Soil Brief EC06

ECUADOR

Reference soil of the Amazon region

HAPLIC NITISOL
(Typic Kandiudult)

ISRIC Soil Monolith EC06

INTERNATIONAL SOIL REFERENCE AND INFORMATION CENTRE

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J.H. Kauffman
D. Creutzberg

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ISRIC
P.O. Box 353
6700 AJ Wageningen
The Netherlands

FOREWORD

The objective of a Soil Brief is to provide a description of a reference soil in its ecological setting. The Soil Brief is composed of a text part and data annexes.
The text part includes graphical presentations and provides a description and discussion of the major characteristics of the soil, its classification, and an evaluation of its soil/land qualities. If relevant, attention will be given to special topics such as erosion, soil formation etc.
In the annexes the soil and other environmental data, available from field, laboratory and office work are given.

The Soil Brief is written for soil specialists and non-soil specialists. For the latter the comprehensive information in the annexes is often too detailed and therefore requires further explication in the text. For the soil scientist the text part can be of use as it summarizes the important land and soil qualities, relevant aspects of soil management and soil formation. Furthermore, it provides access to additional information from research and discussions, which cannot be stored in the computerized database.

In 1987 the Ministerio de Agricultura y Ganadería (MAG) and the Museo Ecuatoriano de Ciencias Naturales in collaboration with the International Soil Reference and Information Centre (ISRIC) described and sampled twenty reference soils for the National Soil Collection of Ecuador. Duplicates of these soils were collected for ISRIC's world soil collection. The reference soils were taken from the four major ecological regions of Ecuador. Reference soil Ecuador 06 is representative for one of the dominant soils of the Amazon Region, and is described in this paper.

This report has been compiled in cooperation with J.H.V. van Baren, W.C.W.A. Bomer (graphics), M-B.B.J. Clabaut (text processing), L.P. van Reeuwijk (laboratory) of ISRIC, and G. del Posso of MAG (fieldwork).

Soil Brief EC06, being one of the first in the series of Soil Briefs, was sent to a number of colleagues for judgement. Valuable comments were received from N.H. Batjes, J.A.K. Boerma, V.W.P. van Engelen, G.R. Hennemann, D. Legger, Th. Paape, J.H.M. Pulles, L.R. Oldeman, A.J.M. van Oostrum and J. Sevink. From F. Maldonado comments were received on an earlier version.

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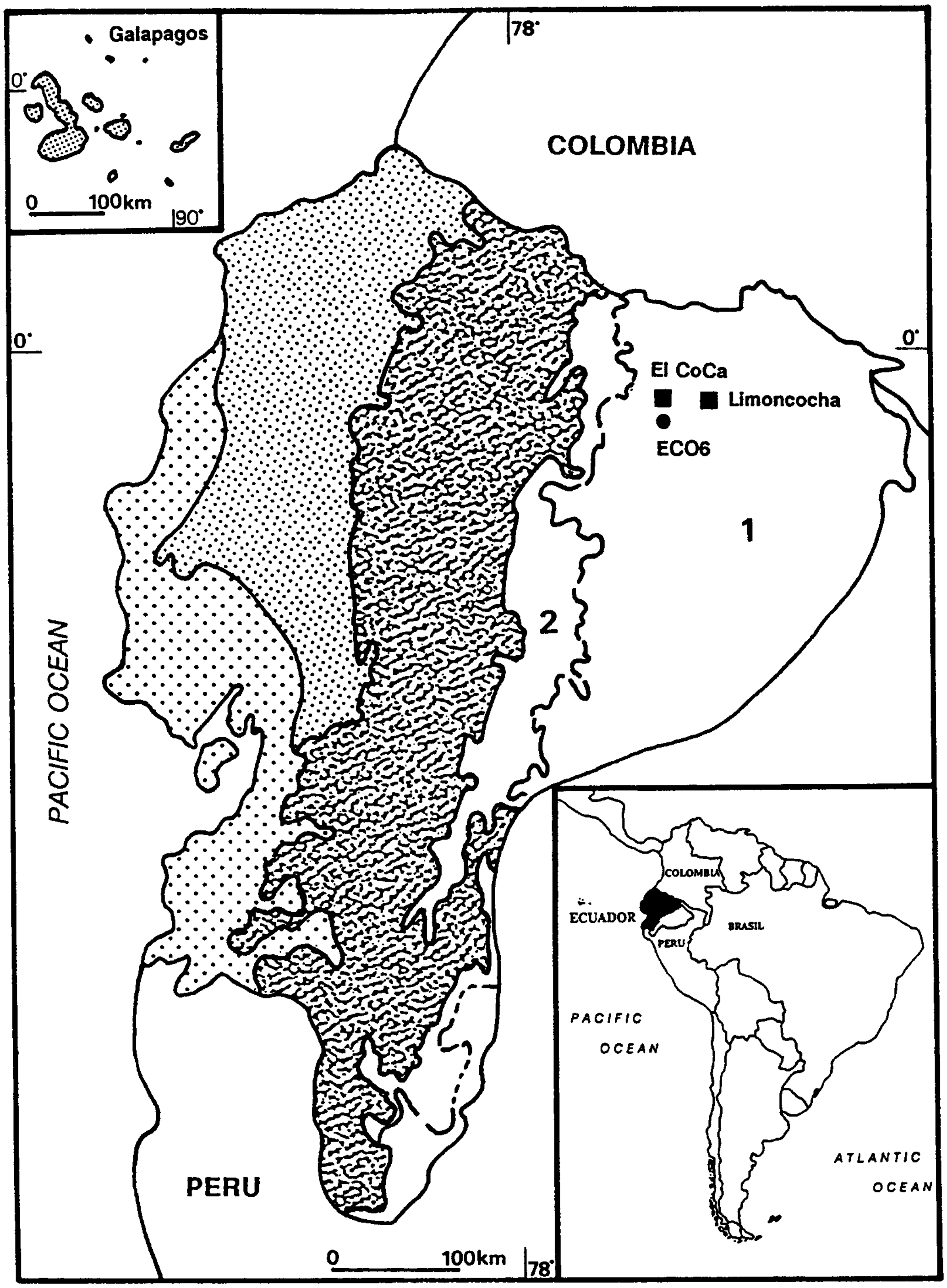
Figure 1 - Major ecological regions of Ecuador/Location map



LEGEND

COASTAL REGION

Moist (precipitation >1200 mm)

Dry (precipitation <1200 mm)

ANDES MOUNTAINS

AMAZON REGION

1 Low altitude (<600 meter)

2 High altitude (>600 meter)

GALAPAGOS ISLANDS

● Location and number of reference soil

■ Meteo stations

1 THE MAJOR ECOLOGICAL REGIONS OF ECUADOR

Ecuador can be divided into the following major ecological regions (fig. 1).

1. The Amazon Region
2. The 'Sierra' or Andes Mountains
3. The Coastal Region
4. The Galapagos Islands

A short characterisation of these regions is given below. More information is given in "Atlas del Ecuador" (Delavaud et. al., 1982) and the "Tour guide for Ecuador" (Beinroth et al., 1985).

East Ecuador forms part of the vast Amazon Basin, which extends into Brazil, Bolivia, Colombia, Peru and Venezuela. Most of this region is covered with tropical rainforest.
A first subdivision of the Amazon Region can be made according to altitude. The greater part is below 600 meter and has a level or a rolling topography. The transition zone towards the Andes Mountains is hilly or mountainous, with altitudes ranging from 600 to about 1200 meter.
In the Amazon Region, at both lower and higher altitudes, rainfall and temperatures are high throughout the year. Soils are derived from strongly weathered parent materials.
The soil under consideration in this paper is situated in the Amazon Region.

The Sierra forms part of the nearly continuous mountain range of the "Cordillera de los Andes" or Andes Mountains, which stretches north-south through South America. The Ecuadorian Andes is a high altitude mountainous area. The climate in terms of precipitation and temperature varies enormously, but can generally be characterized as temperate to cool with a pronounced dry season. Except for the southern Andes, soils are mainly derived from the thick volcanic ash layer covering the Ecuadorian Andes.

The Ecuadorian Coastal Region is for the greater part a (weakly) undulating plain of low altitude. The transition zone towards the Andes is a hilly or mountainous area. Another hilly area occurs in the western part of the Coastal Region. An important subdivision of the Coastal Region can be made according to climate: a moist tropical climate in the north and central part, and a semi-arid climate in the south. The latter region forms part of the coastal desert region of Peru and Chili.

The Galapagos Islands comprise a number of volcanic islands in the Pacific Ocean, located at about 1000 km west of Ecuador. The landscape of each island is determined by one or more volcanoes surrounded by nearly flat to undulating low altitude coastal areas. The climate is related to altitude, from dry and warm at low altitude to very moist and cool at high altitude.

Figure 2

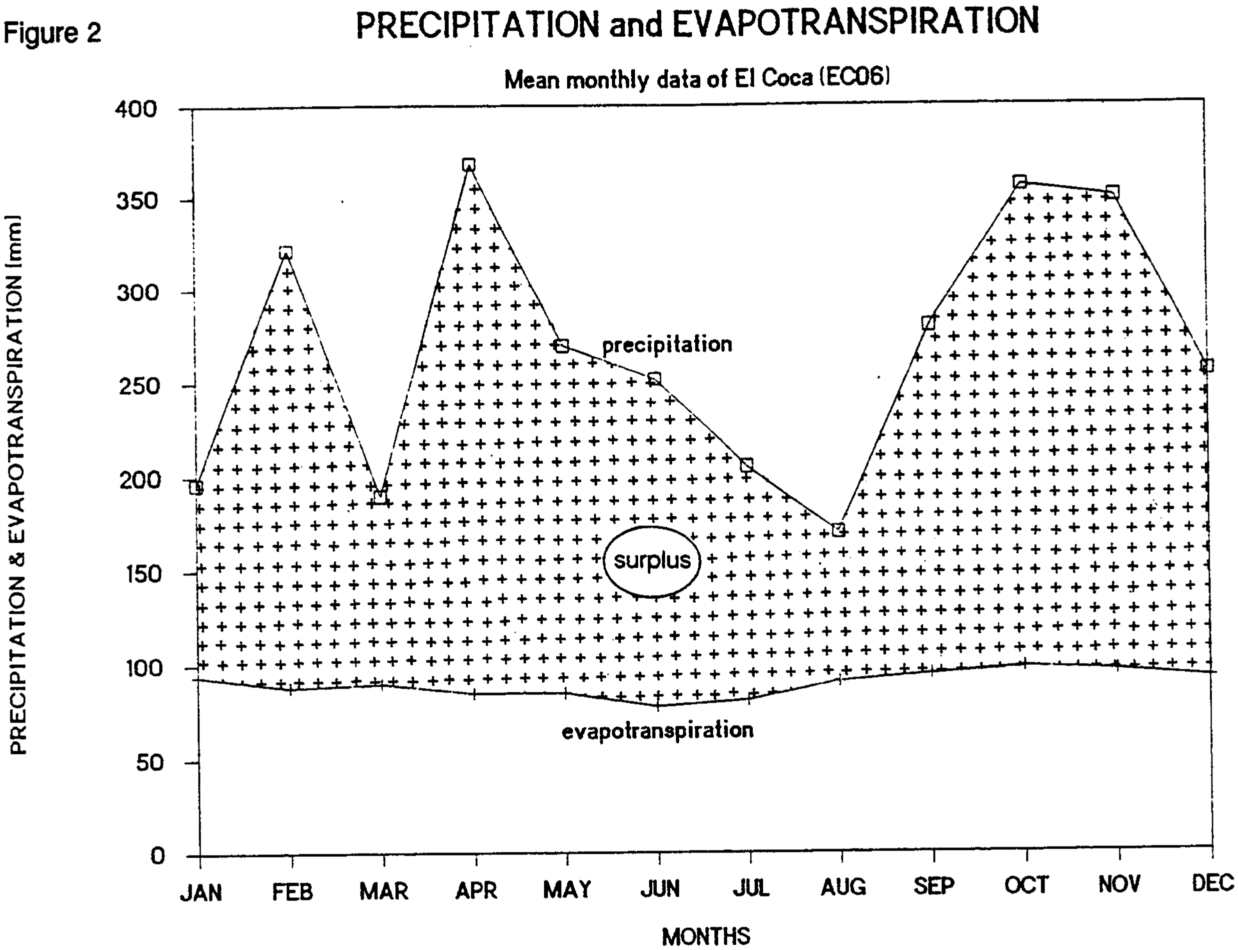
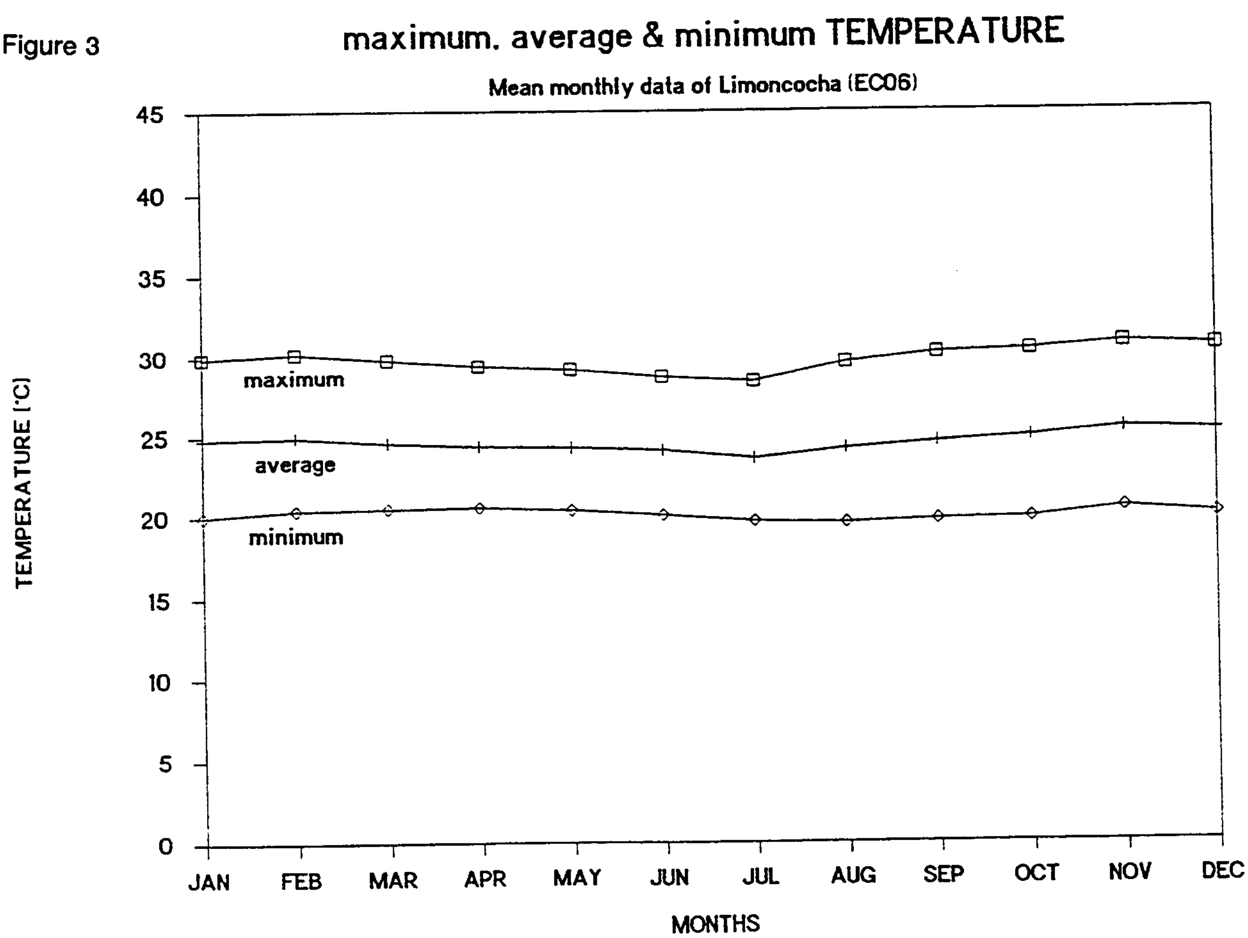


Figure 3



2 THE AMAZON REGION

2.1 Climate

In comparison to the other major ecological zones of Ecuador, the climate of the Amazon region is very uniform over nearly the whole area. Its main characteristics are a constant high temperature with small diurnal and annual variation, plus a high to very high precipitation (>200 mm) in all months of the year.
The meteorological stations El Coca and Limoncocha (for location, see fig. 1), are representative for the site of Ecuador 06. From these stations, sufficient data are available to construct climatic diagrams showing average monthly precipitation, evaporation and temperatures. The data for these diagrams and of other climatic elements are given in tables in Annex 1 - Soil and environmental datasheet.

The Precipitation - Evapotranspiration diagram of meteo station El Coca (fig. 2) shows mean rainfall exceeding mean evaporation for all months. The total leaching rainfall or surplus of rainfall percolating through the soil, is 2000 mm or more per year.
The Maximum, Average and Minimum Mean Temperature diagram of meteo station Limoncocha (fig. 3) shows the nearly constant temperature over the year.
Other climatic characteristics of importance for agriculture are the high relative humidity of the air and the cloudiness of the sky reducing the incoming solar radiation at the earth surface.

2.2 Landscape and Soils

The distribution of soils in the Ecuadorian Amazon region is not well known. The 'Programa Nacional de Regionalización Agraria' (PRONAREG) of the Ministerio de Agricultura y Ganadería (MAG) has executed a number of exploratory surveys. The results of these surveys are summarized on the 1:1,000,000 soil map of Ecuador (SECS, 1987) and PRONAREG's 1:500,000 soil map.
The dominant soils and landscapes as shown on the map legend of the 1:1,000,000 soil map are given below. The soil classification according to FAO/Unesco (FAO) and Soil Taxonomy (ST) is given in parentheses:

- Red clay soils in low hilly landscapes [Dystric Cambisols (FAO), Dystropepts (ST)]
- Brown clay soils on higher river terraces [Dystric Cambisols and Ochric Andosols (FAO), Dystropepts and Dystrandepts (ST)]
- Black clay soils in volcanic ash areas occurring in the transition zone towards the Sierrà [Humic Andosols (FAO), Hydrandepts (ST)]
- Recent alluvial soils of varying colour and texture occurring on low river terraces and river floodplains [Gleyic Cambisols (FAO), Tropaquepts (ST)]
- Peat soils of swampy areas [Histosols (FAO), Tropofibrists (ST)].

Additional information on landscapes and soils in the Amazon Region is given by Sourdat (1986).

Photo 1

Photo 2

Photo 1 - Landscape near site EC06

Photo 2 - Soil profile EC06

3 REFERENCE SOIL EC06

In this chapter, a selection of data and research information of reference soil EC06 will be discussed. Comprehensive field and laboratory data are given in Annex 1 - Soil and environmental datasheet, which was made with the ISRIC Soil Information System (ISIS, 1988).

3.1 Location and occurrence

Reference soil EC06 is located 20 km south-east of El Coca (Puerto Francisco de Orellano). Reference soil EC07 is located 40 km north-east of El Coca.
According to the exploratory surveys of PRONAREG about 15 percent of the Amazon region consists of dissected plains. EC06 is a good example of the predominant soil in this hilly landscape.
The hill on which EC06 was sampled, has a uniform soil distribution from upper to lower slope. The transition to a hydromorphic soil in the valley bottom is rather abrupt. The soil was sampled at the middle slope.

3.2 Landscape, geology, vegetation and landuse

The general landscape consists of a low altitude dissected plain, with rounded smooth hills with maximum slopes of about 25% (see photo 1).
The parent material varies considerably, several roadcut observations from a few to 10 meters deep show layers of completely weathered conglomerate and claystone.
The dense tropical forest has recently been cleared by settlers on both sides of a tarmac road constructed for oil exploration.
Agricultural exploitation is mainly restricted to small holdings with low technology input. Major cash crops are Robusta coffee and Cocoa, although the latter does not occur near site EC06. Other important crops are banana and cassava. Clearing of forest for extensive rangeland is a common practice.

3.3 Soil characterisation

Brief field description
Very deep, (moderately) well drained, yellowish red, fine clay soil; moderately structured, showing a weak yellowish mottling in the subsoil (see photo 2).
A detailed description of soil horizons to a depth of 150 cm, according to FAO Guidelines for Soil Profile Description (FAO, 1977) is given in Annex 1.

Figure 4

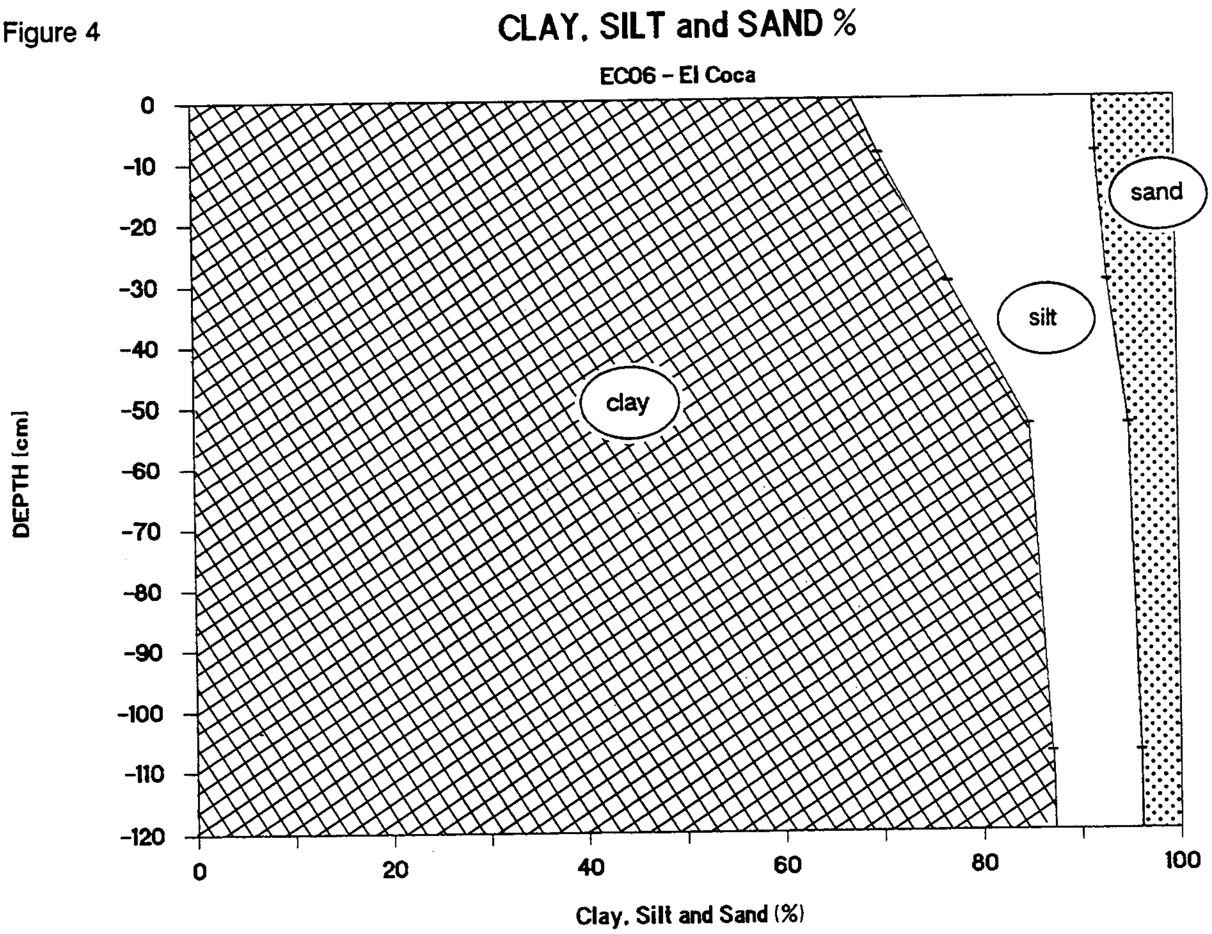
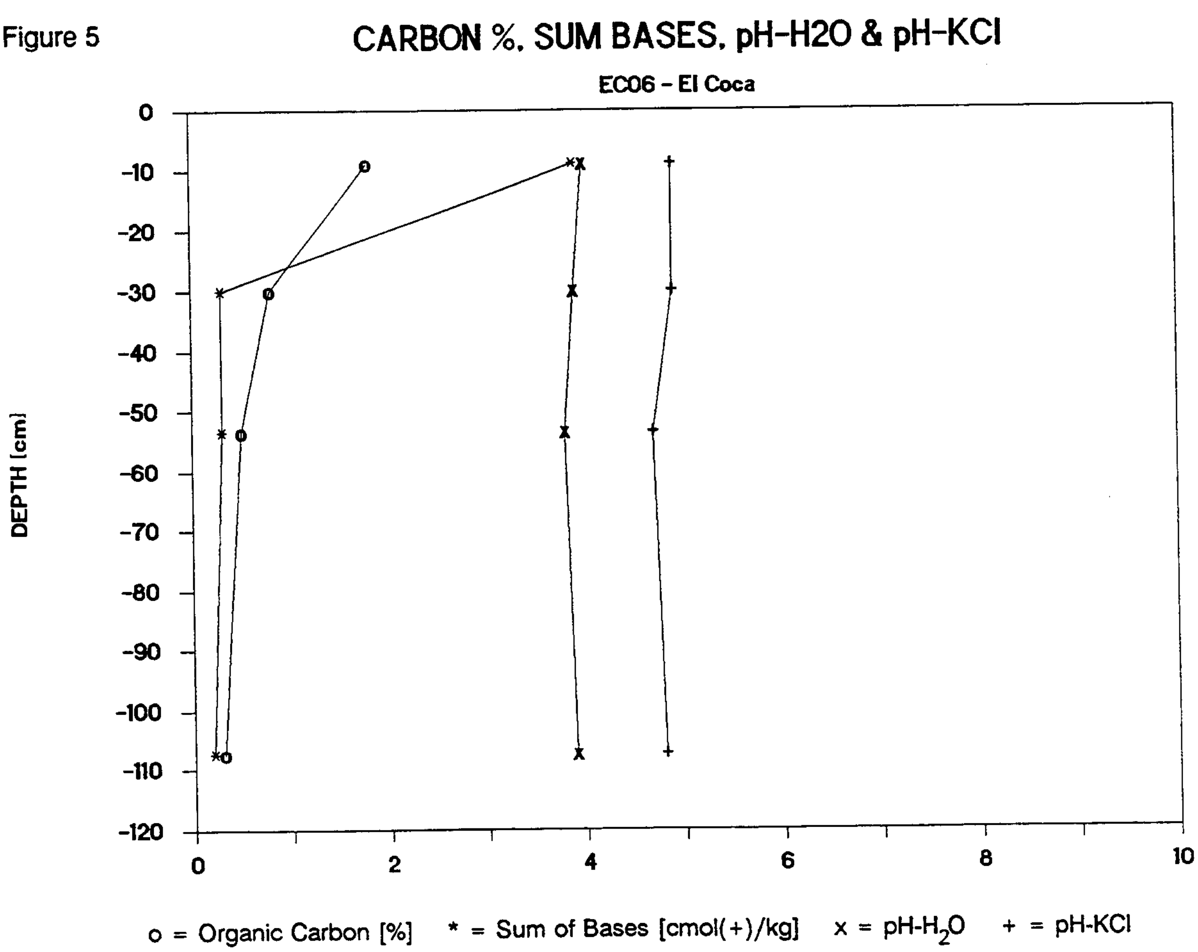


Figure 5



Brief analytical characterisation

Soil samples were analyzed at ISRIC's soil laboratory according the procedures as described by van Reeuwijk (1987).

Texture	:	clay; clay content increases with depth from 70 to 90% in upper 50 cm.
Organic carbon	:	medium (1.5%) in the upper 25 cm
Acidity	:	strongly acid (pH-H_2O 4.9)
Sum of bases	:	topsoil low (3.9 cmol(+)/kg), subsoil very low (0.3); the relatively high value in the topsoil is caused by burning of the vegetation
Cation Exch.Cap.	:	low (about 6 cmol(+)/kg soil) throughout the profile
Exch. aluminium	:	high (>50%)
Clay mineralogy	:	kaolinite dominant
Air capacity	:	topsoil moderate (11%), subsoil very low (5), the low percentage of large pores in the subsoil causes water stagnation. This is shown by the weak mottling.
Available soil moisture	:	high (15 to 18%).

Figure 4 shows the textural composition of the soil at different depths. The soil has a high clay content, giving an indication for the basic nature of the parent material. The clay increase is a prominent feature, however, it is difficult to perceive in the field. The textural gradient is sufficient for an argic/argillic horizon (see Section 3.4).

Figure 5 presents 'depth-versus-property profiles' for three chemical properties. The organic carbon percentage, the sum of the exchangeable bases (Calcium, Magnesium, Potassium and Sodium), and the soil acidity (pH-H_2O and pH-KCl).
The organic carbon is considered to show approximately the equilibrium carbon profile of the soil under original forest, because the forest has been cleared very recently. In an equilibrium profile, the organic matter accumulation at any depth is similar to the organic matter decomposition (Bennema, 1974). A comparison of the present organic carbon profile with the carbon profile as developed after some years of cultivation will be useful to study the changes caused by the currently introduced landuse (i.e. rangeland, perennial and annual cropping).
The sum of the exchangeable bases is low to very low, except for the topsoil. This is mainly attributed to the recent clearing and burning of the original forest.
The soil is acid throughout the profile. The diagram shows the nearly constant difference of 1 pH unit between pH-H_2O and pH-KCl.

3.4 Classification

FAO-Unesco	:	Haplic Nitisol
USDA Soil Taxonomy:		clayey, kaolinitic, isohyperthermic Typic Kandiudult

FAO-Unesco (1988)

The soil qualifies as a Nitisol because it has an argic B horizon with a clay distribution which shows a gradual increase continuing to a depth of 150 cm, in addition to nitic properties.
It should be noted, however, that the nitic properties are moderately developed, i.e. the structure of the argic B horizon is moderate (sub-) angular blocky without apparent clay skins, yet, conspicuous shiny ped faces. In addition, the analytical data indicate that the oxalate extractable Fe (0.1 %) is too low to meet the requirements for nitic properties

(should be 0.2 %). It keys out as a Haplic Nitisol on account of the thin Ah horizon and the colours of the argic B horizon that have hues not redder than 5Y.

USDA Soil Taxonomy (1987)
The soil classifies as a Udult on account of the presence of an argillic horizon with an low base saturation at a depth of 125 cm below the upper boundary of the argillic horizon, in addition to a udic moisture regime. The soil is classified as a Kandiudult because the major part of the argillic horizon has a CEC < 16 cmol(+)/kg clay, a ECEC < 12 cmol(+)/kg clay, and the clay percentage steadily increases down to a depth of 150 cm. Because there are no other special features, the soil keys out as a Typic Kandiudult.

3.5 Soil/Land suitability

The tropical rain forest impresses by its enormous biomass and species variation per surface area. The suggestion that the soil must therefore have a high fertility level, has already been opposed by soil scientists for many years. Abundant precipitation and high temperatures over the year are the primary cause of the high biomass production. The nutrients necessary for plant growth are for the greater part locked-up in the biomass itself. Dead organic material mineralizes rapidly and is quickly taken up by the growing vegetation.

A qualitative evaluation of relevant land qualities according to the Framework for Land Evaluation (FAO, 1983) was made. According to this methodology an evaluation should be made for each of the different land use types. In this case, however, the evaluation was made only for a deep rooting, nutrient demanding crop such as maize. For illustrative purposes, the results are presented in a comprehensive listing of soil/land qualities in Annex 2. The lay-out of the list is such that it directly shows the major constraints for agriculture, which are briefly discussed here.
Sustainable permanent agriculture needs considerable initial inputs. Attention should be given to land preparation, soil fertility and erosion.
The clearing of the forest should be done carefully. The soil stickiness and plasticity indicates that heavy machinery must be avoided as this provokes soil compaction. Reference is made to Suwardjo (1987), showing the effects of several clearing methods, as well as to Sanchez on his work in Yurimaguas.
Soil fertility needs improvement. The high level of exchangeable aluminium and the (very) low fertility require liming and fertilizers.
Although the soil under natural vegetation has a high stability, there exists a potential danger for soil erosion. The strong relief is the basic cause for erosion, the latter may be enhanced by soil compaction, causing a higher surface water flow.

The soil feature of the (very) weak mottling in the subsoil, requires attention. The practical implications of this mottling is not yet well understood. Micromorphological analysis show that the mottling is a gley phenomenon (see Section 3.6). The permeability of the subsoil is probably too low to transmit the high surplus of rainfall (i.e. the leaching rainfall). Therefore, the natural soil permeability is considered to be a critical soil property. In addition to this, compaction should be avoided to prevent further lowering of the soil's capacity to transmit water.

Potential agricultural production is somewhat reduced in comparison to e.g. to coastal land at the same latitude, because of the moderate direct solar radiation reaching the earth surface, caused by the cloudiness. Testing with the crop growth simulation model WOFOST, as documented in Van Diepen et al.(1988), shows about 15% yield reduction in comparison to sites in coastal regions, which have less cloudiness and having similar soil qualities.

Although a more detailed land evaluation analysis based on a soil survey will give more information, the present rapid land quality assessment gives some preliminary conclusions on sustainable agricultural land use.
In view of the very low nutrient retention and content in the soil, probably the most sustainable land use system is a silvicultural system based on exploitation of hard woods in the natural forest, as described for example by Poels (1987).
In the case of a cultivation of crops, and taking into consideration similar constraints, it is concluded that perennials are recommended. During the fieldwork in April 1987 small plantations of Robusta coffee were frequently observed. The coffee seems to be growing well, but no reliable production data could be obtained.
The ecological zone of EC06 is very suitable to adopt different agroforestry techniques. For further reading on agroforestry and hedgerow (alley) cropping techniques, reference is made to Steppler and Nair (1987), Huxley (1986) and Sanchez (1989).
Of interest are the results of the agroforestry trials coordinated by Robert Peck. This may be obtained from Dirección Nacional Agro Forestal of the Ministeria de Agricultura y Ganadería (DINAF-MAG).

3.6 Soil formation

The landscape has been formed in Tertiary sediments. Dissection of the sedimentary plains resulted in a rolling, hilly topography. The dense forest vegetation and the warm humid tropical climate are major factors in the formation of the very deep, strongly weathered soil. The balance between rainfall and evapotranspiration results in a high surplus of precipitation, which for the major part percolates through the soil, leaching bases and silica. It is assumed that the textured differentiation between topsoil and subsoil can be contributed to the leaching of clay to the deeper subsoil as well as lateral removal of the clay by run-off water during very high rainfall intensities. The dense forest vegetation minimizes the rate of natural soil erosion, being less in comparison to the rate of soil formation.

A micromorphological study, presented in Annex 3, has shown the following.
The parent materials from which the soil has derived, are strongly weathered, with the exception of a very small number of quartz sand grains. These grains occur throughout the profile, and their micromorphological habit suggests that some of these are of metamorphic origin while others are volcanic. Grains of hornblende occur only in the topsoil, suggesting that these are the remnants of volcanic ash, admixed when the soil was already in an advanced stage of development. There is no other evidence of pyroclastic materials. It is concluded that the original parent material consisted of a variety of different rocks with probably claystones dominant.

Significant quantities of organic carbon occur only in the upper 18 cm. In this horizon are many very fine living roots. Recognizable dead plant remnants are very few.

The distinct mottles in the subsoil are evident in thin section as depletion features, i.e. they show up as bleached patches from which ferric iron has been removed under (temporary) saturated conditions. Their close association with voids, channels and infillings where soil fauna has disturbed and loosened the soil material, suggests that water preferentially has saturated these relatively porous locations, thereby reducing, mobilizing and removing the iron from the surrounding soil material (gley).

REFERENCES

Beinroth et. al., 1985. Proceedings of the Sixth International Soil Classification Workshop, Chili and Ecuador. Part III: Tour guide for Ecuador. Sociedad Chilena de la Ciencia del Suelo, Santiago, Chile

Delavaud A.C. et. al., 1982. Atlas del Ecuador. Les Editions Jeune Afrique & Banco Central del Ecuador

Diepen C.A. et al., 1988. CWFS Crop Growth Simulation Model WOFOST, documentation version 4.1. CWFS c/o CABO, Wageningen

FAO, 1977. Guidelines for soil profile description (2nd edition), Rome, Italy

FAO, 1983. Guidelines: land evaluation for rainfed agriculture. FAO Soils Bulletin 52, Rome

FAO, 1988. FAO/Unesco Soil Map of the World, Revised Legend. World Resources Report 60, FAO, Rome

Huxley P.A., 1986. Rationalising research on hedgerow intercropping, an overview. ICRAF, Nairobi

Poels, R.L.H., 1987. Soil, water and nutrients in a forest ecosystem in Surinam. Doctoral thesis, Agricultural University, Wageningen

Reeuwijk, L.P. van, 1987. Procedures for soil analysis. Technical Paper 9 (2nd edition), ISRIC, Wageningen

Sanchez P.A., 1989. Humid Tropics. In: Tropsoils Technical Report 1986-1987, North Carolina State University

Sociedad Ecuatoriana de la Ciencia del Suelo (SECS), 1986. Mapa General de Suelos del Ecuador, on scale 1 : 1 million

Soil Survey Staff, Soil Conservation Service -USDA (1975). Soil Taxonomy, a basic system of soil classification for making and interpreting soil surveys. Agriculture Handbook No.436, Washington

Soil Survey Staff, 1987. Keys to Soil Taxonomy, third edition. SMSS Technical Monograph no. 6. Ithaca, New York

Sourdat, M., 1986. Les sols de l'Amazonie équatorienne; situation, nature et perspective d'exploitation. Cah. ORSTOM, sér. Pédol. vol. XXII, no. 4.

Steppler H.A. and R.P.K. Nair, 1987. Agroforestry, a decade of development, ICRAF, Nairobi

Waveren, E.J. van, and A.B. Bos, 1988. ISRIC Soil Information System, user manual and technical manual. Technical Paper 15, ISRIC, Wageningen

ANNEX 1 - Soil and other environmental data

monolith number: EC 06   country: ECUADOR   soil description   ISRIC 09/15/91

CLASSIFICATION FAO/UNESCO,1974: dystric nitosol ;haplic nitisol (FAO, 1988)
USDA,1975: paleudult typic, clayey, isohyperthermic ;typic kandiudult (ST, 1987)
Diagnostic horizons: argillic
(other) Diagn. criteria: ferric properties
Local classification: Suelo Rojo

LOCATION : Napo, Francisco de Orellana (El Coca), 12 km south of El Coca
: Latitude: 0 31 S   Longitude: 76 56 W   Altitude: 250 (m.a.s.l.)
AUTHOR(S) - DATE (mm.yy) : Kauffman, del Posso - 5.87

GENERAL LANDFORM : low hill   Topography: hilly
PHYSIOGRAPHIC UNIT : "colina" (interfluve)
SLOPE Gradient/aspect/form: 25 % convex
POSITION OF SITE : middle slope
MICRO RELIEF Kind:
SURFACE CHAR. Rockoutcrops: none   Stoniness: none
Cracking: small cracks   Sealing: nil   Salt: nil   Alkali: nil
SLOPE PROCESSES Soil erosion: slight sheet

PARENT MATERIAL I : residual material   Derived from: conglomerate   Texture:
Weathering degree: Resistence: high
Remarks: Tertiary

EFFECTIVE SOIL DEPTH(cm) : 300

WATER TABLE Depth(cm):   Kind: no watertable observed
DRAINAGE : well
PERMEABILITY :
FLOODING frequency: nil   Run off: rapid
MOISTURE CONDITIONS PROFILE : 0 - 300 cm moist

LAND USE : low level arable farming, coffee,
VEGETATION Structure: evergreen forest
Landuse/vegetation remarks: recently cleared land, coffee major crop

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CLIMATE koppen: Af   Soil Moisture Regime: udic
Station: EL COCA -----0 29 S/76 59 W;245 (m.a.s.l); 12 km N from site. Relevance: good

EL COCA	Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
EP penman (mm)	4	72	61	65	55	54	59	60	67	63	76	70	81	783
Rel. Hum.(%)		91	90	90	90	91	92	91	91	93	90	89	89	90
Precipitation (mm)		196	322	190	368	270	252	205	170	280	356	350	256	3214
T mean (C)		26.1	26.0	25.9	25.4	25.2	24.8	24.3	25.2	25.4	25.3	25.5	25.4	25.4
windspeed (m/sec)		0.5	0.6	0.5	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.5	0.6	0.5
bright sunsh.hrs/day		4.0	3.1	2.6	3.2	2.4	2.2	2.7	3.0	2.6	3.8	3.8	3.7	0.0

PROFILE DESCRIPTION

A 0- 18cm 10.0YR 3.0/6.0 moist; clay; fine to medium moderate subangular blocky; sticky plastic friable; many/few medium random continuous inped tubular pores; many very fine roots throughout; gradual smooth boundary to

AB 18- 42cm 10.0YR 4.0/6.0 moist; clay; fine to medium moderate subangular blocky and fine to medium moderate wedge-shaped ang.bl.; sticky plastic friable; broken moderately thick clay cutans ; many/few medium random continuous inped tubular pores; common very fine roots throughout; very few pebbles fragments; gradual smooth boundary to

B 42- 75cm 5.0YR 5.0/6.0 moist; clay; fine to medium moderate subangular blocky and fine to medium moderate wedge-shaped ang.bl.; sticky plastic friable; continuous moderately thick clay cutans ; many very fine random continuous inped tubular pores; few very fine roots throughout; very few pebbles fragments; diffuse smooth boundary to

B(g) 75-150cm 2.5YR 4.0/8.0 moist; clay; medium to coarse moderate subangular blocky and medium to coarse moderate wedge-shaped ang.bl.; sticky plastic friable; common fine distinct diffuse (10.0YR 6.0/6.0) mottles; continuous moderately thick clay cutans ; common very fine random continuous inped tubular pores; few very fine roots throughout; very few pebbles fragments;

REMARKS:

Road cut observations show completely weathered parent materials like conglomerate.
The subsoil shows a weak yellowish mottling probably due to redox processes. The soil shows clear narrow cracks when dry.
The soil is well structured which contributes to the classification as Nitosol. If the morphology is not taken into account it will come out as ferric Acrisol.

monolith number: EC 06 analytical data <missing value = -1> ISRIC: 09/15/91

NO	TOP	BOT	>2 mm	2000 1000	1000 500	500 250	250 100	100 50	TOT	50 20	20 2	<2 um	DISP	BULK DENS	pF- 0.0	1.0	1.5	2.0	2.3	2.7	3.4	4.2	SPEC SURF
1	0	18	0	1	1	2	2	2	8	6	16	70	21	1.01	58	56	51	47	0	42	35	32	
2	18	42	0	1	2	1	2	2	8	3	13	77	0	0.00	0	0	0	0	0	0	0	0	
3	42	65	0	0	1	1	1	1	4	2	8	85	0	1.01	61	60	56	55	0	53	40	37	
4	65	150	0	0	1	1	1	1	4	1	8	87	0	0.99	60	60	57	55	0	52	42	38	

No.	pH- H2O	KCl	CaCO3 %	ORG- MAT. C %	N %	EXCH CAT. Ca	Mg	K	Na	sum	EXCH AC. H+Al	Al	CEC soil	clay	OrgC	ECEC	BASE SAT %	Al SAT %	EC 2.5 mS/cm
						meq /100g-													
1	4.9	4.0		1.8	0.18	2.3	1.1	0.5	0.0	3.9	1.4	1.1	8.4			5.3	45	13	0.16
2	4.9	3.9		0.8	0.08	0.2	0.1	0.0	0.0	0.3	3.6	3.7	6.5			3.9	5	57	0.03
3	4.7	3.8		0.5	0.07	0.2	0.1	0.0	0.0	0.3	3.1	3.2	5.9			3.4	5	54	0.02
4	4.8	3.9		0.3	0.04	0.0	0.1	0.1	0.0	0.2	2.2	2.1	6.8			2.4	2	32	0.02

CLAY MINERALOGY < 1 very weak, 2 weak, 3 medium, 4 strong, 5 very strong > EXTRACT. Fe Al Si

No	MICA/ ILL	VERM	CHLOR	SMEC	KAOL	HALL	MIX*	QUAR	FELD	GIBB	GOET	HEM	FEo	ALo	SIo	MNo	FEd	ALd	SId	FEp	ALp	C
1					5		2				3		0.4	0.2		0.0	4.2	0.7				
2					5		2				3		0.1	0.2		0.0	5.1	0.8				
3					5		2				3		0.1	0.2		0.0	5.7	0.9				
4					5		2				3		0.1	0.2		0.0	5.8	0.8				

ANNEX 2 - Evaluation of soil/land qualities

Profile number: EC06

LAND QUALITY	Availability (1) / Hazard/Limitation (2)	VH / N	H / W	M / M	L / S	VL / VS	REMARKS
CLIMATE							
Radiation regime:							
- total radiation	1						
- day length	1						
Temperature regime	1						
Climatic hazards (hailstorm, wind, frost)	2						
Conditions for ripening	1						
Moisture availability:							
- length growing season (GS)	1	■					
- drought hazard during GS	2	■					
SOIL							
Moisture availability:							
- potential total soil moisture	1			■			
Oxygen availability	1		■				
Nutrient availability	1						
Nutrient retention capacity	1						
Rooting conditions	1		■				
Conditions affecting germination	1		■				
Excess of salts:							
- salinity	2	■					
- sodicity	2	■					
Soil toxicities (e.g. high Al sat.)	2				■		high exch. Aluminium
LAND MANAGEMENT							
Initial land preparation	2				■		
Workability	1						
Potential for mechanization	1			■			
Accessibility:							
- existing	1				■		slope/relief
- potential	1						
Erosion hazard:							
- wind	2	■					
- water	2						
Flood hazard	2	■					
Pests and diseases	2			?			high rel. humidity

VH = very high
H = high
M = moderate
L = low
VL = very low

N = not present
W = weak
M = moderate
S = serious
VS = very serious

ANNEX 3 - Brief micromorphological description

Origin of the soil material

The parent material of this soil has been weathered almost completely and has transformed into clay, with the exception of some angular and sub-rounded sand and silt-sized grains of quartz and quartzite, and few sand and silt-sized yellowish red translucent grains.
Some of the quartz grains show corroded boundaries indicating their volcanic origin. The yellowish red grains have been identified as weathered mafic minerals, also suggesting the volcanic nature of the original material.
The fragments of quartzite indicate that at least a small proportion of the original material consisted of metamorphic rocks.
It is concluded that the original parent material of this soil consisted of a variety of different rocks.

Silt-sized grains of hornblende, occurring only in the Ah horizon, indicate the admixture of volcanic materials in the topsoil, most likely ash, when the present soil was already at an advanced stage of development. There is no other evidence of pyroclastic materials.

Microstructure

Observations in thin sections confirm the structure as described in the field, i.e. the soil material appears to be pedal throughout the profile. The subangular blocky peds are partly to completely accommodated, i.e. the pedality is moderately developed throughout the profile. The average size of the peds is medium in the Ah and AB horizon, to coarse in the B horizon.

The interior of the peds has a vughy or a channel structure, or both: i.e. animal burrows, many filled up with soil material and mineral excrements, are common in the B horizon and many in the Ah. In the upper 5 cm of the Ah horizon the frequency of channels and other voids is abundant, creating a complex porous structure with crumbs, granules and fine angular blocky aggregates.

Examination in polarized light of the fine mass of the interior of peds in the B horizon reveals the existence of a lower level of structure. The soil material appears to be weakly to strongly aggregated into accommodated micropeds (0.1 - 0.3 mm), delimited and separated from each other by circular streaks of birefringent (oriented) clay that are considered to be surfaces of weakness. In many places these micropeds are associated with very thin clay skins (see below). These are characteristic for Nitosols .

The porosity of the soil is determined by the frequency of vughs, channels and planar voids. It is high in the upper 5 cm and moderate below.

Mineral components

The content of coarse mineral components (sand and silt) is low throughout the profile. It concerns mostly angular and sub-rounded quartz and quartzite grains. Accessory are yellowish red grains of goethite (presumably weathering products of some mafic mineral), and some opaque minerals. The coarse components are fully embedded in the fine mass. The fine mineral components consist of clay, strong brown in the Ah to yellowish red in the B horizon. The colours are mainly due to extremely fine (hydr)oxides of iron adsorbed by the clay. Examination in polarized light shows the fine mass to have a low birefringence in the Ah, grading to moderate in the B horizon. These optical properties indicate either small crystal size or a low birefringence of the clay minerals, or both. This character of the birefringence is common for kaolinite, the presence of which is confirmed by X-ray analysis. These birefringent characteristics, however, are unlike those of most oxic materials. The b-fabric in the Ah horizon is weakly speckled and locally weakly striated. The development of these fabrics increases with depth to moderate speckled, and monostriated and random and circular striated in the B horizon.

Organic components

There are very few recognizable coarse plant remains. Fine silt and clay-sized fragments and punctuations occur in the groundmass throughout the profile.

Pedofeatures

Thin coatings of illuvial clay are common on the walls of vughs and channels in the AB and the B horizon. Some of the birefringent streaks are considered to be deformed clay coatings. The quantity of clay coatings is sufficient to meet the requirements of the argillic horizon. Very thin clay coatings, not thicker than 2-3 µm, (leptocoatings), occur in virtually all vughs and channels of the B horizon that do not have the common thin clay coatings. The abundant occurrence of leptocoatings, combined with the circular striated b-fabric constitute the "nitic syndrome". The nitic syndrome is diagnostic for the B horizon of Nitosols (Creutzberg & Sombroek, 1987; Creutzberg & Sombroek, "Micromorphological characteristics of Nitosols", in: Soil Micromorphology, Proc.VII Int.Working Meeting Soil Micromorphology, Paris, 1987).
Contrasting brownish yellow (10YR) zones of various shape and size (up to 1 cm across) occur within the yellowish red (5YR) groundmass of the B horizon. These are depletion features from which ferric iron has been removed. Their close association with voids, channels, and zones where soil animals have disturbed and loosened the soil material, suggests that water preferentially has saturated these relatively porous locations, thereby reducing, mobilizing and removing the iron from the surrounding soil material (gley).

ANNEX 4 - Glossary (for the non-soil specialist)

CLASSIFICATION

FAO (1974)	= Legend of the FAO/Unesco Soil Map of the World (1974)
FAO (1988)	= Revised FAO-Unesco Soil Map of the World legend (1988)
ST (1975)	= Soil Taxonomy, USDA soil classification system (1975)
ST (1987)	= Key to Soil Taxonomy, 2nd edition (1987)

SOIL CHARACTERISATION (laboratory)

Texture	= Soil particle size composition; the field description gives an estimation of the clay, silt and sand percentages; the analytical characterisation gives the percentages as determined in the laboratory.
Organic carbon	= The percentage of organic carbon in the soil, indicative for the quantity of organic matter in the soil.
pH value	= Expression for degree of acidity or alkalinity of a soil
CEC	= Expression for the nutrient retention capacity of a soil
Sum of bases	= Exchangeable Calcium, Magnesium, Potassium and Sodium
Base saturation	= The ratio of Sum of bases and CEC, expressed as percent
Exch.aluminium	= Exchangeable aluminium, at high levels toxic for most crops
Phosphate retention	= In some soils phosphate is strongly bound to soil components. This phenomenon is common in volcanic ash soils and in some strongly weathered tropical clay soils.
Clay mineralogy	= Type of clay
kaolinite	= Crystalline, non-cracking clay type with low nutrient retention capacity, very common in tropical red clay soils;
smectite	= Crystalline, cracking clay type with high nutrient retention capacity;
allophane	= Non-crystalline or amorphous clay type with high nutrient retention capacity, very common in volcanic ash soils.
pF value	= Expression for degree of soil moisture tension
Air capacity	= Quantity of soil moisture between pF 0 and pF 2, indicative for the amount of larger pores.
Available soil moisture	= Quantity of moisture between pF 2 and pF 4.2, indicative for the amount of moisture available for plant growth.