A CLINO-SEQUENCE OF RED AND BROWN SOILS ON BASALT IN THE NKAMBE AREA, NORTH-WEST CAMEROON : CHARACTERIZATION, CLASSIFICATION AND AGRICULTURAL IMPLICATIONS

E.T. AWAH*, Ph. A. KIPS**, H. Ng MOUKOURI KUOH***, F. TCHUENTEU****

ABSTRACT

Soil patterns in the Nkambe area are complicated due to the variety of rock types present and the overall mountainous, relief-rich nature of the terrain. Geomorphologically the area has a staircase configuration consisting of a number of superimposed basalt and trachyte plateaus, surrounded by lower denudation surfaces on basement rock, dissected to various degrees of steepness.

We describe a sequence of seven soils on basalt along a transect stepwise in profile, going from the high plateau of Nkambe down to the lower levels. After describing the morphology of the soils, their physico-chemical properties are discussed. Based on these data the soils are classified in the US Soil Taxonomy and the French CPCS System. In this way an area-specific correlation is established between these two systems. Finally the agricultural use and potential of the soils are briefly discussed.

RESUME

La répartition des sols dans la zone de Nkambe est compliquée par la variété lithologique et la nature globale accidentée et montagneuse du terrain. La géomorphologhie de la zone consiste en plusieurs plateaux basaltiques et trachytiques entourés de niveaux de dénudation plus bas sur socle, tous disséqués à divers degrés. On décrit une séquence de sept sols sur basalte le long d'une coupe transversale, descendant du haut plateau de Nkambe jusqu'aux niveaux inférieurs. Leurs caractéristiques physico-chimiques sont discutées. A partir de ces données, les sols sont classés dans la " Soil Taxonomy " et la Classification CPCS Française. Une tentative de corrélation, valable pour cette zone, est établie entre ces deux systèmes. Enfin le potentiel agronomique des sols et leur mise en valeur sont brièvement discutés.

* National Soil Centre IRA-Ekona CAMEROON

** FAO/UNDP Soil Resources Project IRA-Ekona CAMEROON

*** National Soil Centre IRA-Nkolbisson CAMEROON

**** National Soil Centre IRA-Ekona CAMEROON

INTRODUCTION

The Nkambe area in NW Cameroon lies between Latitude 6° and 7° N and Longitude 10° and 11° E in the lower savannah belt of Cameroon. The area is part of the SW-NE stretching Western Highland Range with general minimum altitudes of 1000m. The highest peak is Mount Oku (3011m) in the centre of the area (figure 1).

Geomorphologically the area has a staircase configuration made up of a number of superimposed trachyte and basalt plateaus surrounded by lower planation surfaces on basement rock, dissected to various degrees of steepness. In the western part of the area recent volcanic ash sheets are present locally, blanketing the residual weathering mantle.

Average rainfall is between 2000 and 3400 mm per annum mostly falling from June to October. The area experiences a marked dry season from December to mid-March. November, April and May are intermediate months (figure 2). Large differences in temperature exist that are related to altitude (Hawkins and Brunt 1965). For every 100 m rise in elevation temperature decreases by about 0.5 to 0.6°C. Nkambe town is at 1650 m altitude and has an average yearly temperature of 20°C. Temperatures are fairly constant over the year.

Soil patterns in the area are complicated due to the variety of rock types present and the overall mountainous, relief-rich nature of the terrain. Even over short distances soils may differ considerably in such characteristics as texture, effective depth and gravel content.

Agriculturally the Nkambe area is very powerful. The lands are used intensively for subsistence farming with maize as major crop, apart from groundnuts, yams, beans, irish potatoes, carrots, plantains etc. The major cash crop is coffee, grown by smallholders. In savannah areas extensive cattle rearing is important. Burning of grasses takes place every year in January and February to promote vigorous regrowth when the rains start in March.

The National Soil Centre of Cameroon is at this time carrying out a reconnaissance soil survey and land evaluation of the area at the 1:200 000 scale. The data presented in this paper are drawn from this survey.

MATERIALS AND METHODS

We describe a sequence of seven soils on basalt along the so-called ring-road from Nkambe in western direction to Misaje and Tricorner Ketambo (figure 1). The transect is stepwise in profile from the high plateau to the lower levels. The soils were described macroscopically in the

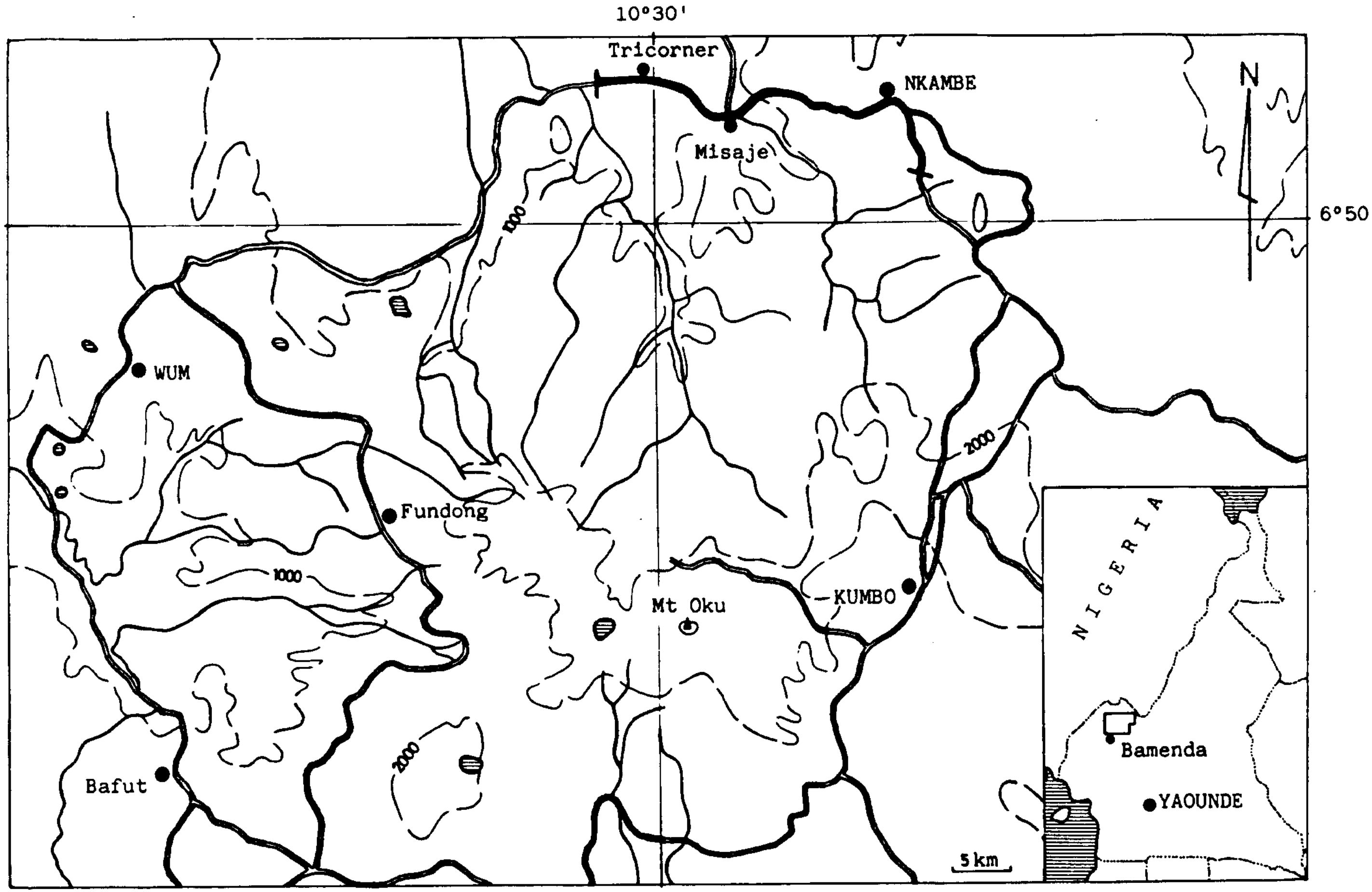

Fig. 1 : The Nkambe area

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	Exchangeablebases. 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
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	Exchangeable hydrogen. Substance content in dry soil of acidity exchanged in 1N KCl minus Al	meq/100g

Table 1 : Definitions of exchange characteristics and acronyms used

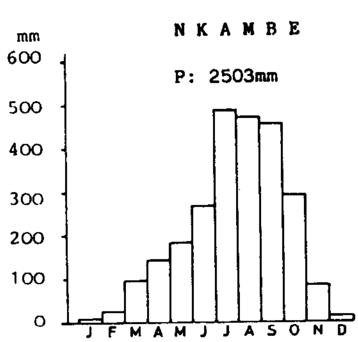

Fig. 2 : Rainfall histogram of Nkambe

field and five soils were sampled. In the laboratory following analyses were done:

- organic carbon (C) by Walkley-Black wet combustion method
- total nitrogen (N) by Kjeldahl digestion method
- texture; 3 fractions, sand, silt, clay (USDA standard technique)
- pH in water and 1N KCl using a 1:2.5 and 1:1 soil-reagent ratio respectively
- exchangeable bases K^+, Na^+, Ca^{++}, Mg^{++} in NH4OAc at pH7
- cation exchange capacity in NH4OAc, pH7
- exchangeable $Al^{+++}$and H^+ in 1N KCl
- extractable acidity (Al^{+++} and H^+) in BaCl2, pH 8.2

Exchange Characteristics

From the above basic exchange properties we calculated a number of derived parameters that further characterize the soils (table 1).

Cation Exchange Capacity (CEC)

CEC is a measure of the ability of the soil to retain and supply plant nutrients. For classification (Soil Taxonomy) CEC is determined at pH 7 with NH4OAc (CEC7), or at pH 8.2 with BaCl2 triethanolamine (CECS). For acid soils like those in the Nkambe area this leads to an overestimation of the exchange capacity under field conditions. A more realistic measure is the effective CEC (ECEC) since this involves leaching with unbuffered KCl, hence determination is at the ambient pH of the soil.

Base Saturation (BS)

For base saturation the situation is reverse. When calculated from CECS (BS8.2) or from CEC7 (BS7) it is underestimated making the soil more leached than it actually is. This in turn may lead to mis-interpretations as to the use and management of the soils. Base saturation calculated from ECEC (BS-ECEC) more accurately reflects true field circumstances.

Aluminium saturation (Al-sat)

The amount of adsorbed aluminium relative to the amount of other cations is an indication of possible toxicity of aluminium for plant growth. High aluminium saturation strongly inhibits root growth and the uptake of calcium and phosphorus by the plant. Crops have varying tolerancies to aluminium (Sanchez 1976). Liming strongly reduces Al-saturation.

RESULTS

Morphology of the soils (figure 3)

The rolling Nkambe plateau (±1650m) is characterized by three soils with similar physiographic positions; one is a deep, red very gravelly clay (TBA16); the other is a deep dark red silty clay over very gravelly clay (TBA2) and the last one is moderately deep very gravelly and stony reddish brown clay over a fractured laterite crust (TBA1). Gravel and stones are mostly reddish ironscrust fragments and yellowish brown ferruginous basalt gragments. The gravelly horizons in these profiles make part of one'stoneline', varying in thickness and depth from place to place. Leaving the plateau the first steep escarpment slope has a moderately deep strong brown clay soil over soft dark-multicoloured basalt saprolite with silt loam texture (MSA2). On the

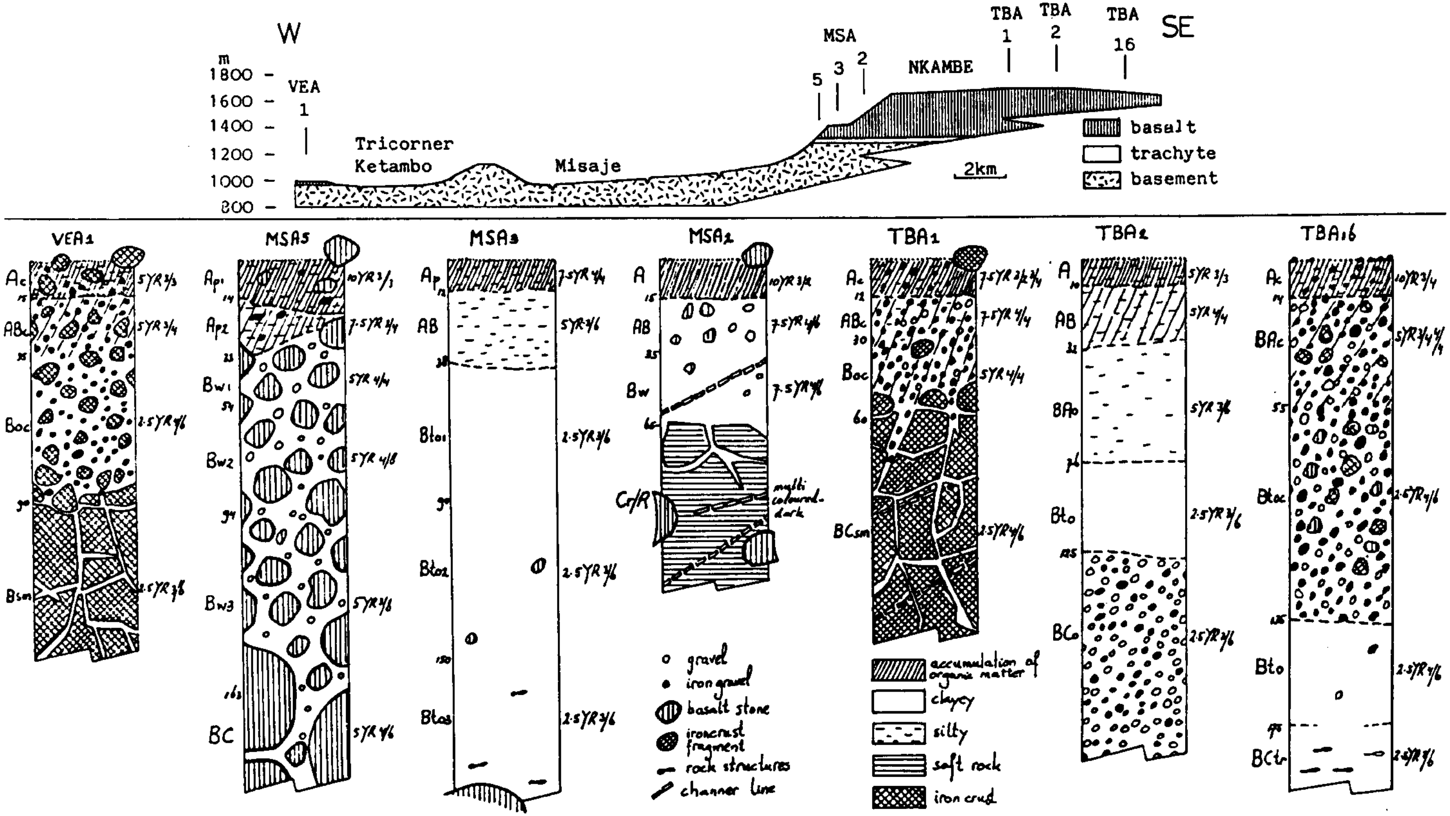

Fig. 3 : The soil sequence and the profiles

first lower level, a sloping shoulder at 1400m altitude with distinct slope breaks at both ends, the soil is again deep. It is a dark red clay with some basalt fragments in the deeper subsoil (MSA3). Going down further, the second steep escarpment slope has soils like MSA2, but also towards to foot of the escarpment, soils built up of slope materials: large mostly unweathered basalt stones and boulders embedded in a reddish brown and yellowish red clay matrix (MSA5). Finally, on the rolling lowest level ($\pm$ 1000m) an indurated soil is present. It is a moderately deep very gravelly (ironcrust fragments) clay over a fractured, slightly dislocated laterite crust with deep fingery interpenetrations of fine earth (VEA1). This soil is not extensive and is completely surrounded by soils on basement rock.

All soils of the sequence have moderate subangular blocky structure in the B horizon. Except for profile MSA2 the soils have good porosity with many fine tubular pores within the peds. Permeability is estimated moderate in topsoils and moderately slow in subsoils. In profile MSA2 porosity is distinctly less and permeability is estimated slow.

Physico-chemical Properties (table 2)

Profiles TBA1 and MSA3 were not sampled. Consequently they will not be considered in the following discussion.

pH Most soils are strongly acid with pH water between 5 and 5.5 in B horizons. Profile VEA1 is very strongly acid with pH between 4.5 and 5. In profile TBA16 pH decreases slightly with depth. In profiles TBA2 and MSA5 pH increases distinctly with depth. The escarpment soils MSA2 and MSA5 have negative Δ pH (pH-KCl minus pH water) in all horizons, pointing to net negative charge (cation exchange capacity, Mekaru and Uehara 1972). The red soils (TBA16, TBA2 and VEA1), have positive Δ pH in lower B horizons and BC horizons, thus indicating a change to net positive charge (anion exchange capacity) with depth. Net negative charge points to the presence of oxides of iron and aluminium (Uehara and Gillman 1981).

Organic carbon and organic carbon/nitrogen ratio Organic carbon is high, above 5%, in all topsoils; with depth it decreases regularly to values of 0.5 to 1%. C/N values are in the range of 10 to 15 in all topsoils except in profile VEA1. Here C/N is very high, pointing to an extremely poor mineralisation of organic matter and strong nitrogen deficiency.

Texture Topsoils of the red soils on the Nkambe plateau (TBA16, TBA2) are rather silty. In profiles TBA16, TBA2 and MSA5 there is a distinct clay increase with depth followed by a decrease. In profile MSA2 and VEA1 clay is more or less constant with depth. The basaltic saprolite substratum of profile MSA2 is low in clay and high in silt.

Cation exchange capacity In all soils CECS is higher than CEC7 and CEC7 is higher than ECEC. This is in conformity with theoretical considerations that CEC depends on the acidity of the saturating solution and strongly increases with pH and electrolyte concentration (Parfilt 1980, Uehara and Gillman 1981). In the red soils CECs are low and decrease regularly with depth. In the brown and reddish brown escarpment soils they are higher and show a more erratic behaviour. CEC7 and CECS differ by a factor 3 to 8 in the red soils; for the escarpment soils this factor is 2 or less. ECEC and CEC7 differ with a factor of generally more than 10 in the red profiles of the Nkambe plateau (TBA16, TBA2), in the other profiles this factor is about 5.

Horizon	Depth (cm)	pH H2O	pH KCl	Texture clay (%)	Texture silt	Texture sand	Org C (%)	C/N	Exchangeable bases (meq/100g soil)	Exchangeable Al	Exchangeable H	CEC-soil CEC (meq/100g soil)	CEC-soil CEC7	CEC-soil ECEC	CEC-clay CECS (meq/100g clay)	CEC-clay CEC7	CEC-clay CEC7-cor.[2)]	Base saturation BS8.2 (%)	Base saturation BS7	Base saturation BS-ECEC	Al-sat (%)
Profile TBA16																					
Ac	0- 14	5.3	4.3	37.9	51.5	10.6	5.3	11	1.4	1.20	0.00	67.5	27.9	2.6	178	74	18	2	5	53	47
BAc	- 55	5.5	4.4	47.4	21.7	30.9	4.0	15	0.7	0.66	0.00	43.8	16.2	1.3	92	34	17	2	4	50	50
Btoc	-135	5.2	4.7	61.1	18.5	20.8	2.0	13	0.2	0.06	0.28	34.4	10.1	0.6	56	17	3	1	2	40	21
Bto	-175	5.2	5.3	69.7	20.6	9.7	0.7	9	0.2	0.00	0.06	20.3	5.3	0.3	29	8	4	1	5	80	0
BCtr	-200	4.9	5.0	65.0	20.4	14.7	0.6	10	0.2	0.00	0.10	20.8	5.2	0.3	32	8	4	1	5	81	0
Profile TBA2																					
A	0- 10	5.5	4.4	39.2	56.7	4.0	5.5	12	4.3	0.68	0.00	70.4	23.5	5.0	180	60	4	6	18	86	14
AB	- 32	5.4	4.5	43.2	52.4	4.4	4.2	16	1.3	0.52	0.00	57.4	17.1	1.9	133	40	1	2	8	72	28
BAo	- 76	5.4	4.5	51.8	45.1	3.2	2.6	15	2.2	0.38	0.00	43.3	10.6	2.5	84	20	0	5	20	85	15
Bto	-125	5.6	5.3	62.4	30.5	7.1	1.2	12	0.3	0.00	0.02	21.5	4.0	0.3	34	6	neg	1	7	93	0
BCo	-190	5.6	5.7	45.3	36.4	18.4	0.6	10	0.3	0.00	0.00	19.4	2.5	0.3	42	6	0	1	12	100	0
Profile MSA2																					
A	0- 15	5.2	3.8	57.7	35.4	6.9	5.4	11	5.5	-	1.38	82.1	42.0	-	142	72	35	7	13	-	-
AB	- 35	5.0	3.7	57.7	31.9	10.4	3.7	13	1.0	-	0.00	60.1	30.3	-	104	53	27	2	3	-	-
Bw	- 65	5.1	3.6	58.9	32.7	8.4	1.9	11	2.5	-	0.00	53.3	29.8	-	90	51	38	5	8	-	-
Cr/R	- 160	5.1	3.4	12.4	60.7	26.9	0.5	17	0.7	-	0.00	52.8	40.1	-	426	323	307	1	2	-	-
Profile MSA5																					
Ap1	0- 14	5.5	4.6	36.4	39.4	24.2	5.8	10	12.0	0.00	0.20	73.1	38.7	12.2	201	106	43	16	31	98	0
Ap2	- 33	5.6	4.5	35.4	40.8	25.2	5.8	12	7.5	0.17	0.23	73.6	39.3	7.9	208	111	46	10	19	95	2
Bw1	- 54	5.4	3.9	58.3	20.9	20.7	3.2	14	1.4	1.92	0.10	52.2	23.2	3.4	90	40	18	3	6	41	58
Bw2	- 94	5.4	4.5	58.7	22.2	19.0	1.8	11	1.1	1.96	0.06	38.9	16.7	3.1	66	28	16	3	6	35	65
Bw3	-163	5.6	3.9	62.4	15.1	22.4	0.8	9	3.8	0.00	0.16	29.1	14.4	3.9	47	23	18	13	26	96	0
BC	-200	5.7	4.5	47.6	34.8	17.7	0.9	8	6.2	0.00	0.10	34.0	17.1	6.3	71	36	28	18	36	98	0
Profile VEA1																					
Ac	0-15	4.8	4.0	37.9	39.5	23.0	6.3	158	1.4	2.06	0.00	75.0	15.5	3.5	198	41	neg	2	9	41	59
ABc	-35	4.6	4.2	41.8	18.7	39.6	4.8	119	1.1	1.20	0.00	33.9	10.5	2.3	123	25	neg	3	11	49	52
Boc	-90	4.8	5.0	43.9	27.4	28.9	2.0	101	0.8	0.14	0.00	21.6	5.1	0.9	49	12	neg	4	16	85	15
Bsm	-200	5.0	5.6	43.5	33.5	21.9	1.0	49	0.7	0.06	0.00	16.4	2.3	0.7	38	5	neg	4	29	92	8

1) results based on oven-dry weight; profiles TBA1 and MSA3 not sampled

2) calculation unreliable (see text)

Table 2 : Physico-chemical properties of the soils [1)]

CEC-clay values are invariably high in topsoils. In the red soils CEC-clay decreases with depth to values below 10 meq. In the escarpment soils CEC-cla increases again in the lowest horizon due to the influence of freshly weathered material containing minerals with high CEC.

The influence of organic matter on CEC can be assessed roughly by applying a correction factor (Buurman 1980). Before dividing by the mass fraction of clay 4 meq/g organic carbon is substracted from CEC7-soil. This correction brings down the CEC-clay values dramatically in topsoils of the red soils. Of course using the same correction for all horizons is not realistic, since the type of organic matter probably changes with depth (humic acid in topsoils, fulvic acid in subsoils). Where CEC-clay-corrected is negative the method is obviously wrong. Nevertheless it serves to illustrate the considerable influence of organic matter on the CEC of these soils.

Aluminium saturation High in profiles TBA16 and VEA (topsoils). On these soils the choise of crops in restricted if no amending fertilizer is applied.

Classification

In table 3 the soils are classified in the US Soil Taxonomy (USDA, 1975) and in the French CPCS System (1967). In both systems classification is at the subgroup level with a phase c.q. 'facies' addition on particle size class (Soil Taxonomy) and effective depth and gravel content (CPCS). Some data, notably those on weatherable minerals and micromorphological data (clay skins) are not available and therefore some ascriptions are tentative. All soils have udic moisture regimes. The temperature regime is isothermic for all soils except profile VEA1 that has an isohyperthermic temperature regime (Van Wambeke 1982).

Profile	Soil Taxonomy	CPCS
TBA16	Orthoxic Tropohumults (clayey-skeletal)	Sols Ferrallitiques fortement désaturés remaniés faiblement rajeunis (peu profonds, graveleux)
TBA2	Orthoxic Tropohumults (clayey)	Sols Ferrallitiques fortement désaturés remaniés modaux (profonds, non graveleux)
MSA2	Typic Humitropepts (clayey)	Sols Bruns 'eutrophes' tropicaux peu evolués (peu profonds, regosoliques)
MSA5	Oxic Humitropepts (clayey-skeletal)	Sols Bruns 'eutrophes' tropicaux ferruginisé (profonds, caillouteux)
VEA1	Tropeptic Umbriorthox (clayey-skeletal)	Sols Ferrallitiques fortement désaturés remaniés indurés (graveleux)

Table 3 : Classification of the soils

Profiles MSA5 and VEA1 have umbric epipedons, the other soils have ochric epipedons. Profile VEA1 has an oxic horizon with CEC7-clay of 16 meq or less and 10 meq or less of bases plus Al per 100g clay. Profiles TBA 16 and TBA2 have an argillic horizon with shiny faces of peds that were interpreted as clay skins. In both soils this is accompanied by an absolute clay increase of more than 8% (within 30cm) from the BA horizon to the B horizon. Profiles MSA2 and MSA5 have cambic horizons. Although there is a considerable clay increase in profile MSA5 from the A horizon to the B horizon, we did not detect clay skins in the B horizon. It is thought that the topsoil of this profile has lost clay downslope through the combined effect of farming and erosion. The A horizon is thoroughly worked, the soil surface has plow ridges and the slope is rather steep (25%).

DISCUSSION

When strictly applying the French classification to our soils, all red ones would classify as Sols Ferrallitiques fortement désaturés humifères, since these have a content of organic matter above 1% to a depth of 1 meter. In the Nkambe area nearly all red soils are sufficiently high in organic matter to classify as Sols Humifères, leading to an oversimplified soil map, limited in use. However the CPCS system is flexible and, given the kind and distribution of soils in a particular survey area and the scale of mapping, it is left to the surveyor to choose categories that will best set apart different soils. The objective is to produce soil maps that can be used as a basis for interpretations as to the use and management of the soils. In doing so the CPCS system serves as a general frame of reference, not as a strict key.

Although this approach may be acceptable within a given area to be surveyed, it creates enormous problems when correlating soils of different areas. It is clear that a correlation as the one in table 3 between CPCS and Soil Taxonomy is inevitably area-specific and cannot be applied outside the Nkambe area.

The application of Soil Taxonomy in naming the Nkambe soils also poses a problem. This concerns the concept of the argillic horizon. Placed at the highest (order) level of classification the presence or absence of the argillic horizon has a big impact on the naming of the soils. The argillic horizon is defined on the basis of a distinct increase in clay content within a depth of 30 cm, accompanied by clay skins formed by the accumulation of translocated clay from higher borizons. The identification of clay skins is subjective, both in the field and in the laboratory from thin-sections (McKeague and others 1980). Originally, one of the reasons for the distinction of the argillic horizon was its unfavourable physical properties. The argillic horizon would impede root growth and drainage because of the accumulation of translocated clay in pores (Buurman 1980). In the soils on the Nkambe plateau classified as Ultisols (TBA16 and TBA2) this is clearly not the case and the presence of clay skins is irrelevant to crop performance on these soils. In fact profiles TBA16 and TBA2 have exactly the same characteristics and horizon sequences as other soils on basalt in the Nkambe region that are classfied as Oxisols simply because they do not have clay skins. The depth and thickness of gravelly stonelines in these soils is of much greater agronomic significance than the presence of an argillic horizon. Mapping these soils as an Ultisols-Oxisols complex is not satisfactory.

PRESENT AND POTENTIAL LAND USE

Except for profiles TBA1 and MSA5, which are farmed, the soils are in use for extensive cattle rearing. This does not mean that these soils are unsuitabl for other agricultural uses; the reason for this is that the population is not dense and most of the arable farming is done near the villages. The following crops are grown: maize, irish potatoes, beans, carrots, plantains, yams. Coffee is a major cash crop.

When we consider the requirements of various crops and the quality of the lands we see that the rather shallow and fragile soils on steep slopes like MSA2 (MSA5) should best be put under forest, the rather shallow and gravelly plateau soils like VEA1 and TBA1 should be restricted to grass for cattle. The other soils are suitable for the crops grown in the area. Their major constraints to agriculture are low fertility, high Al-saturation, high gravel content (to be mapped out in detail) and poor communication. One industrial crop that can be considered on the Nkambe plateau is tea.

CONCLUSIONS

The stepwise sequence of soils on basalt from the high Nkambe plateau down to the lower levels shows that a strong relation exists between soil and slope. It is this characteristic that should be exploited when mapping the soils in the area. Where slopes are gentle (plateaus and shoulders) the soils are red and partly indurated and/or gravelly. Where slopes are steep (escarpment slopes) the soils are brown or reddish brown, shallow to parent rock or stony, formed in slope materials. Red soils have positive Δ pH in subsoils pointing to the presence of oxides of iron and aluminium and to an advanced stage of weathering. They have low CECs. The escarpment soils have largely opposite characteristics. The red plateau soils classify as Tropohumults and Umbriorthox, the escarpment soils as Humitropepts. Soils of the high Nkambe plateau are underexploited and have a potential for tea cultivation.

ACKNOWLEDGEMENT

Mr. P. Faure, ORSTOM-France, has visited most of the pits with us and helped with classifying the soils in the French System.

REFERENCES CITED

CPCS 1967. Classification des sols. Commission de Pédologie et de Cartographie des Sols. Mimeo.

Buurman P. (ed.) 1980. Red Soils in Indonesia. Pudoc, Wageningen, Netherlands 169 p.

Hawkins P. and M. Brunt 1965. The soils and ecology of West Cameroon (2 Vols.) FAO Report 2083, Project CAM/TE/LA, FAO, Rome.

McKeague J.A., R.K. Guertin, K.W.G. Valentine, J. Bélisle, G.A. Bourbeau, A. Howell, W. Michalyna, L. Hopkins, F. and L.M. Bresson 1980. Estimating illuvial clay in soils by micromorphology. Soil Sci. 129, No. 6, p 386-388.

Parfitt R.L. 1980. Chemical properties of variable charge soils. Chapt. 10 in B.K.G. Theng (ed.): Soils with variable charge. New Zealand Soc. of Soil Sci., Offset Publications Palmerston North, p 167-194.

Sanchez P. 1976. Properties and management of soils in the tropics. Wiley, New York, 618 p.

Uehara G. and G. Gillman 1981. The Mineralogy, chemistry and physics of tropical soils with variable charge clays. Westview Trop. Agr. Series No. 4. Westview Press Boulder Colorado 80301, USA, 170 p.

USDA 1975. Soil taxonomy. Agr. Handbook 436, US Government Print. Office, Washington, 754 p.

Van Wambeke A. 1982. Africa soil moisture and temperature regimes. SCS - Soil Management Support Serv. Ithaca, New York.