), thus having about the same age as the early eruptiva in the Mount Cameroon area. When looking in detail Tiko plain consists of a series of fluvio-marine terraces at successive lower levels (Hasselo 1961) and at least part of the sediments are thought to have a younger, Quaternary age. The Mondoni area for instance (figure 1) should be regarded as a subrecent alluvial basin with deposits showing fresh stratification of sands and clays (Kips and others 1984). A low, abrupt terrain step, roughly coinciding with the 5m contour line forms the limit of the plain with the mangrove swamps to the SE. The 80m contour is the approximate limit with the Mount Cameroon slope to the NW.

Lithologically Tiko plain can be divided into two parts (Hasselo 1961): the so-called volcanic part with finely layered tuffites in the SW and the non-volcanic part in the NE (Fig.1). In this paper we concentrate on the non-volcanic part, which consists of unconsolidated sediments with fair amounts of quartz in the sand and silt fractions.

Typical for the non-volcanic part of Tiko plain are the large sheets of outcropping laterite duricrust ('ironcrust'). These occupy somewhat higher positions in the landscape, more resistant as they are to erosion. Residual soil covers on the crusts are rather shallow and contain high amounts of ironstone gravel (laterite rubble).

Temperature being fairly constant over the year (26°C), the seasons are distinguished by the rainfall pattern with one rainy season from June through September (500 to 600 mm in August) and one very distinct dry season from December to mid-March (10 to 15 mm in December). April-May and October-November are intermediate periods with about 100 to 200 mm a month. Rainfall decreases from about 2700 mm (yearly total of Tiko airport)in the S to about 1680 mm in the N (Mondoni oilpalm estate) and this trend is caused by the increasing rain-shadow influence of Mount Cameroon in this direction.

The studied part of Tiko plain is under rubber (*Hevea brasiliensis*). Small areas are in use for subsistence farming with maize, yams, cassava and plantains as main crops.

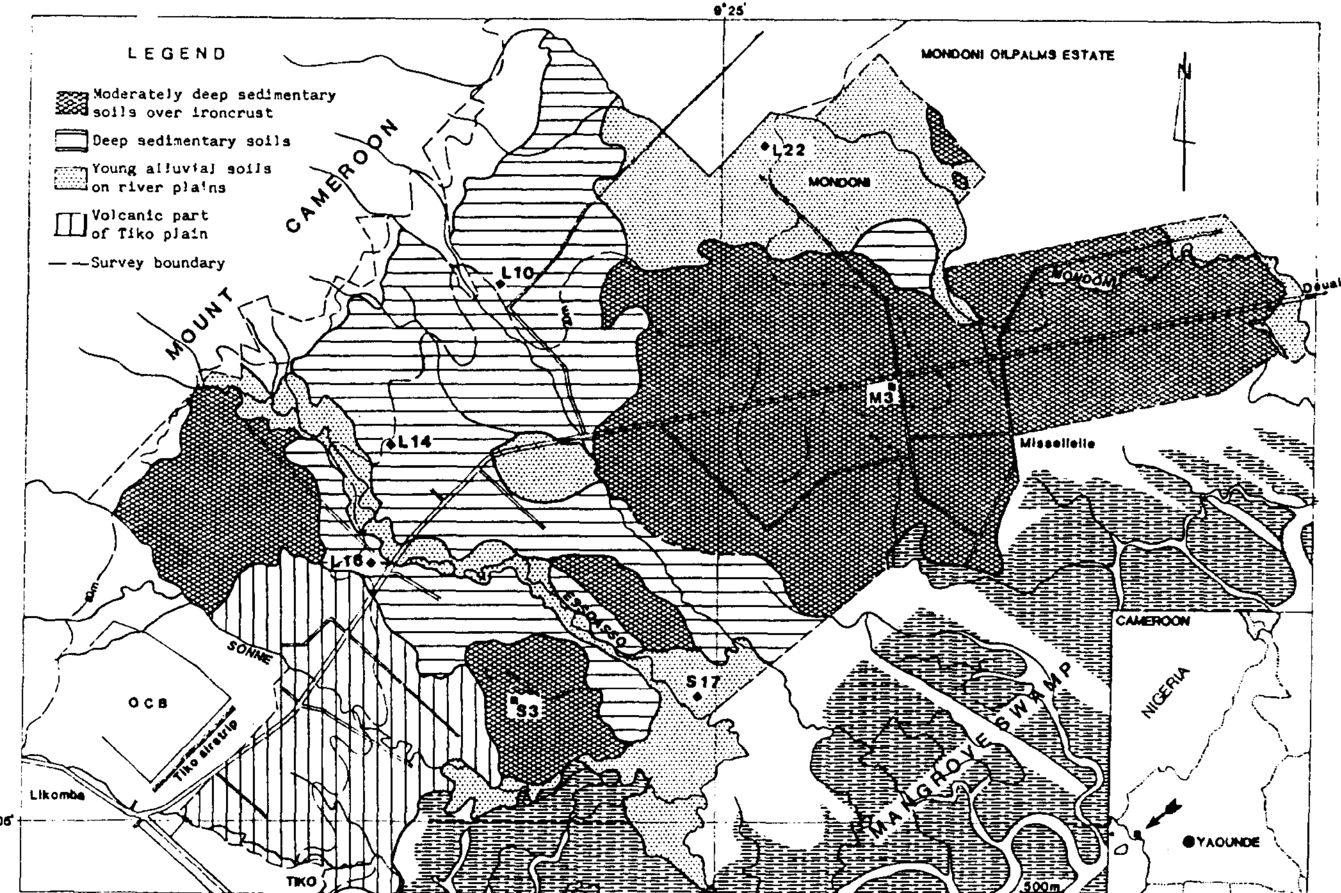

Fig. 1 : Physiography and major soils of Tiko plain

MATERIALS AND METHODS

Seven profiles were selected. These are coded L 10, L 14, L 16, L 22, M 3, S 3 and S 17. These profiles practically cover the full range of soils on the plain. Each of the profiles is itself the typifying pedon of a soil series or soil variant distinguished during soil mapping. Detailed profile descriptions are given in the survey report (Kips and others 1984), sites are indicated in figure 1.

In the laboratory the following analyses were carried out :
- organic carbon
- texture; 3 fractions, sand, silt and clay
- pH in water and 1N KCl, using a 1:1 soil-reagent ratio
- exchange characteristics by leaching with different salts (table 1)
- 'free' iron, by citrate-dithionite extraction
- mineralogical composition of the silt and clay fractions (B horizons) by X-ray diffraction with different pretreatments.

Cation Exchange Capacity And Base Saturation

For classification purposes CEC is determined at pH7 with NH4OAc (CEC7), or at pH 8.2 with BaCl2-triethanolamine (CECS). For acid soils like those on Tiko plain this has the disadvantage that values obtained are higher than those at the actual soil pH. More realistic measures are the effective CEC (ECEC) and CEC-NH4Cl, since these involve leaching with unbuffered salts, i.e. KCl and NH4Cl, determined at the ambient pH of the soil.

As to base saturation the situation is reverse. Base saturation calculated from CECS (BS8.2) or from CEC7 (BS7) is underestimated, making the soil more acid than it is. When calculated from ECEC (BS-ECEC) it more accurately reflects field conditions.

Aluminium Saturation (Al-sat)

High Al saturation strongly inhibits root growth and the uptake of calcium and phosphorus by the plant. If Al-saturation is above 60% a crop like maize is seriously affected. Cassava and certain fruittrees can withstand Al-saturation up to about 75% (Sanchez 1976). Rubber on Tiko plain seems unaffected even at very high Al-saturation, i.e. more than 90%.

RESULTS

Morphology Of The Soils

On the basis of their morphological field characteristics the soils can be combined into three groups (figure 1) :

I Moderately deep sedimentary soils over ironcrust These are the Tiko series and the Tiko deep variant. Tiko soils are weakly structured moderately well drained, (yellowish) brown (10YR 5/3, 5/4) very gravelly clays. They contain about 80% densely packed ironstone gravel in the B horizon. In many places their surface is paved with iron gravel and bestrewn with large ironcrust fragments. Noteworthy are also the scattered basalt boulders and blocs on the surface. The underlying rigid ironcrust is at depths between 50 and 100 cm. The crust cannot be cut with a spade and is practically impenetrable to roots. It has a vesicular appearance with many irregular pores filled by the fine earth. Tiko deep variant soils are like Tiko soils but here only the lower part of the B horizon is gravelly while the ironcrust beneath is at depths between 100 and 150 cm.

acronym	definition	unit
AC8.2	Extractable acidity. Substance content in dry soil of acidity extracted with BaCl2-triaethanolamine at pH 8.2	meq/100g
Al	Substance content in dry soil of aluminium exchanged in 1N KCl	meq/100g
Al-sat	Al at the adsorption complex at pH-KCl of the soil divided by bases plus Al	%
Bases	Exchangeable bases (sum of K, Na, Ca and Mg). Substance content in dry soil of bases exchanged in 1N NH4OAc at pH7	meq/100g
BS7	Base saturation. Bases divided by CEC7	%
BS8.2	Base saturation on CECS. Bases divided by CECS	%
BS-ECEC	Base saturation on ECEC. Bases divided by ECEC	%
CEC7	Cation exchange capacity in dry soil at pH7 with 1N NH4OAc.	meq/100g
CEC-clay	Cation exchange capacity of the clay fraction (uncorrected for organic matter). CEC divided by mass fraction of clay	meq/100g
CEC-NH4Cl	Cation exchange capacity in dry soil with unbuffered NH4Cl	meq/100g
CECS	Cation exchange capacity by sum of cations. Sum of AC8.2 and bases	meq/100g
ECEC	Effective cation exchange capacity. Sum of bases, Al and H	meq/100g
H	Exhangeable hydrogen. Substance content in dry soil of acidity exchanged in 1N KCl minus Al	meq/100g

Table 1 : Exchange characteristics, definitions and acronyms

II Deep sedimentary soils These surround the soils over ironcrust of group I and occupy somewhat lower positions in the landscape. To this group belong the Mafanja series, the Sonne series and the Camp 7 Likomba series. Mafanja soils are moderately well drained moderately structured yellowish brown (10YR 5/6) sandy clay loams. Sonne soils are moderately well drained, well-structured light olive brown (2.5Y 5/4) clays that have prominent motlling with plinthite in the lower subsoil. Camp 7 Likomba soils are like Sonne soils but have a gravelly stoneline (ironstone gravel) in the BC or lower B horizon and do not have plinthite.

III Young alluvial soils on river plains These are the Mondoni series and the Essoasso series. They occupy the lowest positions in the landscape. Mondoni soils are along Mondoni river. They are poorly drained, weakly structured mottled clays over sandy clay loams and sandy loams and these again over clays. Typically they are layered with abrupt boundaries and have intercalated sand lenses in the topsoil. Essoasso soils are mainly on low terraces along the Essoasso river. Typical for this series is the rather dark colour (10YR 4/4) of the AB and upper B horizons, reflecting a comparatively high content of organic matter. Texture is heavy clay. Essoasso soils are somewhat poorly or moderately well drained.

Mineralogy

The most common minerals present in B horizons of all soils are quartz, feldspars, kaolinite, goethite and anatase. B horizons of soils around the lateritic crusts and on river plains (group II and III soils) contain, besides the above minerals, mica and smectite. In these latter samples features indicating mixed layers are present. On the X-ray patterns the mixed layers are shown by first order reflections (around 2.4 nm), but in most cases, a first order ray cannot be noticed, and the mixed layers can be recognized only by broad second order reflections situated between 1.0 and 1.4 nm.

The irregular broad reflections between 1.0 and 1.4 nm, followed by a gradual collapse on proceeded heating, may be due to the presence of irregular mica-vermiculite and/or mica-smectite mixed layers. These mixed layers are composed of an irregular succession of mica layers of 1.0 nm, and open layers, the basal spacing of which varies according to the saturating cation. Replacing Mg by K and subsequent heating make the open layers collapse gradually down to 1.0 nm. In some soils a clear reflection at 0,485 nm is noticed, probably due to the presence of gibbsite.

Mineralogy of the silt fraction (table 2) The silt fraction of the soils over the laterite crusts (group I soils) is characterized by a rather high amount of quartz, some kaolinite, anatase, a reflection at 0.485 nm which is probably due to gibbsite, and traces of feldspar. The silt fraction of the soils around the laterite crusts (group II soils) contains more kaolinite and more weatherable minerals : feldspar and micaceous layers of which part has swelling properties. This last feature is best expressed in the soils on the lowest parts of the plain (group III soils). The presence of smectite layers in the silt fraction can be an indication of pseudo-particles, possibly due to an incomplete separation.

Mineralogy of the clay fraction (table 2) The clay fraction of the soils over the laterite crusts only contains an important amount of kaolinite, some goethite and traces of quartz. The soils around the crusts have, besides these minerals, an important amount of 2/1 minerals with variable basal spacing, smectites, as well as micaceous layers, partly swelling.
A striking observation in this sequence is the gradual increase of smectite

Soil	silt fraction									clay fraction								
	quartz	feldspars	mica	mixed layers	smectite	kaolinite	goethite	gibbsite	anatase	quartz	feldspars	mica	mixed layers	smectite	kaolinite	goethite	gibbsite	anatase
Tiko deep variant	++++	(+)	-	-	-	+	-	++	+	(+)	-	-	-	-	++(+)	+	-	-
Mafanja series	++(+)	+++	(+)	-	-	++	(+)	-	+	+	-	+(+)	+	+	+++	+	-	-
Sonne series	+++	+++	(+)	-	-	++	(+)	+	+	+	-	+	+	++	+++	(+)	-	-
Camp 7 Likomba series	+++	+++	(+)	-	-	++	(+)	-	+	+	-	+	+	++	+++	(+)	-	-
Mondoni series	++	++	+	+	+	+++	(+)	(+)	+	+	-	+	++	+++	+++	+	-	-
Essoasso series	++	++	++	(+)	(+)	+++	(+)	+	+	+	-	+	++	++++	++++	(+)	(+)	-

relative amounts: ++++ predominant +++ high amount ++ moderate + very small (+) trace - absent

N.B. Tiko series not analysed

Table 2 : Silt and clay mineralogy of B horizons (control sections)

in the soils in lateral direction from the laterite crusts towards the lowest parts of the plain.

Chemical And Physical Properties (table 3)

Organic carbon In all soils, except Mondoni series, organic carbon decreases regularly with depth. In general organic carbon contents are low, (lowest values in group I soils) but in the A and AB horizons of Mondoni series and Essoasso series (group III soils) the levels are markedly higher. This is thought to be related to the poorer drainage of these soils causing a less perfect mineralisation of organic matter.

pH Most soils are very strongly acid with pH water values between 4.5 and 5.0. Tiko deep variant and Sonne series are extremely acid with pH between 4.0 and 4.5 in the B horizon. All soils have negative ΔpH (pH-KCl minus pH water) indicating net negative charge and thus capacity to exchange cations (Mekaru and Uehara 1972).

Cation exchange capacity The trend in the majority of the soils is : CECS > CEC7 > CEC-NH4Cl > ECEC. This is in conformity with the theoretical consideration that CEC depends on the acidity of the saturating solution and strongly increases with pH and electrolyte concentration (Parfitt, 1980). In Tiko series CEC-NH4Cl is higher than CEC7. This discrepancy was observed earlier in certain Inceptisols and Ultisols from Southeast Asia (Subagyo and Buurman 1980) and is as yet unexplained. ECEC values (topsoils) increase from group I to group III soils. In most soils ECEC and CEC7 values differ by a factor 1.5 to 3. In Mafanja soils this factor is much higher and this deviation is not understood.

Aluminium saturation Tiko series, Tiko deep variant and Sonne series have high aluminium saturation (> 80% in AB or upper B horizons). Aluminium saturation is very low in Mafanja series and Mondoni series (< 35%), corresponding to high base saturations over ECEC. Camp 7 Likomba series has an intermediate value (45%).

Classification

In table 4 the soils are classified in the US Soil Taxonomy (USDA 1975), the FAO-Unesco World Soil Map Legend System (1974) and the French CPCS System (1967). Some data, notably those on the weatherable minerals of the sand fractions and micromorphological data, are not available and therefore some ascriptions are tentative. The calculated soil moisture regime is ustic according to Van Wambeke (1982), using a hypothetic freely drained profile. In our opinion Tiko plain soils are border cases between udic and ustic. Until decisive data are available we have adopted a udic moisture regime for the soils, since all soils have more or less impeded drainage and we suppose that these remain moist long enough in most years to classify as such.

All soils have ochric epipedons (Kips and others 1984). Tiko series and Tiko deep variant have oxic horizons with CEC7-clay of 16 meq or less and CEC NH4Cl-clay of 10 meq or less and/or bases plus Al of 10 meq per 100 g clay or less. Tiko series has a petroferric contact within a depth of 100 cm. Sonne series, Camp 7 Likomba series and Essoasso series have argillic horizons with shiny faces of peds that were interpreted as illuvial clay skins. In the first two of these soils the clay ratio of B horizons and AB horizon is more than 1.2 (1.4, 1.9). Essoasso series has an absolute clay increase of more than 8% from the A horizon to the AB horizon. Mafanja series and Mondoni series have cambic horizons. Mondoni soils have low chroma mottles due to wetness, within a depth of 100 cm. Essoasso soils have low chroma mottles within a depth of 75 cm.

Soil group	Horizon	Depth (cm)	pH H20	pH KCl	Texture clay (%)	Texture sand (%)	Org C	Exchangeable bases (meq/100g soil)	Exchangeable Al	Exchangeable H	CEC-soil CEC7 (meq/100g soil)	CEC-soil NH4Cl	CEC-soil ECEC	CEC-soil CECS	CEC-clay CECS (meq/100g clay)	CEC-clay NH4Cl	CEC-clay CEC7	Base saturation BS7 (%)	Base saturation BS8.2	Base saturation BS-ECEC	Al-sat (%)	Fe2O3 (%)
I	Tiko series (profile M3)																					
	Ap	0- 5	4.3	3.8	46.8	34.9	0.88	0.1	1.98	0.46	5.6	4.6	2.6	13.1	28	10	12	3	1	4	93	0.4
	Bo	- 25	4.7	3.8	65.4	33.6	0.73	0.0	2.21	0.56	5.3	-	2.8	-	-	-	8	0	-	0	99	0.4
	Boc	- 75	4.7	3.7	73.2	25.5	0.62	0.0	1.91	0.32	6.0	7.1	2.2	14.5	20	10	8	0	0	0	100	0.2
	BCsm	-100	4.6	4.0	37.8	41.9	0.59	0.3	1.40	0.05	5.1	6.4	1.7	13.7	36	17	14	6	0	18	83	0.4
	Tiko deep variant (profile S3)																					
	Ap	0- 10	4.2	3.9	26.5	64.4	0.81	1.0	1.51	0.00	4.7	3.3	2.5	8.9	34	12	18	21	11	39	61	2.3
	Bo1	- 40	4.4	3.9	35.9	52.4	0.68	0.5	2.07	0.44	6.0	4.3	3.0	8.5	24	12	17	9	6	17	80	2.7
	Bo2	- 90	4.2	3.8	49.0	45.3	0.71	0.5	2.07	0.00	6.4	5.5	2.6	8.3	17	11	13	8	7	21	79	2.9
	Boc	-120	4.2	3.8	50.6	43.8	0.66	0.9	2.07	0.72	6.9	5.8	3.7	7.7	15	12	14	13	11	24	70	3.7
	BCsm	-150	5.2	3.9	25.7	49.3	0.51	13.2	0.98	0.10	20.0	14.6	14.3	22.6	88	57	78	66	58	92	7	6.6
II	Mafanja series (profile L10)																					
	Ap	0- 5	4.8	4.4	16.7	78.7	1.10	3.9	0.63	0.07	21.6	4.6	4.6	-	-	27	129	18	-	85	13	3.5
	AB	- 20	4.8	4.2	18.1	75.1	0.52	2.0	0.44	0.08	19.2	3.0	2.5	-	-	17	106	10	-	80	18	3.5
	Bw1	- 60	5.1	4.0	21.5	70.1	0.38	1.6	0.87	0.03	18.5	3.3	2.5	-	-	15	86	9	-	64	35	4.5
	Bw2	-105	4.9	3.8	32.9	62.6	0.26	2.4	1.82	0.94	20.7	7.2	5.2	-	-	22	63	12	-	46	42	5.7
	BCw	-145	5.2	3.8	31.3	63.4	0.15	4.2	2.12	1.43	14.4	6.0	7.8	-	-	19	46	29	-	54	34	1.6
	BCg	-175	4.2	3.9	11.6	77.7	-	0.8	0.66	0.17	14.1	1.5	1.6	-	-	13	122	5	-	50	46	5.5
	Sonne series (profile L16)																					
	Ap	0- 5	4.7	4.4	24.8	41.8	1.34	3.5	2.18	0.00	12.5	6.4	5.6	14.9	60	26	50	28	23	61	39	5.7
	AB	- 15	4.1	3.7	29.5	35.3	0.93	0.7	1.84	0.46	11.5	6.0	4.0	12.9	44	20	39	6	5	18	81	4.4
	Bt	-105	4.2	3.5	44.7	26.3	0.33	1.0	-	2.53	13.9	12.3	-	16.6	37	28	31	7	6	-	-	6.3
	Btg	-145	4.7	3.5	58.7	18.4	0.29	1.2	-	-	17.9	15.4	-	19.3	33	26	31	7	6	-	-	4.4
	BCtgv	-190	4.6	3.5	58.9	21.7	0.13	1.2	1.64	-	22.5	18.2	-	27.4	47	31	38	5	4	-	58	12.5
	Camp 7 Likomba series (profile L14)																					
	Ap	0- 10	4.9	4.3	29.0	52.7	0.87	3.4	0.82	0.00	10.5	5.5	4.3	-	-	19	36	33	-	79	19	4.0
	AB	- 35	4.7	3.8	34.6	34.7	0.51	2.1	1.69	1.57	10.9	5.7	4.4	-	-	17	31	20	-	48	45	5.9
	Bt1	- 85	4.6	3.7	49.6	28.2	0.43	1.6	-	-	13.4	8.3	-	-	-	17	27	12	-	-	-	8.4
	Bt2	-110	4.7	3.7	53.6	21.8	-	2.0	-	-	17.9	11.4	-	-	-	21	33	11	-	-	-	9.2
	BCc	-135	4.8	3.8	36.9	45.5	0.15	1.9	-	-	16.6	11.0	-	-	-	30	45	11	-	-	-	12.4
	BCg	-185	4.6	3.6	55.5	13.2	0.17	2.0	-	-	19.8	14.7	-	-	-	26	36	10	-	-	-	8.4

* results based on oven-dry weight

Table 3 : Physical and chemical properties of yellowish soils in the tiko plain area*

Soil group	Horizon	Depth (cm)	pH H2O	pH KCl	Texture clay %	Texture sand %	Org C	Exchangeable bases (meq/100g soil)	Exchangeable Al	Exchangeable H	CEC-soil CEC7 (meq/100g soil)	CEC-soil NH4Cl	CEC-soil ECEC	CEC-soil CECS	CEC-clay CECS (meq/100g soil)	CEC-clay NH4Cl	CEC-clay CEC7	Base saturation BS7 (%)	Base saturation BS8.2	Base saturation BS ECEC	Al-sat (%)	Fe2O3 (%)
III	Mondoni series (profile L22)																					
	Ap	0- 6	5.0	3.8	35.7	9.5	2.52	22.1	0.08	0.59	33.8	24.4	22.8	38.4	108	68	95	65	58	97	0	5.8
	AB	- 20	4.8	3.8	77.2	11.9	1.74	20.6	0.14	0.69	30.0	19.9	21.4	33.1	43	26	39	69	62	96	1	1.8
	Bw1	- 32	4.7	3.6	55.1	27.5	0.94	14.8	0.50	2.22	22.5	20.2	17.5	23.9	43	37	41	66	62	85	3	6.8
	3Bw3**	40-65	4.8	3.6	50.7	35.3	0.76	11.2	0.46	1.83	18.0	16.5	13.5	25.4	50	33	36	62	44	83	4	8.9
	3BCg	-120	4.8	3.8	53.3	31.4	0.60	14.0	0.23	1.25	21.9	18.8	15.5	29.7	56	35	41	64	47	90	2	2.3
	4Cg1	-140	4.8	3.9	31.6	62.2	0.57	9.1	0.09	0.50	10.4	8.9	9.7	15.9	50	28	33	87	57	94	1	2.6
	4Cg2	-175	4.8	3.9	18.0	79.0	0.41	6.0	0.07	0.53	7.2	6.9	6.6	11.1	62	39	40	84	54	91	1	1.4
	5Cg3	-200	5.1	3.6	59.8	20.8	0.76	8.0	-	-	17.7	-	-	-	-	-	30	45	-	-	-	-
	Essoasso series (profile S17)																					
	Ap	0- 25	5.0	3.7	55.8	14.0	2.10	10.7	-	-	17.4	16.2	13.7	25.5	-	29	31	62	42	-	-	2.0
	ABt	- 60	5.0	3.5	69.7	4.7	1.38	7.8	-	-	26.5	20.2	17.4	31.4	-	29	38	30	25	-	-	6.2
	Bt	- 80	4.9	3.4	79.8	4.3	1.02	6.2	-	-	26.5	19.6	18.2	29.3	-	25	33	24	21	-	-	3.1
	Btg	-105	4.9	3.4	23.6	6.8	0.87	5.1	-	-	24.2	19.8	17.3	27.7	-	27	33	21	19	-	-	6.3
	BCg1	-145	5.0	3.6	63.4	22.7	0.65	2.2	-	-	11.1	9.7	7.5	13.8	-	15	18	20	16	-	-	0.7
	BCg2	-180	4.9	3.6	57.6	19.0	0.68	1.2	-	-	9.9	10.3	6.8	14.2	-	18	17	12	9	-	-	0.8

* results based on oven-dry weight
** intercalated sand lens 32 to 40 cm not sampled

Table 3 (continued)

Soil	Soil Taxonomy	FAO-Unesco	CPCS
Tiko series	Typic Haplorthox, clayey-skeletal, kaolinitic, isohyperthermic, shallow	Orthic Ferralsols	Sols Ferrallitiques fortement désaturés, remaniés, indurés
Tiko deep variant	Tropeptic Haplorthox, clayey over clayey-skeletal 1), oxidic, isohyperthermic	Orthic Ferralsols	Sols Ferrallitiques fortement désaturés, remaniés , indurés
Mafanja series	Typic Dystropepts, fine-loamy, oxidic, isohyperthermic	Ferralic Cambisols	Sols Ferrallitiques moyennement désaturés, typiques, jaunes
Sonne series	Plinthic Tropudults, clayey, oxidic/ kaolinitic 2)/mixed 3), isohyperthermic	Ferric Acrisols	Sols Ferrallitiques fortement désaturés, lessivés, modaux
Camp 7 Likomba series	Typic Tropudults, clayey, kaolinitic/ mixed 3), isohyperthermic	Ferric Acrisols	Sols Ferrallitiques moyennement désaturés, remaniés, jaunes
Mondoni series	Fluvaquentic Eutropepts, fine, mixed, isohyperthermic	Gleyic Cambisols	Sols Hydromorphes peu humifères, à gley peu profond
Essoasso series	Aquic Tropohumults, clayey, mixed, isohyperthermic	Humic Acrisols	Sols Hydromorphes peu humifères, à pseudogley

1) contrasting particle size class created
2) if smectite < 10% and extractable Fe2O3 (%) plus gibbsite (%) divided by clay < 0.2
3) if smectite > 10%

Table 4 : Classification of the soils

CONCLUSION

Soils on Tiko plain have a wide variety in properties. They differ in texture, effective depth, gravel content, drainage and mineralogical and exchange characteristics. A striking phenomenon is the increase in smectite levels in the soils from the highest to the lowest parts of the plain. This could be related to its geomorphic history being built up of (fluvio-)marine terraces at successive lower levels (Hasselo, 1961). The residual soils on the laterite crusts are the oldest and most weathered ones in which all smectites were transformed to kaolinite and oxides of iron and aluminium, while the stratified river basin soils are young and still contain high amounts of "transformable" smectite. However drainage may play a role as well. With drainage becoming more impeded at lower levels more smectities may have been formed by neo-formation and/or preserved.

Soils on the laterite crusts classify as Typic ans Tropeptic Haplorthox. Those around the crusts classify as Typic Distropepts and Plinthic and Typic Tropudults. Soils of the river plains classify as Fluvaquentic Eutropepts and Aquic Tropohumults.

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