Soil Brief *Costa Rica 1*

Reference soils in the Atlantic Coastal region under forest and pasture

ISRIC Soil Monoliths:

Number	*FAO-Unesco*	*Soil Taxonomy*
CR 6	Umbric Andosol	Eutric Hapludand
CR 7	Umbric Andosol	Eutric Hapludand
CR 8	Ferralic Cambisol	Andic Humitropept
CR 9	Ferralic Cambisol	Andic Humitropept

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CONTENTS

ABSTRACT

This Soil Brief describes two different soil types of the humid tropical Atlantic Zone of Costa Rica; a relatively young soil of volcanic origin (Umbric Andosol: CR 6 and CR 7) and a relatively old soil of volcanic origin (Ferralic Cambisol: CR 8 and CR 9). The parent material of both soils is of similar mineralogical composition, the main difference is the degree of weathering. The soil types were described and sampled to investigate the effect of deforestation and pasture establishment on soil characteristics. The recent history of the Atlantic Zone of Costa Rica is characterized by ongoing deforestation, and a demonstration of the deforestation is that the forest that was present at CR 9 in 1991 was cleared in 1993 and turned into pasture. Another characteristic of the recent history of the Atlantic Zone is the production of bananas. There have been banana 'booms' in the beginning of this century, in the 1960s and in the early 1990s. Nowadays, it is one of the main banana producing areas in the world. The banana plantations are mainly found on slightly weathered soils with Andic properties, of which CR 6 and CR 7 are representatives. Because of their lower fertility, the main land use on the strongly weathered soils, like CR 8 and CR 9, is pasture. In the last decade, farmers have experimented with several other crops. The production of Palm-heart from the 'pejibaye' palm (*Bactris gasipaes*) and pine apple are two of the successful experiments. Although conditions for crop production are not ideal for CR 8 and CR 9, the main problems that farmers encounter are not of agronomical nature but have to do with marketing. Prices vary and transport to the market causes problems.

FOREWORD

This report is the result of the joint research programme of Centro Agronómico Tropical de Investigación y Enseñanza (CATIE) and the International soil Reference and Information Centre (ISRIC). In 1991 the present four reference soils from the Atlantic Zone of Costa Rica were described and sampled for the establishment of a Costarican soil reference collection and pedon database at CATIE. Duplicates of these soils were collected for ISRIC's world soil collection.
All four profiles in this soil brief, were used in a study to the effects of deforestation on Soil Organic Carbon dynamics (Veldkamp, 1994). CR 8 and CR 9 were the two members of a deforestation sequence on which the effects of deforestation on trace gas emissions were studied (Keller *et al.*, 1993). Sampling of the four reference profiles was done by M. Jímenez and G. Ortiz.

Figure 1 Geographical location of the reference sites.

1 THE ATLANTIC COASTAL REGION

Costa Rica is divided by two mountain ridges. The Northern ridge (the Cordillera Central) is of volcanic origin. The southern mountain ridge (Cordillera de Talamanca) is not volcanic. The mountain ridges divide the country into three main regions:

(i) The Pacific Coastal Region
(ii) The 'Cordillera' Mountains
(iii) The Atlantic Coastal Region

The Atlantic Coastal Region has a wet to moist humid tropical climate, the Pacific Coastal Region is very dry in the northern part and moist or wet in the southern part. In the Cordillera Mountains, tropical to subalpine climates occur. In Figure 2 the main ecological regions are shown which is a simplification of the 'Ecological map of Costa Rica' (Tosi, 1969).

1.1 Climate

The climate of the Atlantic Coastal Region is characterized by high temperatures with relatively small diurnal and annual variations. The precipitation is high to very high in all months of the year. The climatic conditions for this region were taken from the meteorological stations 'La Rita' and '28 Millas' (see Fig. 2). The station La Rita (Fig. 3) is representative for the sites CR 6 and CR 7, the meteorological station 28 Millas (Fig. 4) is representative for the sites CR 8 and CR 9.

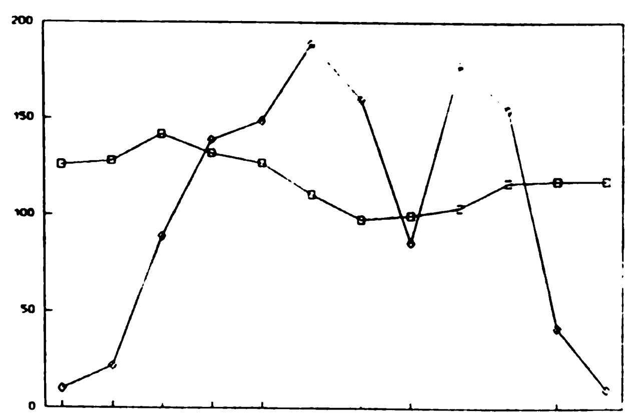

Figure 3 Precipitation (◊) and evapotranspiration (□) in mm at La Rita.

Precipitation - evapotranspiration diagrams show that mean rainfall exceeds evaporation in each month. Due to its topographical location, La Rita receives higher rainfall during the 'wet period' (May to November). The total leaching rainfall or surplus of rainfall percolating through the soil, is almost 3000 mm per year at both sites.

Temperature is nearly constant over the year (Fig. 5 and 6). The average temperature curves of the two meteorological stations are similar. La Rita has lower temperatures due to its higher elevation (+110m) as compared to 28 Millas. Relative air humidity is high at both sites.

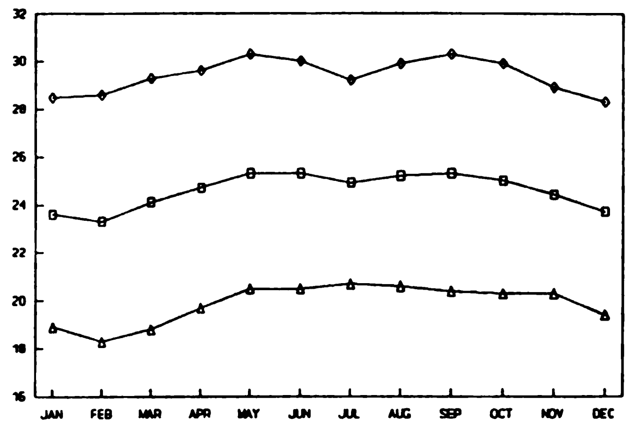

Figure 5 Maximum (◊), average (□) and minimum (△) temperature in °C at Los Diamantes.

1.2 Landscape and soils

The distribution of soils in the North Atlantic Zone is well known. The 'Programa Zona Atlantica' of CATIE-WAU-MAG has conducted a soil survey and the result of this survey is available in a Geographical Information System ('SIESTA') at a scale of 1:100,000 (Wielemaker & Vogel, 1993). The dominant soils are:

- Soils high in organic material (Histosols).
- Slightly weathered soils with Andic properties (Andosols).
- Strongly weathered soils (Cambisols).

The reference profiles described in this Soil Brief are from the second group (CR 6 and CR 7) and the third group (CR 8 and CR 9). CR 7 and CR 8 situated under tropical rain forest; CR 6 and CR 9 are under 25 years old pasture.

Andosols are relatively young and fertile soils. The Cambisols of the third soil group are regarded to be the old weathered remnants of the Andosol.

2 THE REFERENCE SOILS

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

2.1 Location and occurrence

Reference soil CR 6 is located on the experimental station 'Los Diamantes' of the Ministry of Agriculture (MAG). CR 7 is located on the west bank of the Rio Diamantes which borders the agricultural high school and Los Diamantes. Both soils are representative for the well drained, fertile alluvial soils in the Atlantic Zone, which are mainly classified as Andosols.
Reference soils CR 8 and CR 9 are located in the Neguev settlement which is located northwest of Siquirres. The area is distributed into parcels of 8 to 10 ha each. Most of the parcels were under tropical moist forest when the settlement was founded. Deforestation took place during the last 18 years and still continues. Reference soil CR 8 is located on a remnant 'forest island', on parcel nr. 252, close to the hamlet Silencio. CR 9 is located on the same ridge as CR 8, a few hundred meters southeast, on parcel nr. 255. Both soils are representative for the well drained soils with a low fertility, and are mainly classified as Cambisols.

2.2 Landscape, geology, vegetation and land use

The landscape of profile CR 6 and 7 is an alluvial fan formed by the Rio Toro Amarillo which carries draining water from the Turrialba volcano. The slope of the alluvial fan is about 3%. Parent materials are alluvial deposits of andesitic composition and both soils are formed in sandy deposits over large rounded unweathered boulders. Natural vegetation at the site of CR 7 consists of dense premontane wet forest. The Atlantic Zone was rapidly deforestated during the last 40 years, mainly for the establishment of banana plantations and pastures. At the site of reference soil CR 6, forest was cleared about 25 years ago. Currently the land is under low productive pasture, dominated by species like *Axonopus compressus*.
Reference soils CR 8 and CR 9 are located on a low altitude, dissected alluvial terrace with maximum slopes of 25%. The landscape consists of well drained, flat topped hills alternated with valleys with poorly drained soils. Parent materials are older fluvio-laharic deposits of andesitic composition. The natural vegetation consists of dense tropical wet forest, which is found on the site of reference soil CR 8. After deforestation in the Neguev settlement, farmers mostly establish low productive pasture, dominated by species like *Ischaeum ciliare* and *Axonopus compressus*. Locally, pineapple and palm heart plantations are established.

2.3 Soil characterization

<u>Brief field description</u>
CR 6 and CR 7 are deep and have a very dark brown surface sandy loam topsoil over a brown loamy sand. The topsoil of CR 7 has a very strong medium crumb structure, and the topsoil of CR 6 has a subangular blocky structure. Both soils have thixotropic characteristics.
CR 8 and 9 are deep and have dark brown colours and silty clay loam textures. The topsoil of CR 8 has a very strong medium crumb structure with fine subangular blocky components.

<u>Brief analytical characterization</u>
Soils were analyzed at ISRIC's soil laboratory according to procedures described by Reeuwijk (1987). In table 1 a brief tabular description is given.
Fig. 7 and 8 show the textural composition and pH profiles of CR 6 and 7.
The profile under forest has a higher clay content in the upper 70 cm than under pasture, while the silt content is lower. Both profiles have sandy loam textures in the upper 80 cm, and loamy sand in the deeper subsoil. In the forest soil the texture is sand below 90 cm depth.
Fig. 9 and 10 show the textural composition and pH profiles for CR 8 and 9. The soils have high clay contents and comparable silt contents. The texture of both profiles is classified as clay. In CR 9 beneath 110 cm depth, silt loam is found.
Acidity is decreasing from strongly acid in the topsoil to medium acid in the deeper subsoil of profile CR 6 and 7 (Fig. 11 and 12).
Base saturation and CEC are medium in the topsoil due to high organic matter contents. The base saturation in the pasture soil was somewhat higher than in the forest profile, but differences are relatively small. Although the soil organic matter content is very high in both, CR 6 and CR 7, carbon budget calculation showed that since clearing about 22 t C ha was lost (Veldkamp, 1994).
Reference soils CR 8 and 9 have a very low pH which changes little with depth (Fig. 13 and 14).
Remarkable is the extremely acid topsoil of the forest profile. The most striking difference between forest and pasture soils is the base saturation percentage. It is extremely low in the forest, which demonstrates its leached character. The relatively high base saturation percentage of the pasture topsoil results of burning.

Table 1 Summary of main properties of the reference soils CR 6 to CR 9

parameter	CR 6 and CR 7	CR 8 and CR 9
texture	sandy loam in the upper 80 cm; sand content increasing with depth	clay
pH H_2O	strongly acid (4.2-5.3) in the topsoil, medium acid (5.5-6.2) in the subsoil	extremely acid in the topsoils under forest, strongly acid under pasture
sum of bases	medium in the topsoil, very low between 25 to 70 cm	very low in the topsoils under forest, low under pasture
CEC	medium in the topsoil, very low in the subsoil	medium in the topsoils under forest and pasture
mineralogy	allophane dominantly	gibbsite and kaolinite
air capacity	under forest high, under pasture low in the topsoil	high under forest, low in the topsoils under pasture
available soil moisture	high in the topsoils under forest and pasture	low under forest throughout the profile, high in the topsoils under pasture.

Reference soil CR 6 and 7 have high porosities due to the andic properties (Fig. 15 and 16). Total pore space in the topsoil of the forest is high due to aggregation and the soil has a very high hydraulic conductivity. Under pasture, hydraulic conductivity was much lower due to compaction.
As result of its originally andic properties, CR 8 and 9 have also a high porosity (Fig. 17).

2.4 Classification

FAO-Unesco (1988)
CR 6 an CR 7 are classified as Andosols because they have andic properties: the acid oxalate extractable Al plus half of the acid oxalate extractable iron is more than 2.0%; bulk density of the fine earth measured in the field moist is less than 0.9 kg/dm^3 and phosphate retention is more than 85 percent. Base saturation is lower than 50% which results in an Umbric A-horizon. The final classification is Umbric Andosol for CR 6 as well as CR 7.

Reference soils CR 8 and CR 9 are classified as Cambisols because the B horizon has no clay increase and is not leached strong enough for the classification of a ferrallic B Horizon. At subunit level the soils are classified as Ferrallic Cambisols because the B horizons have ferralic properties (CEC of less than 24 cmol$_c$ kg^{-1}).

USDA Soil Taxonomy (1990)
Reference soils CR 6 and CR 7 are classified as Andisols because of the Andic properties. The soils are Udands because of the perudic moisture regime; they are further classified as Eutric Hapludands because the sum of bases is more than 25.0 cmol$_c$ kg^{-1}.
CR 8 and CR 9 are classified as Inceptisols because they have cambic horizons. They are Tropepts because the soil temperature regime is isohyperthermic. At a higher level they are classified as Humitropepts because base saturation is lower than 50% and the organic carbon content is more than 12 kg per square meter to a depth of 1 m. The soils are finally classified as Andic Humitropept because bulk density measured at 33 kPa water retention is less than 1.0 g cm^{-3}.

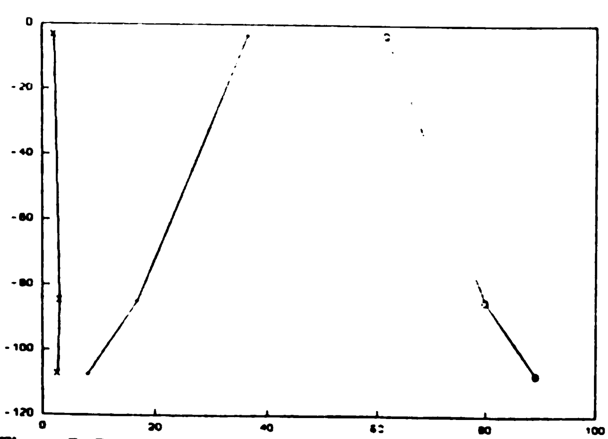

Figure 7 Percentages clay (x), silt (+) and sand (o) versus depth (cm) in profile CR 6.

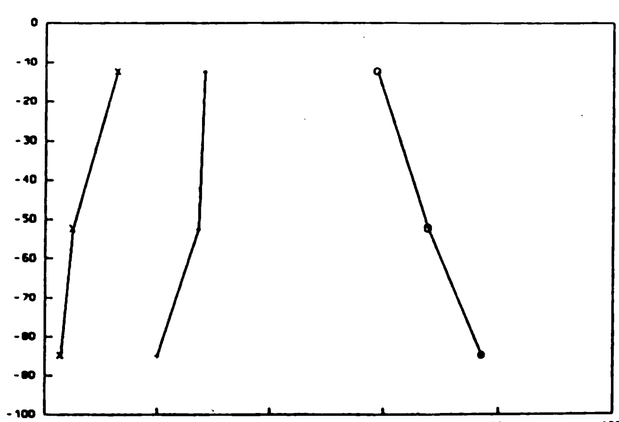

Figure 8 Percentages clay (x), silt (+) and sand (o) versus depth (cm) in profile CR 7.

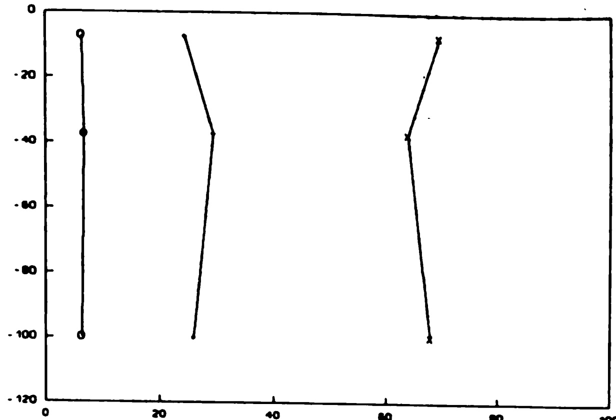

Figure 9 Percentages clay (x), silt (+) and sand (o) versus depth (cm) in profile CR 8

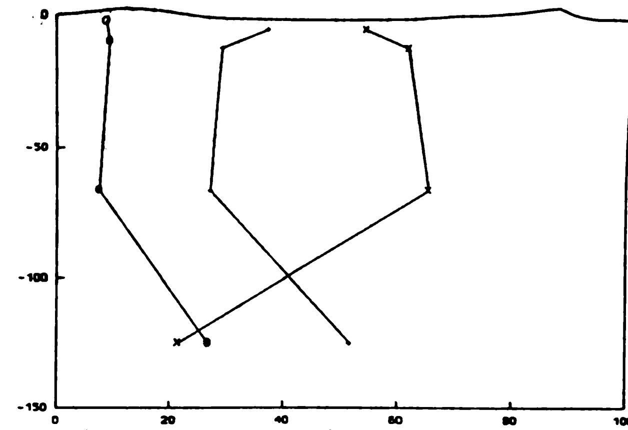

Figure 10 Percentages clay (×), silt (+) and sand (o) versus depth (cm) in profile CR 9.

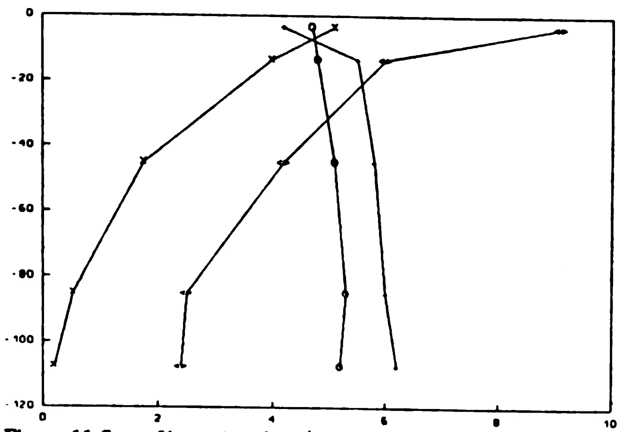

Figure 11 Sum of bases (cmol$_c$ kg^{-1} soil) (< >), pH-H_2O (+), pH-KCl (o) and organic carbon (×) versus depth (cm) in profile CR 6.

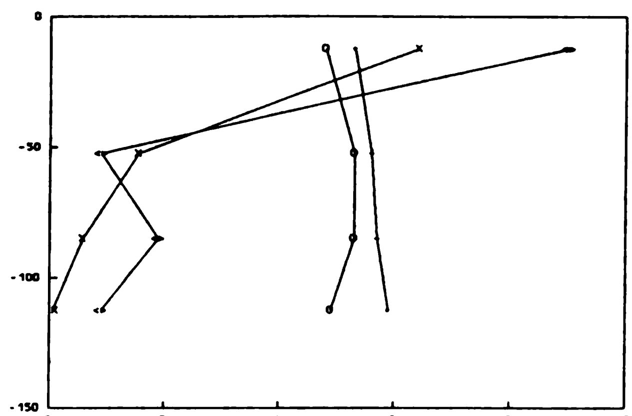

Figure 12 Sum of bases (cmol$_c$ kg^{-1} soil) (< >), pH-H_2O (+), pH-KCl (o) and organic carbon (×) versus depth (cm) in profile CR 7.

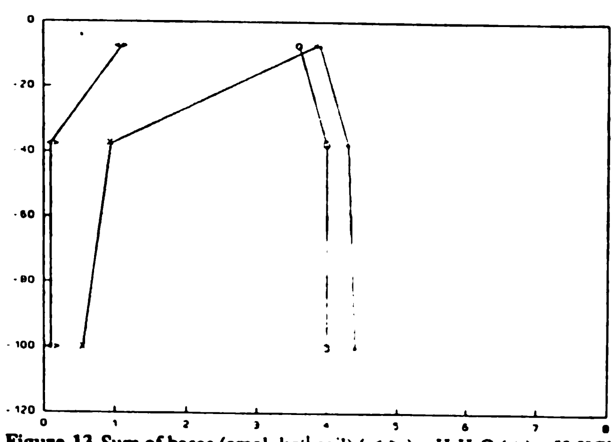

Figure 13 Sum of bases (cmol$_c$ kg^{-1} soil) (< >), pH-H_2O (+), pH-KCl (o) and organic carbon (×) versus depth (cm) in profile CR 8.

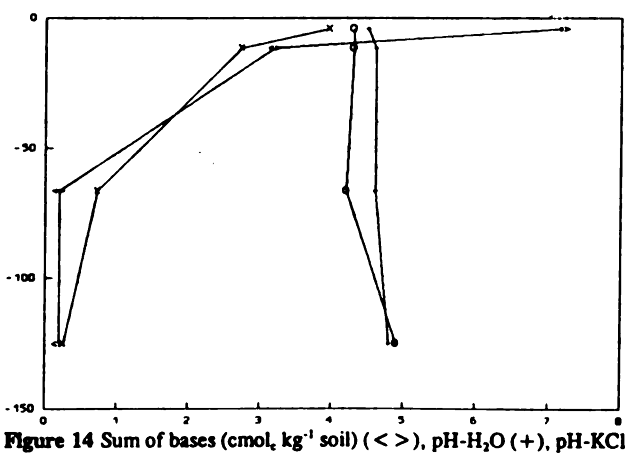

Figure 14 Sum of bases (cmol$_c$ kg^{-1} soil) (< >), pH-H_2O (+), pH-KCl (o) and organic carbon (×) versus depth (cm) in profile CR 9.

2.5 Land suitability

A qualitative evaluation of relevant land qualities according FAO's framework (1983) was made. The land was evaluated for a deep rooting, high nutrient demanding crop such as maize. The results of this evaluation are presented in Annex 2.

2.5.1 Reference soils CR 6 and CR 7

CR 6 and CR 7 are among the most productive soils of Costa Rica. Problems may occur with mechanization as in some places large boulders are abundant at shallow depths (within 30 cm). Heavy machinery can not be used when the soil is too wet because of the low bulk density and Andic properties. Forest clearing by tractors and cattle trampling increases the soil bulk density. The increase in bulk density particularly occurs in the topsoil but also in deeper layers. The soils are sensitive to soil compaction. Although compaction occurs and hydraulic conductivity decreases as a result of this compaction, it is not a limiting factor for production because the infiltration rates remain favourable. CR 6 and CR 7 are representative for the fertile soils which are mainly used for very intensive banana production. Banana is suitable for this soil type and the climatic conditions are favourable. Pests and diseases may cause problems. This is illustrated by the fact that since the introduction of banana plantations in the last century the total production has been vanished twice, due to fungus diseases i.e. 'Panama disease' in 1901 and 'Sigatoka negra' in the 1960s. Another example is the 'monilia' fungi, which has destroyed the cocoa production of Costa Rica since the early 1970s.

2.5.2 Reference soils CR 8 and CR 9

CR 8 and CR 9 are representatives of the low fertile soils of Costa Rica. The same soil physical problems as mentioned for CR 6 and CR 7 may occur i.e. compaction and decreasing hydraulic conductivities.
CR 8 and CR 9 are mainly used for extensive cattle grazing. The soils are also used for small scale, intensive pineapple and palm heart production in the Neguev area. Palm heart is a relatively new crop in the Neguev area. Production has sharply increased during the last years due to new world markets.

2.6 Soil formation

2.6.1 CR 6 and CR 7

The landscape of the reference soils CR 6 and 7 has been formed in Holocene alluvial sediments. Comparison of soil development with soils developed in Holocene beach ridges (Nieuwenhuyse *et al.*, 1992) reveals that the age of the sediment is probably between 2000 and 5000 years. The andesitic composition of the sediment combined with the dense forest vegetation and the warm humid tropical climate, are major factors in the formation of this Andosol.
The difference between rainfall and evaporation results in a high surplus of precipitation (almost 3000 mm per year), which for the major part percolates through the soil, hence leaching bases. Because of these extreme leaching conditions, the base saturation is low. Considerable amount of weatherable primary minerals are still present in the soil.

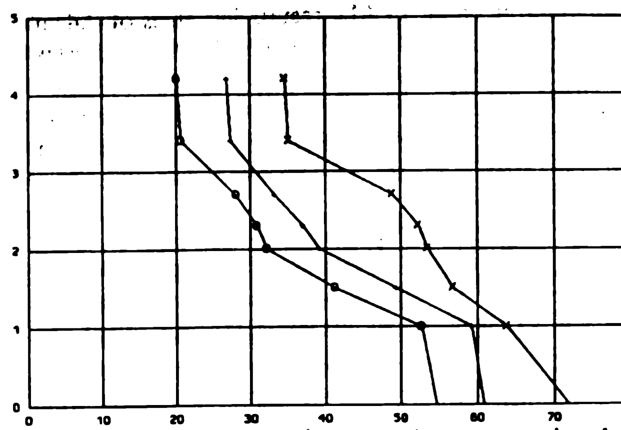

Figure 15 pF or moisture retention curves (water content in vol % versus suction) at depth 7-20 cm (×), 20-70 cm (+), 70-100 cm (o) in profile CR 6.

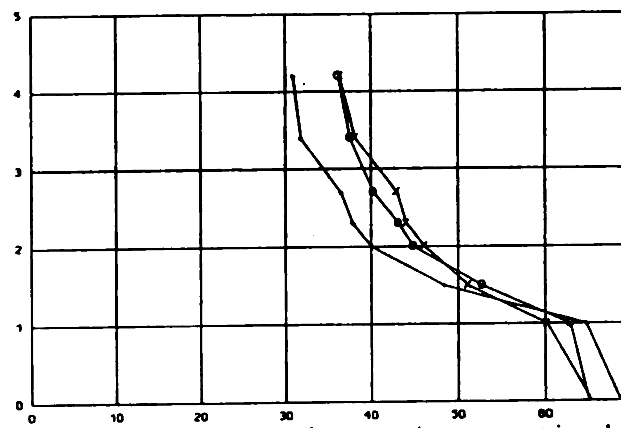

Figure 16 pF or moisture retention curves (water content in vol % versus suction) at depth 0-25 cm (×), 25-80 cm (+), 80-90 cm (o) in profile CR 7.

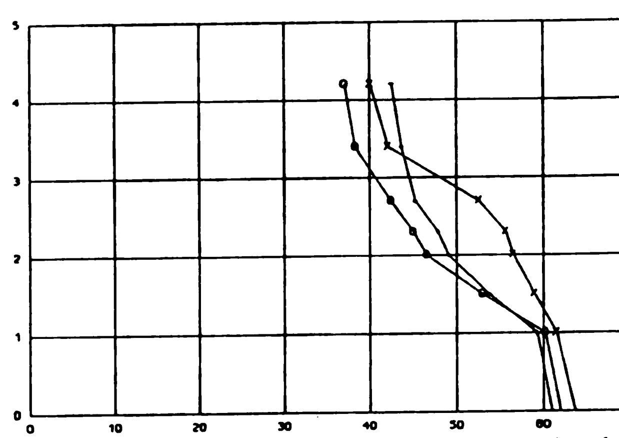

Figure 17 pF or moisture retention curves (water content in vol % versus suction) at depth 0-15 cm (×), 15-80 cm (+), 80-140 cm (o) in profile CR 8.

Calculating the ratio AVAI,, results in values of 0.4 in the topsoil and about 0. 1 in the subsoil. This indicates that the soil is mainly an "allophanic" Andosol in which the allophane/imogolite association tends to dominate over the Fe-Al-humus association (Mizota & van Reeuwijk, 1989). It can be concluded that the soil is relatively young.
The reference soils are very rich in soil organic matter throughout the profile. Veldkamp (1994) showed that a large fraction of the organic matter in these profiles was stabilized by stable Al-humus complexes and allophane. For CR 6, Veldkamp found that after 25 years of pasture 63% of the organic matter in the topsoil originated from the forest. This means that the remaining 37% of the organic matter can be considered as 'active'.

2.6.2 CR 8 and CR 9

The landscape of reference soils CR 8 and CR 9 has been formed in fluvio laharic sediments of Pleistocene age (Eemien). The terrace in which this soil has been formed was deposited in a time when the base level was higher. Nowadays, the flat tops of the dissected terrace are about 20m over the base level.
The difference between rainfall and evaporation results in a high surplus of precipitation (almost 3000 mm per year), which for the major part percolates through the soil, hence leaching bases.
Reference soils CR 8 and CR 9 can be considered as remnants of a mature Andosol. Some Andic properties are still present and that is why the soils are classified as Andic Humitropept. The bulk densities are low to very low, and the acid oxalate extractable Al + 0.5 Fe is more than 1.0. There is no allophane left in these soils. It has been transformed into gibbsite and kaolinite and in some parts of the profile gibbsite can be recognized as small (1 mm) weak white nodules.
The soils are extremely deep (8-9 m). The top part of the profile may be younger that the underlying part. In the toppart andesitic pebbles rounded by weathering, are found regularly. Also the rejuvenation due to volcanic ashes cannot be excluded, although no morphological prove has been found.
Reference soils CR 8 and CR 9 contain soil organic matter throughout the profiles. Veldkamp (1994) showed that a large fraction of the organic matter was stabilized in Al-humus complexes and ferrihydrite ($FeOH_3$) with intimately adsorbed organic matter.

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1. Landscape near CR 6
2. Topsoil of CR 7 showing strong crumb structure
3. Landscape near CR 9. This low productive pasture was established in 1975

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4. **Forest of CR 8 in 1991.**
   This area was cleared in 1993
5. **Profile CR 8**

Annex 1A ISIS Data Sheet CR 6

Reference soil CR 6, COSTA RICA — Print date: 26 June 199?

FAO/UNESCO (1988) :
(1974) : Andosols
USDA/SCS SOIL TAXONOMY (1992) : coarse-loamy over sandy/sandy-sk., isohyperthermic
(1975) : Typic Dystrandept
LOCAL CLASSIFICATION : Suelo Los Diamantes

DIAGNOSTIC CRITERIA
USDA/SCS (1992) :
Soil moisture regime : perudic
Soil temperature regime : isohyperthermic

(CLASSIFICATIONS ARE FIELD CLASSIFICATIONS)

LOCATION : Costa Rica, Guapiles, Los Diamantes, 200m N of cow-shed.
Latitude / Longitude : 10°13'15"N / 83°46'45"W — Altitude : 250 m a.s.l.
AUTHOR(S) : Veldkamp, E./A.Weitz — Date : March 1991

GENERAL LANDFORM : alluvial fan — Topography : undulating
PHYSIOGRAPHIC UNIT : river terrace on alluvial fan
SLOPE Gradient, Aspect, Form : 3%, E , straight, — Position of site : middle slope
MICRO RELIEF Kind :
SURFACE CHAR. Rock outcrop : nil — Cracking : nil
Stoniness, Size, Form : very few stones, 50 cm, , (sub)rounded — Salt : nil
Slaking/crusting : nil — Alkali : nil
SLOPE PROCESSES Soil erosion : no

PARENT MATERIAL 1 type, texture : alluvium derived from fine-grained intermediate igneous, sandy
Remarks : Andesitic origin

EFFECTIVE SOIL DEPTH : 100 cm
WATER TABLE Kind, Depth : no watertable observed, -
DRAINAGE : well
PERMEABILITY : high — No slowly permeable layer(s) cm
FLOODING Frequency : nil
MOISTURE CONDITIONS PROFILE : 0-130 cm moist

LAND USE : cultivated pasture, no irrigation, not relevant
Improvements : none
Land use/vegetation remarks : Forest cut approximately in 1963

CLIMATE Köppen : af
MET. STATIONS Name, Location : LOS DIAMANTES, 10°13' / 83°46', 249 m a.s.l
Distance to site (relevance) : LOS DIAMANTES lays 1 km SSE of the site (very good)

LOS DIAMANTES		No. years of record	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
relative humidity	%	13	87	85	84	86	88	89	89	89	88	88	89	88	87
precipitation	mm	37	289	220	190	245	399	430	482	428	358	446	489	485	4466
T mean	°C	19	23.6	23.3	24.1	24.7	25.3	25.3	24.9	25.2	25.3	25.0	24.4	23.7	0.6
T max	°C	19	28.5	28.6	29.3	29.6	30.3	30.0	29.2	29.9	30.3	29.9	28.9	28.3	0.5
T min	°C	19	18.9	18.3	18.8	19.7	20.5	20.5	20.7	20.6	20.4	20.3	20.3	19.4	1.0
bright sunshine	$h\ d^{-1}$	14	4.6	4.6	4.7	4.7	4.5	3.3	3.4	4.0	4.1	3.7	3.7	4.1	4.2

PROFILE DESCRIPTION :

Ah1	0 - 7 cm	very dark grayish brown (10YR 3.0/2.0, moist) loam; strong fine subangular blocky non sticky, non plastic, friable, slightly hard; no mottles; no cutans; common very fine continuous exped tubular pores and common fine vertical continuous exped interstitial pores; many very fine roots throughout and many fine roots throughout; no inclusions; no fragments;; clear smooth boundary to
Ah2	7 - 20 cm	dark brown (10YR 3.0/3.0, moist) loam; moderate fine subangular blocky and moderate fine angular blocky non sticky, non plastic, friable, slightly hard; no mottles; no cutans; common very fine continuous exped and inped tubular pores and common fine vertical continuous exped and inped interstitial pores; many very fine roots throughout and many fine roots throughout; no inclusions; no fragments;; gradual smooth boundary to
Ah3	20 - 70 cm	dark brown (10YR 3.0/3.0, moist) sandy loam; weak medium angular blocky non sticky, non plastic , very friable, soft; no mottles; no cutans; common very fine continuous exped and inped tubular pores; few very fine roots throughout and few fine roots throughout; no inclusions; no fragments; frequent coprogenic elements;; clear smooth boundary to
B	70 - 100 cm	dark brown (10YR 4.0/3.0, moist) loamy sand; weak medium angular blocky non sticky, non plastic , very friable, loose; few very fine continuous exped and inped tubular pores; few very fine roots and few fine roots;; clear smooth boundary to
C	100 - 115 cm	dark brown (10YR 3.0/3.0, moist) sand; structureless non sticky, non plastic, loose, loose; many fine continuous interstitial pores; highly porous; no roots;; clear smooth boundary to
2b	115 - 140 cm	dark yellowish brown (10YR 4.0/4.0, moist) loamy sand; weak medium angular blocky non sticky, non plastic, friable, slightly hard; common very fine continuous exped and inped tubular pores and common fine random continuous exped and inped tubular pores; moderately porous; no roots;;

ADDITIONAL REMARKS

Brief soil description:
Moderately deep, well drained, dark brown to brown coarse loamy over sandy soil, well structured.

Some pot splinters were found at about 30 cm depth indicating former indian activity at site. Between 30 and 60 cm abundant small balls of dung (?) were found originating from dung beetles.

Actual classification:
FAO (1988): Umbric Andosol
USDA (1992): Vitric Hapludand

ANALYTICAL DATA:

				PARTICLE SIZE DISTRIBUTION (μm)												pF							
			>2	2000	1000	500	250	100	TOT	50	20	TOT		WDIS	BULK								
Hor.	Top	Bot.	mm	1000	500	250	100	50	SAND	20	2	SILT	<2	CLAY	DENS	0.0	1.0	1.5	2.0	2.3	2.7	3.4	4.2
Ah1	0 -	7	0	1	4	16	28	12	62	9	28	36	2	1.6	-	-	-	-	-	-	-	-	-
Ah2	7 -	20	0	1	4	13	34	11	63	9	27	36	-	3.7	0.56	72	64	57	54	52	49	35	35
Ah3	20 -	70	0	1	2	15	38	16	71	8	21	29	-	2.5	0.85	61	59	49	39	37	33	27	27
B	70 -	100	0	1	4	15	48	13	80	8	9	17	3	0.0	1.01	55	53	41	32	31	28	21	20
C	100 -	115	0	0	1	17	59	12	89	5	4	8	3	2.4	-	-	-	-	-	-	-	-	-

	pH	pH		ORG. MATTER		EXCHANGEABLE CATIONS					EXCH. ACID.		CEC	CEC	CEC		BASE	AL		
Hor.	H2O	KCl	CaCO3	C	N	Ca	Mg	K	Na	sum.	H+Al	Al	soil	clay	OrgC	ECEC	SAT	SAT	EC2.5	ESP
Ah1	4.2	4.7	-	5.1	0.65	6.0	2.5	0.3	0.3	9.1	0.4	0.0	17.1	814	17.9	9.5	53	0	0.18	
Ah2	5.5	4.8	-	4.0	0.46	4.7	1.1	0.1	0.1	6.0	-	-	16.2	-	14.0	6.0	37	-	0.08	
Ah3	5.8	5.1	-	1.8	0.18	3.0	0.7	0.2	0.3	4.2	-	-	9.0	-	6.2	4.2	47	-	0.03	
B	6.0	5.3	-	0.5	0.04	1.9	0.3	0.2	0.1	2.5	-	-	5.5	177	1.9	2.5	45	-	0.02	
C	6.2	5.2	-	0.2	0.02	1.9	0.4	0.1	0.0	2.4	-	-	4.5	167	0.7	2.4	53	-	0.02	

CLAY MINERALOGY (1 = very weak .. 8 = very strong)

Hor.	MI	VE	CH	SM	KA	HA	ML	QU	FE	GI	GO	HE
Ah1	.	.	.	.	.	.	.	.	.	.	.	.
Ah2	.	.	.	.	.	.	.	.	.	.	.	.
Ah3	.	.	.	.	.	.	.	.	.	.	.	.
B	.	.	.	.	1	.	.	.	.	.	.	.
C	.	.	.	.	2	.	.	.	2	.	.	.

EXTRACTABLE Fe, Al, Si, Mn by amm. oxal.(o), Na dith(d) & pyroph.(p)

Hor.	Fe(o)	Al(o)	Si(o)	Fe(d)	Al(d)	Fe(p)	Al(p)	Pret	pHNaF
Ah1	1.01	1.77	0.14	-	-	-	-	-	-
Ah2	0.81	1.72	0.08	-	-	-	-	-	-
Ah3	0.59	2.08	0.18	-	-	-	-	-	-
B	0.45	1.06	0.08	-	-	-	-	-	-
C	0.58	0.81	0.17	-	-	-	-	-	-

Reference soil CR 7, COSTA RICA — Print date: 26 June 1995

FAO/UNESCO (1988)	:
(1974)	: Andosols
USDA/SCS SOIL TAXONOMY (1992)	: coarse-loamy over sandy/sandy-sk., isohyperthermic
(1975)	: Typic Dystrandept
LOCAL CLASSIFICATION	: Suelo Los Diamantes

DIAGNOSTIC CRITERIA
USDA/SCS (1992) :

Soil moisture regime : perudic
Soil temperature regime : isohyperthermic

(CLASSIFICATIONS ARE FIELD CLASSIFICATIONS)

LOCATION	: Costa Rica Guapiles, on west bank of Rio Diamantes, colegio agropec.		
Latitude / Longitude	: 10°13'40"N / 83°46'30"W	Altitude	: 240 m a.s.l.
AUTHOR(S)	: Veldkamp,E.GJ.Weer	Date	: March 1991

GENERAL LANDFORM	: alluvial fan	Topography	: undulating
PHYSIOGRAPHIC UNIT	: river terrace on alluvial fan		
SLOPE Gradient, Aspect, Form	: 3%, S , straight,	Position of site	: middle slope
MICRO RELIEF Kind	: level	Pattern	: none
SURFACE CHAR. Rock outcrop	: nil	Cracking	: nil
Stoniness	: nil	Salt	: nil
Slaking/crusting	: nil	Alkali	: nil
SLOPE PROCESSES Soil erosion	: no		

PARENT MATERIAL 1 type, texture	: alluvium derived from fine-grained intermediate igneous, sandy
Weathering degree, resistance	: slight, -
Remarks	: Andesitic origin

EFFECTIVE SOIL DEPTH	: 90 cm
WATER TABLE Kind, Depth	: no watertable observed, -
DRAINAGE	: somewhat excessively
PERMEABILITY	: No slowly permeable layer(s) cm
FLOODING Frequency	: nil
MOISTURE CONDITIONS PROFILE	: 0-150 cm moist

LAND USE	: (semi-)natural vegetation, no irrigation, not relevant		
Improvements	: none		
VEGETATION Type	: closed forest	Status	: cut over
Land use/vegetation remarks	: forest strip of 50 m width along river		

CLIMATE Köppen	: Af
MET. STATIONS Name, Location	: LOS DIAMANTES, 10°13' / 83°46', 249 m a.s.l
Distance to site (relevance)	: LOS DIAMANTES lays 1 km SSE of the site (very good)

LOS DIAMANTES		No. years of record	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
relative humidity	%	13	87	85	84	86	88	89	89	89	88	88	89	88	87
precipitation	mm	37	289	220	190	245	399	430	482	428	358	446	489	485	4466
T mean	°C	19	23.6	23.3	24.1	24.7	25.3	25.3	24.9	25.2	25.3	25.0	24.4	23.7	0.6
T max	°C	19	28.5	28.6	29.3	29.6	30.3	30.0	29.2	29.9	30.3	29.9	28.9	28.3	0.5
T min	°C	19	18.9	18.3	18.8	19.7	20.5	20.5	20.7	20.6	20.4	20.3	20.3	19.4	1.0
bright sunshine	$h\ d^{-1}$	14	4.6	4.6	4.7	4.7	4.5	3.3	3.4	4.0	4.1	3.7	3.7	4.1	4.2

PROFILE DESCRIPTION :

Ah1	0 - 25 cm	very dark brown (10YR 2.0/2.0, moist) sandy loam; strong medium crumb non sticky, non plastic , very friable; many continuous exped and inped tubular pores; highly porous; many very fine to coarse roots throughout;; clear smooth boundary to
Ah2	25 - 80 cm	dark brown (10YR 3.0/3.0, moist) sandy loam; weak medium to coarse subangular blocky non sticky , non plastic, very friable; many very fine continuous exped and inped tubular pores and many fine random continuous exped and inped tubular pores; highly porous; many very fine to coarse roots throughout;; gradual smooth boundary to
B	80 - 90 cm	dark brown (10YR 3.0/3.0, moist) loamy sand; weak medium to coarse angular blocky non sticky, non plastic, friable; many very fine continuous exped and inped tubular pores and many fine random continuous exped and inped tubular pores; highly porous; few fine roots throughout; abrupt smooth boundary to
C	90 - 135 cm	very dark brown (10YR 2.0/2.0, moist) sand; structureless non sticky, non plastic, loose, loose; many fine continuous interstitial pores; highly porous; no roots;; abrupt wavy boundary to
2Bb	135 - 150 cm	dark brown (10YR 3.0/3.0, moist) loamy sand; weak medium angular blocky non sticky, non plastic , very friable; common very fine continuous exped and inped tubular pores and common fine random continuous exped and inped tubular pores; moderately porous; no roots;;

ADDITIONAL REMARKS

Brief soil description:
Moderately deep, well drained, dark brown to brown loamy over sandy soil, well structured.

On the boundary of Ah1 to Ah2 a 'panlike structure' is found altough no compaction was found. The structure can be recognized as a grey band with rust coloured edges. Abundant soil fauna: ants, earthworms, termites, jumptails, beetles.

Actual classification:
FAO (1988): Umbric Andosol
USDA (1992): Acrudoxic Hapludand

ANALYTICAL DATA:

PARTICLE SIZE DISTRIBUTION (µm)

Hor.	Top	Bot.	>2 mm	2000 1000	1000 500	500 250	250 100	100 50	TOT SAND	50 20	20 2	TOT SILT	<2	WDIS CLAY	BULK DENS	pF 0.0	1.0	1.5	2.0	2.3	2.7	3.4	4.2
Ah1	0 -	25	0	2	6	16	26	9	59	10	18	28	13	3.1	0.75	65	60	51	46	44	43	38	36
Ah2	25 -	80	0	2	7	16	30	13	68	11	16	27	5	2.1	0.69	69	65	49	40	38	37	32	31
B	80 -	90	0	3	9	22	34	10	77	8	12	20	3	3.0	0.77	65	63	53	45	43	40	38	36
C	90 -	135	0	2	20	46	25	4	96	0	3	3	-	2.4	-	-	-	-	-	-	-	-	-

Hor.	pH H2O	pH KCl	CaCO3	ORG. MATTER C	N	EXCHANGEABLE CATIONS Ca	Mg	K	Na	sum	EXCH. ACID. H+Al	Al	CEC soil	CEC clay	CEC OrgC	ECEC	BASE SAT	AL SAT	EC2.5	ESP
Ah1	5.3	4.8	-	6.4	0.68	6.8	1.8	0.3	0.1	9.0	0.3	0.0	21.0	164	22.5	9.3	43	0	0.24	
Ah2	5.6	5.3	-	1.6	0.17	0.8	0.0	0.0	0.1	0.9	-	-	5.9	120	5.4	0.9	15	-	0.03	
B	5.7	5.3	-	0.6	0.07	1.4	0.3	0.1	0.1	1.9	-	-	5.4	193	2.0	1.9	35	-	0.02	
C	5.9	4.9	-	0.1	0.01	0.6	0.2	0.1	0.0	0.9	-	-	2.8	-	0.2	0.9	32	-	0.01	

CLAY MINERALOGY (1 = very weak .. 8 = very strong)

Hor.	MI	VE	CH	SM	KA	HA	ML	QU	FE	GI	GO	HE
Ah1	·	·	·	·	1	·	1	·	1	·	·	·
Ah2	·	·	·	·	1	·	1	·	1	·	·	·
B	·	·	·	·	1	·	1	·	1	·	·	·
C	·	·	·	·	1	·	1	·	1	·	·	·

EXTRACTABLE Fe, Al, Si, Mn by amm. oxal.(o), Na dith(d) & pyroph.(p)

Hor.	Fe(o)	Al(o)	Si(o)	Fe(d)	Al(d)	Fe(p)	Al(p)	Pret	pHNaF
Ah1	0.69	2.01	0.18	-	-	-	-	-	-
Ah2	0.62	2.26	0.18	-	-	-	-	-	-
B	0.42	1.52	0.24	-	-	-	-	-	-
C	0.61	0.42	0.12	-	-	-	-	-	-

Reference soil CR 8, COSTA RICA

Print date: 26 June 1995

FAO/UNESCO (1988)	:
USDA/SCS SOIL TAXONOMY (1992)	: clayey, kaolinitic, isohyperthermic
(1975)	: Typic Haplorthox
LOCAL CLASSIFICATION	: Suelo Neguev

DIAGNOSTIC CRITERIA
USDA/SCS (1992) :

Soil moisture regime : perudic
Soil temperature regime : isohyperthermic

(CLASSIFICATIONS ARE FIELD CLASSIFICATIONS)

LOCATION	: Prov. de Limon Asentamiento Neguev, Parcela 252		
Latitude / Longitude	: 10°11'0"N / 83°32'30"W	Altitude	: 30 m a.s.l.
AUTHOR(S)	: Veldkamp/GJ.Weerts	Date	: February 1991

GENERAL LANDFORM	: alluvial terrace	Topography	: flat or almost flat
PHYSIOGRAPHIC UNIT	: Flat top Pleistocene terrace		
SLOPE Gradient	: 0%,	Position of site	: flat
MICRO RELIEF Kind	: level	Pattern	: none
SURFACE CHAR. Rock outcrop	: nil	Cracking	: nil
Stoniness	: nil	Salt	: nil
Slaking/crusting	: nil	Alkali	: nil
SLOPE PROCESSES Soil erosion	: no		

PARENT MATERIAL 1 type, texture	: alluvium derived from fine-grained intermediate igneous
Remarks	: see general remarks

EFFECTIVE SOIL DEPTH	: 150 cm	
WATER TABLE Kind, Depth	: no watertable observed, -	
DRAINAGE	:	
PERMEABILITY	: high	No slowly permeable layer(s) cm
FLOODING Frequency	: nil	
MOISTURE CONDITIONS PROFILE	: 0-140 cm moist	

LAND USE	: (semi-)natural vegetation, no irrigation, not relevant		
Improvements	: none		
VEGETATION Type	: evergreen forest	Status	: cut over
Land use/vegetation remarks	: remaining forest island of about 6ha		

PROFILE DESCRIPTION :

Ah	0 - 15 cm	dark brown (10YR 3.0/3.0, moist) silty clay; moderate fine to medium crumb slightly sticky , slightly plastic, very friable; many continuous exped and inped interstitial pores and many random continuous exped and inped tubular pores; highly porous; many very fine to coarse roots; non calcareous; clear wavy boundary to
Bu1	15 - 60 cm	dark yellowish brown (10YR 3.0/4.0, moist) silty clay; weak porous massive slightly sticky , slightly plastic, very friable; many continuous exped and inped tubular pores; highly porous; few very fine to coarse roots;; clear smooth boundary to
Bu2	60 - 140 cm	dark yellowish brown (10YR 3.0/4.0, moist) silty clay; weak porous massive slightly sticky , slightly plastic, very friable; many continuous exped and inped tubular pores; few very fine to coarse roots; weakly cemented discontinuous massive iron pan;

ADDITIONAL REMARKS

Brief soil description:
very deep, well drained, brown clay soil, strongly acid and having a very low sum of exchangeable bases.

Parent material is of fluvio-laharic origin. The original texture is not known. Composition parent material is probably andesitic. The pan has a black color and occurs at about 140cm depth.

Actual classification:
FAO (1988): Haplic Ferralsol
USDA (1992): Andic Haploperox

ANALYTICAL DATA:

Hor.	Top	Bot.	>2 mm	PARTICLE SIZE DISTRIBUTION (μm) 2000-1000	1000-500	500-250	250-100	100-50	TOT SAND	50-20	20-2	TOT SILT	<2	WDIS CLAY	BULK DENS	pF 0.0	1.0	1.5	2.0	2.3	2.7	3.4	4.2
Ah	0	15	0	0	0	1	3	2	6	6	18	24	69	14.2	0.95	64	62	59	57	56	53	42	40
Bu1	15	60	0	0	0	1	3	2	7	7	22	29	64	2.1	0.95	61	59	54	49	48	45	44	43
Bu2	60	140	0	0	0	1	3	2	6	5	21	26	68	2.0	0.87	62	60	53	47	45	43	38	37

Hor.	pH H2O	pH KCl	CaCO3	ORG. MATTER C	N	EXCHANGEABLE CATIONS Ca	Mg	K	Na	sum	EXCH. ACID. H+Al	Al	CEC soil	CEC clay	CEC OrgC	ECEC	BASE SAT	AL SAT	EC2.5	ESP
Ah	3.9	3.6	-	3.8	0.44	0.4	0.3	0.4	0.0	1.1	6.4	5.2	19.4	28	13.4	7.5	6	27	0.34	
Bu1	4.3	4.0	-	0.9	0.14	0.0	0.0	0.1	0.0	0.1	3.8	3.2	10.0	16	3.3	3.9	1	32	0.03	
Bu2	4.4	4.0	-	0.6	0.10	0.0	0.0	0.0	0.1	0.1	3.1	2.4	9.2	14	1.9	3.2	1	26	0.03	

CLAY MINERALOGY (1 = very weak .. 8 = very strong) / EXTRACTABLE Fe, Al, Si, Mn by amm. oxal.(o), Na dith(d) & pyroph.(p)

Hor.	MI	VE	CH	SM	KA	HA	ML	QU	FE	GI	GO	HE	Fe(o)	Al(o)	Si(o)	Fe(d)	Al(d)	Fe(p)	Al(p)	Pret	pHNaF
Ah	·	·	·	·	4	·	1	·	·	2	2	·	0.70	0.50	0.05	-	-	-	-	-	-
Bu1	·	·	·	·	4	·	1	·	·	3	2	·	0.73	0.70	0.06	-	-	-	-	-	-
Bu2	·	·	·	·	4	·	1	·	·	3	2	·	0.73	0.63	0.06	-	-	-	-	-	-

Reference soil CR 9, COSTA RICA Print date: 26 June 1995

FAO/UNESCO (1988) :
USDA/SCS SOIL TAXONOMY (1992) : clayey, gibbsitic, isohyperthermic
(1975) : Tropeptic Haplorthox
LOCAL CLASSIFICATION : Suelo Neguev

DIAGNOSTIC CRITERIA
USDA/SCS (1992) :
Soil moisture regime : perudic
Soil temperature regime : isohyperthermic

(CLASSIFICATIONS ARE FIELD CLASSIFICATIONS)

LOCATION : Prov. de Limón, Asentamiento Neguev, parcela 255.
Latitude / Longitude : 10°10'15"N / 83°32'30"W Altitude : 30 m a.s.l.
AUTHOR(S) : Veldkamp Date : April 1991

GENERAL LANDFORM : alluvial terrace Topography : flat or almost flat
PHYSIOGRAPHIC UNIT : flat top of dissected terrace
SLOPE Gradient : 0%, Position of site : flat
MICRO RELIEF Kind : level Pattern : none
SURFACE CHAR. Rock outcrop : nil Cracking : small cracks
Stoniness : nil Salt : nil
Slaking/crusting : nil Alkali : nil
SLOPE PROCESSES Soil erosion : no

PARENT MATERIAL 1 type, texture : alluvium derived from fine-grained intermediate igneous
Remarks : see general remarks

EFFECTIVE SOIL DEPTH : 140 cm
WATER TABLE Kind, Depth : no watertable observed, -
DRAINAGE : well
PERMEABILITY : high No slowly permeable layer(s) cm
MOISTURE CONDITIONS PROFILE : 0-25 cm dry, 25-140 cm moist

LAND USE : cultivated pasture, no irrigation, not relevant
Improvements : none
Land use/vegetation remarks : deforested approximately in 1975

PROFILE DESCRIPTION :

A 0 - 8 cm very dark grayish brown (10YR 3.0/2.0, moist) silty clay; strong medium prismatic parting to moderate fine subangular blocky slightly sticky, slightly plastic, firm, very hard; common fine continuous exped interstitial pores and common very fine random continuous exped and inped tubular pores; highly porous; many very fine roots in cracks and many fine roots in cracks;; clear smooth boundary to

Bu1 8 - 23 cm dark brown (10YR 4.0/3.0, moist) silty clay; moderate medium prismatic parting to moderate medium angular blocky slightly sticky, slightly plastic, friable, hard; common fine continuous exped interstitial pores and common very fine random continuous exped and inped tubular pores; few very fine roots in cracks and few fine roots in cracks;; clear smooth boundary to

Bu2 23 - 110 cm dark yellowish brown (10YR 3.0/4.0, moist) silty clay; weak fine subangular blocky to weak porous massive slightly sticky, slightly plastic, very friable; many very fine continuous exped and inped tubular pores and many fine random continuous exped and inped tubular pores; few very fine roots throughout and few fine roots throughout;; boundary to

Bu3 110 - 140 cm dark brown (10YR 3.0/3.0, moist) silty clay; weak fine subangular blocky to weak porous massive slightly sticky, slightly plastic, very friable; many very fine continuous exped and inped tubular pores and many fine random continuous exped and inped tubular pores; highly porous; few very fine roots throughout and few fine roots throughout;;^[&a6H

ADDITIONAL REMARKS

Brief soil description:
Very deep, well drained, brown clay soil, strongly acid and having a very low sum of exchangeable bases.

In the lower part of the soil monolith cemented remains of the parent material can be observed. Cementing material is probably silica. Parent material is of fluvio-laharic origin. The original texture is not known with certainty, but appears to be andesitic sand.

Topsoil (0-23) is severely compacted. Profile was described in extremely dry period. Therfore cracks were visible which normally don't occur.

Actual classification:
FAO (1988): Haplic Ferralsol
USDA (1992): Andic Haploperox

ANALYTICAL DATA:

			PARTICLE SIZE DISTRIBUTION (µm)																				
			>2	2000	1000	500	250	100	TOT	50	20	TOT		WDIS	BULK	pF							
Hor.	Top	Bot.	mm	1000	500	250	100	50	SAND	20	2	SILT	<2	CLAY	DENS	0.0	1.0	1.5	2.0	2.3	2.7	3.4	4.2
A	0	8	0	0	1	2	3	3	9	6	31	37	54	7.7	-	-	-	-	-	-	-	-	-
	0	23	0	0	1	2	4	2	9	6	23	29	62	12.7	-	-	-	-	-	-	-	-	-
Bu2	23	110	0	0	1	1	3	2	8	6	22	27	66	10.7	-	-	-	-	-	-	-	-	-
Bu3	110	140	0	1	2	4	13	7	27	16	36	52	22	11.0	-	-	-	-	-	-	-	-	-

	pH	pH		ORG. MATTER		EXCHANGEABLE CATIONS					EXCH. ACID.		CEC	CEC	CEC		BASE	AL		
Hor.	H2O	KCl	CaCO3	C	N	Ca	Mg	K	Na	sum	H+Al	Al	soil	clay	OrgC	ECEC	SAT	SAT	EC2.5	ESP
A	4.5	4.3	-	4.0	0.47	3.2	3.1	0.9	0.0	7.2	0.6	0.2	18.3	34	13.9	7.8	39	1	0.74	
	4.6	4.3	-	2.7	0.34	1.5	1.4	0.2	0.1	3.2	0.8	0.2	13.9	22	9.6	4.0	23	1	0.24	
Bu2	4.6	4.2	-	0.7	0.10	0.0	0.1	0.1	0.0	0.2	1.6	1.2	8.2	13	2.6	1.8	2	15	0.02	
Bu3	4.8	4.9	-	0.3	0.04	0.0	0.1	0.0	0.1	0.2	0.1	0.0	6.0	28	0.9	0.3	3	0	0.02	

CLAY MINERALOGY (1 = very weak .. 8 = very strong)

Hor.	MI	VE	CH	SM	KA	HA	ML	QU	FE	GI	GO	HE
A	·	·	·	2	4	·	·	1	·	6	·	·
	·	·	·	1	4	·	·	1	·	7	·	·
Bu2	·	·	·	1	4	·	·	·	·	6	·	·
Bu3	·	·	·	1	2	·	·	·	·	6	·	·

EXTRACTABLE Fe, Al, Si, Mn by amm. oxal.(o), Na dith(d) & pyroph.(p)

Hor.	Fe(o)	Al(o)	Si(o)	Fe(d)	Al(d)	Fe(p)	Al(p)	Pret	pHNaF
A	1.25	0.53	0.04	-	-	-	-	-	-
	0.93	0.54	0.01	-	-	-	-	-	-
Bu2	0.62	0.61	0.03	-	-	-	-	-	-
Bu3	0.88	0.72	0.07	-	-	-	-	-	-

Annex 2 Evaluation of Land Qualities

LAND QUALITY Availability

(1) | vh | h | m | l | vl |

vh = very high h = high m = moderate l = low
vl = very low

Hazard/Limitation

(2) | n | w | m | s | vs |

n = not present w = weak m = moderate s = serious
vs = very serious

Land quality			CR 6, CR 7					CR 8, CR 9				
CLIMATE												
Radiation regime	- total radiation	1										
	- day length	1										
Temperature regime		1										
Climatic hazards (hailstorm, wind, frost)		2										
Conditions for ripening		1										
Length growing season		1	■					■				
Drought hazard during growing season		2	■					■				
SOIL												
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										■
LAND MANAGEMENT												
Initial land preparation		2				■						■
Workability		1										
Potential for mechanization		1			■						■	
Accessibility	- existing	1	■							■		
	- potential	1	■					■				
Erosion hazard	- wind	2	■					■				
	- water	2	■					■				
Flood hazard		2		■				■				
Pests and diseases		2				■					■	

COMMENTS

Annex 3 Methods of Soil Analysis

Preparation	Each sample is air-dried, cleaned, crushed (not ground), passed through 2 mm sieve, homogenized. Moisture content is determined at 105° C.
pH H_2O	1:2.5): 20 g of soil is shaken with 50 ml of deionised water for 2 hours, electrode in upper part of suspension.
pH-KCl	likewise but shaken with 1 *M* KCl.
EC	(1:2.5): Conductivity of pH-H_2O suspension.
Particle-size distribution	Soil is treated with 15% hydrogen peroxide overnight in the cold, then on waterbath at about 80°C. Then boiled on hot plate for 1 hour. Washings until dispersion. Dispersing agent is added (20 ml solution of 4% Na-hexametaphosphate and 1% soda) and suspension shaken overnight. Suspension sieved through 50 μm sieve. Sand fraction remaining on sieve dried and weighed. Clay and silt determined by pipetting from sedimentation cylinder.
Exchangeable bases and CEC	Percolation with 1*M* ammonium acetate pH7 using automatic extractor. (If EC>0.5mS pre-leaching with ethanol 80%). Cations are determined in the leachate by AAS. CEC: saturation with sodium acetate 1*M* pH7; washed with ethanol 80% and then leached with ammonium acetate 1*M* pH7. Na determined by FES.
Exchangeable acidity and Aluminium	The sample is extracted with *1 M* KCl solution and the exchange acidity (H+Al) titrated with NaOH. Al is measured by AAS.
Carbonate	Piper's procedure. Sample is treated with dilute acidand the residual acid is titrated.
Organic carbon	Walkley-Black procedure. The sample is treated with a mixture of potassium dichromate and sulphuric acid at about 125°C. The residual dichromate is titrated with ferrous sulphate. The result expressed in % carbon (because of incomplete oxidation a correction factor of 1.3 is applied).
Total nitrogen	Micro-Kjeldahl. Digested in H_2SO_4 with Se as catalyst. Then ammonia is distilled, trapped in boric acid and titrated with standard acid.
Extractable Iron, Aluminium, Manganese and Silicon	All determinations by AAS. 1 "Free" (Fe, Al, Mn): Holmgren Shaken with sodium citrate (17%) + sodium dithionite (1.7%) solution for 16 hours. 2 "Active" (Fe, Al, Si): Shaken with acid ammonium acetate 0.2 *M* pH 3 for 4 hours in the dark. 3 "Organically bound" (Fe, Al): Shaken with sodium pyrophosphate 0.1 *M* for 16 hours.
Clay mineralogy	Clay is separated as indicated for particle-size analysis. about 10-20 mg of clay is brought on porous ceramic tile by suction and analyzed using a Philips diffractometer.
Soluble salts	Measuring pH, EC, cations and anions in water extracts. 1 1:5 extract. Shaking 30 g of fine earth + 150 ml of water for 2 hours. 2 saturation extract. Adding to 200-1000 g fine earth just enough water to saturate the sample. Standing overnight. After filtration Ca, Mg, Na, K are measured by AAS. Cl with the Chlorocounter and SO_4 turbidimetrically.
Gypsum	To 10 g of fine earth 100 ml of water is added, shaken overnight and centrifuged. Precipitation by adding acetone. Precipitate redissolved in water and determination of Ca by AAS.
Elemental composition	The fine earth is dried, ignited and fused with lithium tetraborate. The formed bead is analyzed by X-ray fluorescence spectroscopy.
Moisture retention	Moisture determinations on undisturbed core samples in silt box (pF1.0;1.5;2.0) and kaolinite box (pF2.3;2.7) respectivily and on disturbed samples in high pressure pan (pF3.4;4.2). Bulk density obtained from dry weight of core sample.

Units, Glossary, Classes and Acronyms

UNITS

$cmol_c\ kg^{-1}$	centimol charge per kilogram (formerly meq/100 g; 1 meq/100 g = 1 $cmol_c\ kg^{-1}$)
μm	micro-metre: 1/1000th of a millimetre.
$mg\ kg^{-1}$	milligram per kilogram (formerly parts per million (ppm))
$mS\ cm^{-1}$	milliSiemens per cm at 25 °C (formerly mmho cm^{-1})
MJ	Megajoules (formerly kcal; 1 MJ = 4186.8 kcal)

GLOSSARY

Air capacity	Amount of pore space filled with air 2 or 3 days after soil has been wetted. It is calculated from the difference between amount of water under almost saturated conditions (pF 0.0) and moisture retained at "field capacity" (pF 2.0), and expressed as volume percentage.
Al saturation	Ratio of exchangeable aluminium to the CEC, expressed as percentage.
Available soil moisture	Amount of moisture retained between "field capacity" (pF 2.0) and "wilting point" (pF 4.2), expressed as volume percentage (also called "available water capacity"). It is indicative of the amount of moisture available for plant growth.
Base saturation	Ratio of the sum of bases to the CEC, expressed as percentage.
Bulk density	Weight of an undisturbed soil sample divided by its volume.
CEC	Cation exchange capacity, indicative of the potential nutrient retention capacity of the soil.
Clay mineralogy	Type of clay-sized (< 2μm) particles.
kaolinite	Clay mineral with a low nutrient retention capacity, common in soils from (sub)tropical regions.
smectite	Silica-rich clay mineral with a high nutrient retention capacity and the ability to absorb water, resulting in swelling of the clay particles.
illite	Potassium-rich clay mineral with a moderately high nutrient retention capacity, common in soils from temperate regions and in alluvial soils.
vermiculite	Clay mineral with a high nutrient retention capacity and strong potassium-fixation.
chlorite	Aluminium-rich clay mineral with a moderately high nutrient retention capacity, occurring in variable quantities in soils rich in aluminium.
halloysite	Clay mineral with a moderately high nutrient retention capacity, common in soils derived from volcanic ashes.
quartz	Residual silica, resistant to weathering.
feldspar	Residual primary mineral, unstable in soil environments and, if present, indicative of a slight to moderate degree of weathering.
hematite	Reddish coloured iron oxide, common in well drained soils of tropical regions.
goethite	Yellowish coloured hydrated iron oxide, common in soils of temperate regions.
gibbsite	Aluminium hydroxide, indicative of a high degree of weathering.
Consistence	Refers to the degree and kind of cohesion and adhesion of the soil material, or to the resistance to deformation or rupture.
ECEC	Effective cation exchange capacity. It is calculated by addition of the sum of bases and exchangeable acidity, and reflects the actual nutrient retention capacity of the soil.
Exchangeable acidity	Sum of exchangeable hydrogen and aluminium.
Fine earth fraction	Part of the soil material with a particle-size of 2 mm or less (nearly all analyses are carried out on this soil fraction).
Horizon	Layer of soil or soil material approximately parallel to the earth's surface.
Land characteristic	Measurable property of land (e.g. texture).
Land quality	Set of interacting land characteristics which has a distinct influence on land suitability for a specified use (e.g. erosion hazard, which is a.o. influenced by slope, rainfall intensity, soil cover, infiltration rate, soil surface characteristics, texture).
Leaching	Downward or lateral movement of soil materials in solution or suspension.
Mottle	Spot or blotch differing in colour from its surroundings, usually indicative of poor soil drainage.
Organic carbon	Content of organic carbon as determined in the laboratory (% org. C x 1.72 = % org. matter)
Parent material	The unconsolidated mineral or organic material from which the soil is presumed to have been developed by pedogenetic processes.
pF value	Measure for soil moisture tension.
Soil reaction (pH)	Expression of the degree of acidity or alkalinity of the soil.
Soil structure	Aggregates of primary soil particles (sand, silt, clay) called peds, described according to grade, size and type.
Sum of bases	Total of exchangeable calcium (Ca^{++}), magnesium (Mg^{++}), potassium (K^{+}) and sodium (Na^{+}).
Texture	Refers to the particle-size distribution in a soil mass. The field description gives an estimate of the textural class (e.g. sandy loam, silty clay loam, clay); the analytical data represent the percentages sand, silt and clay measured in the laboratory.

CLASSES OF SOME ANALYTICAL SOIL PROPERTIES

Organic Carbon - C (%)

< 0.3	very low
0.3 - 1.0	low
1.0 - 2.0	medium
2.0 - 5.0	high
> 5.0	very high

Acidity pH-H_2O

< 4.0	extremely acid
4.0 - 5.0	strongly acid
5.0 - 5.5	acid
5.5 - 6.0	slightly acid
6.0 - 7.5	neutral
7.5 - 8.0	slightly alkaline
8.0 - 9.0	alkaline
> 9.0	strongly alkaline

Available phosphorus (mg kg^{-1})	Olsen	Bray
low	< 5	< 15
medium	5 - 15	15 - 50
high	> 15	> 50

CEC [pH7] ($cmol_c$ kg^{-1} soil)

< 4	very low
04 - 10	low
10 - 20	medium
20 - 40	high
> 40	very high

Sum of bases ($cmol_c$ kg^{-1} soil)

< 1	very low
1 - 4	low
4 - 8	medium
08 - 16	high
> 16	very high

Base saturation - BS [CEC pH7] (%)

< 10	very low
10 - 20	low
20 - 50	medium
50 - 80	high
> 80	very high

Aluminium saturation (%)

< 5	very low
05 - 30	low
30 - 60	moderate
60 - 85	high
> 85	very high

Exchangeable sodium percentage - ESP (%)

Soil structure		*Crops*
< 5	very low	< 2
05 - 10	low	02 - 20
10 - 15	medium	20 - 40
15 - 25	high	40 - 60
> 25	very high	> 60

Bulk density (kg dm^{-3})

< 0.9	very low
0.9 - 1.1	low
1.1 - 1.5	medium
1.5 - 1.7	high
> 1.7	very high

ACRONYMS

CATIE	Centro Agronómico Tropical de Investigación y Enseñanza
FAO	Food and Agriculture Organization of the United Nations
ISIS	ISRIC Soil Information System
ISRIC	International Soil Reference and Information Centre
Unesco	United Nations Educational, Scientific and Cultural Organization