Soil Brief *Nicaragua 2*

# NICARAGUA

## Reference soils of the Nicaragua Depression

A.W. Vogel
E. Acuña Espinales

Universidad Nacional Agraria

ISRIC

International Soil Reference and Information Centre

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# NICARAGUA

## Reference soils of the Nicaragua Depression

ISRIC Soil Monoliths:

| *Number* | *FAO-Unesco* | *Soil Taxonomy* |
|---|---|---|
| NI 8 | Chromic Luvisol | Typic Rhodustalf |
| NI 9 | Eutric Vertisol | Typic Pellustert |

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A.W. Vogel
E. Acuña Espinales

May 1995

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

UNA
P.O. Box 453
Managua
Nicaragua

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## ABSTRACT

Two soils representative for the Nicaragua Depression, were studied for the Central American Soil Reference Collection and Database (CASREC). Description and sampling was carried out by the "Centro Agronómico Tropical de Investigación y Enseñanza" (CATIE), Costa Rica and the "Universidad Nacional Agraría" (UNA), Nicaragua in collaboration with the International Soil Reference and Information Centre (ISRIC), The Netherlands.

The Nicaragua Depression is formed by subsidence during the late Tertiary and early Quaternary, and its low parts were filled by run-off forming lake Nicaragua and lake Managua. Resorted admixtures of volcanic ash originating from the adjacent volcanoes, form the bulk of the lacustrine and fluvial deposits which were weathered to clay soils. The climate of the zone is characterised by high temperatures and marked wet and dry seasons. The distribution of rainfall determines the periods in which annual crops can be grown.

Both soils are located in the area belonging to the sugar-cane factory "Ingenio Victoria de Julio", near Tipitapa. The first soil (NI 8) is a deep, well drained, (dark) reddish brown, clay to silty clay soil mixed with few pyroclastic fragments. In the profile, a horizon with clay illuviation is distinguished and in the deeper subsoil a transition to the parent material (tuff). The soil is classified as a Chromic Luvisol. The second soil (NI 9) is a deep, imperfectly drained, very dark grey to black, heavy clay soil mixed with few pyroclastic fragments. The B horizon has a well developed wedge structure with slickensides. Deep and wide cracks from the soil surface downward are common in the dry season. The soil is classified as an Eutric Vertisol.

Soil NI 8 is suitable for large-scale mechanised agriculture as long as it is well drained. A wide range of traditional crops as well as pasture can be grown, whereas sugar-cane as the crop needs irrigation. Soil NI 9 is less suitable for low-technology farming due to its poor workability. Specific management practices as artificial drainage are required.



## RESUMEN

Dos suelos representativos, ubicados en la Depresión Nicaragüense fueron estudiados para ser incorporados en la "Central American Soil Reference Collection and Database (CASREC)". La descripción y el muestreo fueron ejecutados por el "Centro Agronómico Tropical de Investigación y Enseñanza" (CATIE), Costa Rica y la "Universidad Nacional Agraria" (UNA), Nicaragua en colaboración con el "Centro Internacional de Referencia e Información en Suelos (ISRIC)", Holanda.

La Depresión Nicaragüense se formó por sumersión durante la ultima fase del Terciario y Cuaternario y sus partes mas bajas fueron rellenados con escurrimiento formando los lagos de Nicaragua y de Managua. Diferentes tipos de cenizas volcánicas proviniendo de los volcanes adyacentes, forman la mayor parte de los depósitos lacustrinos y fluviales, cuales fueron meteorizados hasta arcilla. El clima del área se caracteriza por temperaturas altas y una estación seca y lluviosa bien marcadas. La distribución de la precipitación define directamente los períodos en que los cultivos pueden ser sembrados.

Los suelos estudiados están ubicados a corta distancia del "Ingenio Victoria de Julio", cerca de Tipitapa. El primer suelo (NI 8) es profundo, bien drenado, de color pardo rojizo oscuro y de textura arcilloso a arcillo limoso, mezclada con algunos fragmentos piroclásticos. Dentro del perfil se puede distinguir un horizonte iluvial y en el subsuelo una transición al materiai parental: toba. El suelo se clasifica como un Luvisol crómico. El segundo suelo (NI 9) es profundo, imperfectamente drenado, de color gris muy oscuro a negro y de textura arcilla pesada, mezclada con algunas fragmentos piroclásticos. En el subsuelo se observan superficies brillantes, cutanes de tensión llamados "slickensides". Grietas profundas y anchas que van desde la superficie hasta el subsuelo se encuentran en la estación seca. El suelo se clasifica como un Vertisol éutrico.

El suelo NI 8 se presta bien para la agricultura actual a gran escala a condición de que esté bien drenado. Diferentes cultivos tradicionales y pasto se desarrollan bien, sin embargo la caña de azúcar como cultivo actual necesita riego. Suelo NI 9 no sirve mucho para agricultura de bajos ingresos con implementos sencillos. Es muy importante que el suelo sea cultivado al momento que las condiciones de humedad sean óptimas por que el suelo es altamente plástico y se adhiere a los instrumentos de labranza cuando están húmedos y son duros cuando están secos. Un manejo especifico haciendo uso de drenaje artificial es necesario para alcanzar una producción segura y sostenible.

# FOREWORD

The objective of a Soil Brief is to provide a description of a reference soil typical for a certain agro-ecological zone. The Soil Brief is composed of a text part which includes some graphical presentations of the most outstanding phenomena as well as data annexes. All are young volcanic soils located in the Pacific Volcanic Cordillera of Nicaragua and make part of a larger topo-sequence.

The Soil Brief is written for soil specialists and non-soil specialists. For the latter the comprehensive field and laboratory data as being processed with the ISRIC's Soil Information System (ISIS) are often too complex and/or too detailed and therefore require clarification 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. Also within the text reference is made to specific literature that can be consulted in order to enter more in detail.

In this Soil Brief, the text part includes a general characterization of the major physiographic provinces of Nicaragua (Chapter 1). Also a more specific description is given of the subregions in which the studied soils are situated (Chapter 2). Next a description and discussion of the major characteristics of each of the soils and their taxonomical classification follows, as well as their location and occurrence (Chapter 3). An evaluation of the land qualities and limitations for assessing appropriate land use is included. In the annexes the soil and environmental data, available from field, laboratory and office work are given.

In 1992 the "Centro Agronómico Tropical de Investigación y Enseñanza" (CATIE), Turrialba, Costa Rica and the "Universidad Nacional Agraría" (UNA) of Nicaragua in collaboration with the International Soil Reference and Information Centre (ISRIC), Wageningen, The Netherlands described and sampled seven reference soils for the Central American Soil Reference Collection and Database (CASREC). Duplicates of these soils were collected in order to start the creation of a national soil collection of Nicaragua at UNA and for ISRIC's world soil collection. The reference soils were all taken from the Pacific Region of Nicaragua.

Valuable comments on draft versions of this report were received from UNA and ISRIC staff, Dr. T. de Meester and Mr. A.E. Hartemink. Soil analytical work was carried out at the soil laboratory of ISRIC. The editing and final lay-out of the document was done at ISRIC with contributions of Dr E.M. Bridges (editing), Ms M.B. Clabaut (text processing), Ms J.W. Resink (map compilation), and M. Jímenez of CATIE as well as J. Cortés, A. Avilez, O. Gonzalez and F. Salmerón of UNA (fieldwork).

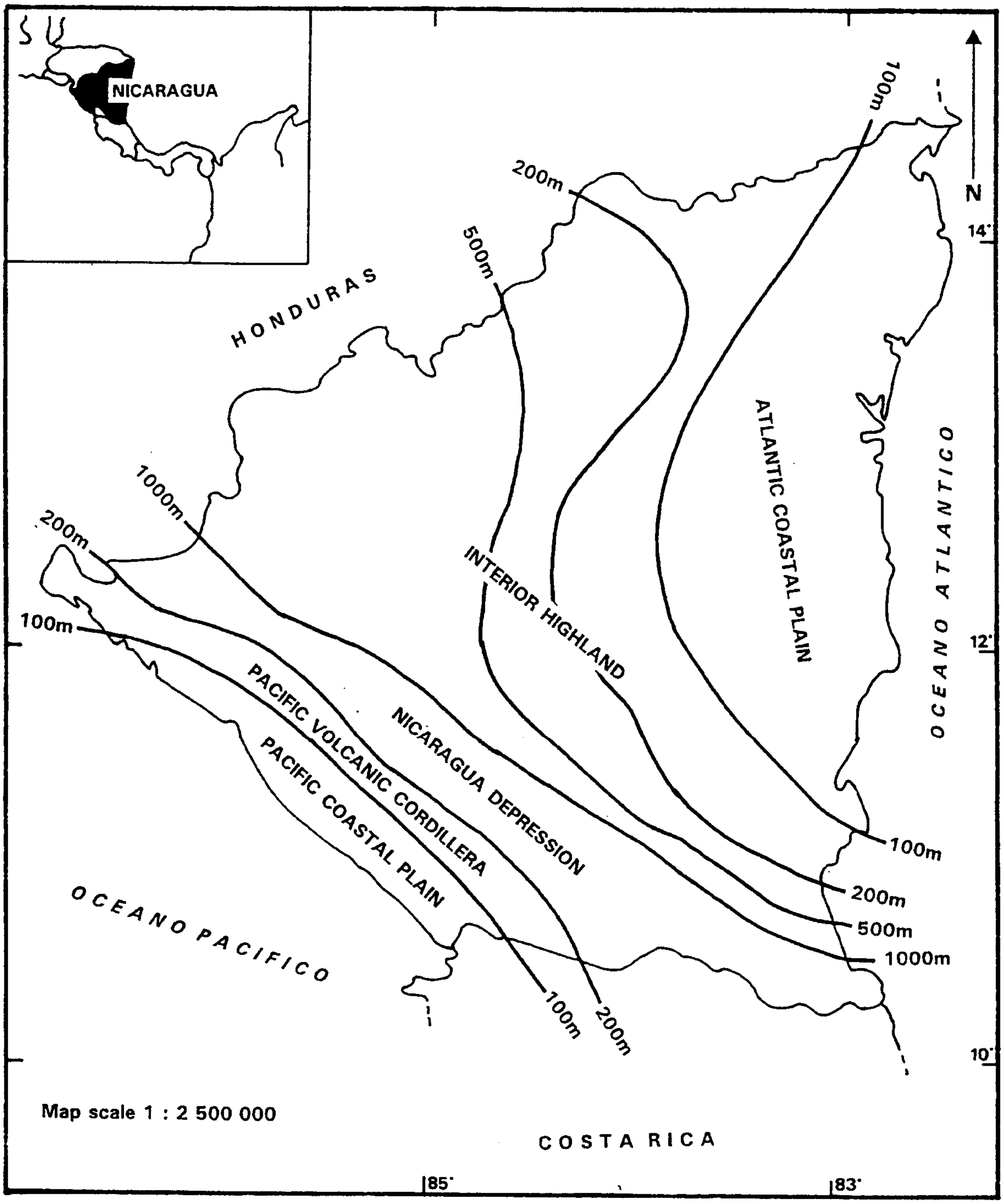



**Figure 1** Major physiographic provinces of Nicaragua

# 1 THE MAJOR PHYSIOGRAPHIC PROVINCES OF NICARAGUA

## 1.1 Geology of Nicaragua

The Central American isthmus started to take form about 60 millions years ago at the beginning of the Tertiary period. Before that time, the two continental land masses of North and South America were separated by a sea. The present central mountainous region of Nicaragua was part of the northern landmass, forming a peninsula with very active volcanism which extended southwards. At that time, the area of what is known today as Costa Rica and Panama was submerged in the sea.
Erosion generated transportation of materials in the direction of the sea at the beginning of the Pliocene (about 5 millions years ago). These submarine sediments were uplifted above sea level and merged with the degraded peninsula of Nicaragua. This uplift also affected the marine sediments in the south which emerged to form Costa Rica and Panama. At the end of the Tertiary (about 1.8 million years ago), the two continental land masses - North and South America - were united.
At the beginning of the Quaternary, a resurgence of volcanic activity occurred, in the coastal plain of marine origin. Along tectonic faults numerous volcanoes were active depositing large quantities of volcanic materials on top of the marine sediments. Even today, some of these younger volcanoes, which make part of the Pacific Volcanic Cordillera, are still active.
This very active volcanism provoked possibly the submergence of the nearby zone forming the "Nicaragua Depression". Later on, the depression was filled with water, forming the actual lakes of Nicaragua and Managua (Solá Monserrat, 1990).

## 1.2 Geomorphology of Nicaragua

From a geomorphological point of view, Nicaragua can be divided into three major regions which are subdivided into five principal provinces, based on altitude as indicated in Fig. 1. Altitude is closely related to the geology history of the country. In the following list the Nicaraguan names are given in brackets (Fenzl, 1989).

1. Pacific Region
   a. Pacific Coastal Plain (Planicie o Llanura Costera del Pacífico)
   b. Pacific Volcanic Cordillera (Cordillera Volcánica del Pacífico)
   c. Nicaragua Depression (Depresión Nicaragüense)

2. Central Region
   d. Interior Highlands (Tierras Altas del Interior/ Región Montañosa del Interior/ Provincia Central de las Cordilleras)

3. Atlantic Region
   e. Atlantic Coastal Plain (Planicie o Llanura Costera del Atlántico/ Provincia Costera del Caribe)

The first three provinces are similar if geological origin, climate and natural vegetation are taken into account (Cardaso *et al.*, 1986), so they are grouped into the Pacific Region. This Region covers an area of about 38,700 $km^2$, which is equivalent to 30 percent of the total Nicaraguan territory. All studied sites are located in the Pacific Region which will be characterized below. A further characterization of the Pacific Coastal Plain is given in section 2.1.

### 1.2.1 The Pacific Coastal Plain

The coastal plain consist of a small strip of land, about 35 km wide and parallel to the Pacific coast. It extends in a NW-SE direction, from the volcano Cosigüina in the north to Rivas in the south. In general the province in the Northern part shows plains with isolated hills which have an altitude ranging from 0 to 200 m a.s.l. In the southern part, the bordering highlands reach altitudes from 500 m a.s.l.

### 1.2.2 The Pacific Volcanic Cordillera

The volcanic cordillera of west Nicaragua consist of a chain of volcanoes which are all relatively young. Extinct or dormant volcanoes as well as active volcanoes occur. The cordillera is NW-SE oriented and forms part of the longer chain of volcanoes extending from Guatemala to Costa Rica with a total length of 600 km (Corrales, 1983). The 300 km long stretch within Nicaragua, is limited in the north by the volcano Cosigüina and in the south by the volcano Maderas (Ometepe island). As a result of the west-bound winds, most of the ash has been deposited on the Pacific-side of the slopes of the volcanoes (Forsythe, 1974).
The Pacific Volcanic Cordillera is one of the world's most active tectonic regions, with most rock layers strongly modified by faulting. Earthquakes are common, and may be very destructive.

### 1.2.3 The Nicaragua Depression

The Nicaragua Depression also called Rift or Central Depression, is a tectonic structure partially covered by alluvial deposits and pyroclastic materials. It can be recognized in the field as a 30 to 45 km wide valley with a smooth relief. It extends from the Gulf of Fonseca in the NW to the Costarican border in the SE. In the SW, the depression is through its lower position clearly

# 2 THE NICARAGUA DEPRESSION

## 2.1 Climate

The climate of the Pacific Region is characterised by high temperatures (> 25°C) during the whole year and a moderately high rainfall of about 1400 mm (Fenzl, 1989).
According to the Köppen climate classification system, the Pacific Region belongs to the area with a Tropical Savanna Climate (Aw), characterised by marked dry and wet seasons. A very strong seasonal drought occurs in November to April which limits rainfed agriculture. Of the total annual precipitation, 85% to 97% falls from May to October, including a short interval of dryness in July and August called "canícula". During this short period there is a deficit of moisture wherein the mean evapotranspiration exceeds the precipitation.
The distribution of rainfall defines the four different periods (Figure 3) in which annual crops can be grown (Prat, 1991):

a. The period after the initial rains is called the "primera". Crops are sown but there is a high risk of yield losses due to the irregularity of the rainfall.
b. After the "primera" the rainfall is guaranteed and this period is indicated as the "postreron". Risks of yield loss are low. However, due to the late moment of sowing, only one crop (e.g. cotton) can be cultivated.
c. The "postrera" is the period after the "canícula" and crops make use of the water stored in the soil. There is a dry period at the end of the growing cycle, which is favourable for crops like beans.
d. The "apante" is the period at the end of the rainy season when crops like pumpkin are sown which does not tolerate precipitation falling directly on the leaves. They make use of the water stored in the soil which is especially available in lower parts of the terrain.

In Nicaragua the climate is dominated by air masses moving across the country by the north-east trades. The total rainfall and its seasonal distribution is determined by the effect of topography on these air masses although there is also a moderate precipitation derived from air masses moving in from the Pacific Ocean. This causes widespread light rains towards the end of the wet season, but even close to the Pacific coast its effect is small compared to the short but heavy rain showers from Atlantic air masses (Taylor, 1963).

Fig. 2 and 3 show monthly data of the mean temperature and mean precipitation as well as evaporation, from the meteorological station "Managua Airport", located 35 km from site NI 8 and 30 km from site NI 9.

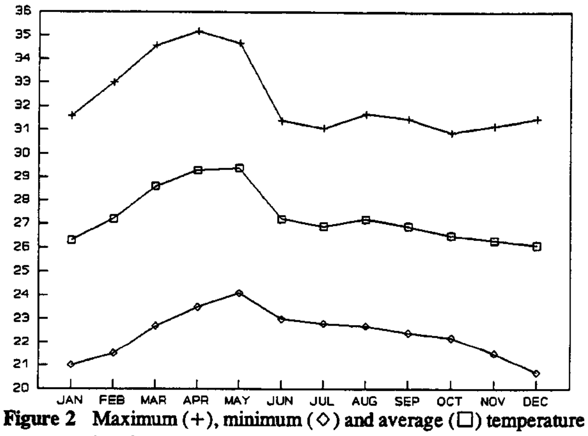



**Figure 2** Maximum (+), minimum (◇) and average (□) temperature in °C at Managua meteorological station.

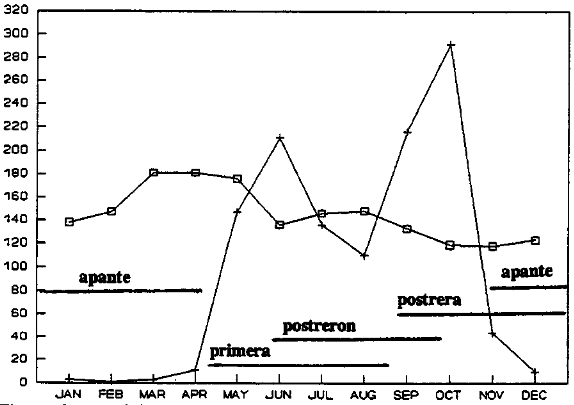



**Figure 3** Precipitation (+) and evapotranspiration (□) in mm at Managua meteorological station.

## 2.2 Geology and geomorphology

The Nicaragua Depression is formed by subsidence during the late Tertiary and early Quaternary, and low parts were filled by run-off forming the Lake Nicaragua and Lake Managua. The lakes are therefore tectonic and not volcanic in origin. They have probably ever been connected to the sea (Weyl, 1980).
Resorted admixtures of volcanic ash (mainly andesitic and basaltic in nature) originating from the adjacent volcanoes, form the bulk of the lacustrine and fluvial deposits (Solá Monserrat, 1990). The original undulating and rolling landscapes are now covered with subaerial ash beds. The primary volcanic minerals are now weathered to clay soils (FAO, 1975). On its western boundary, the Nicaragua Depression consists of Quaternary alluvium deposited by erosion from the Pacific Cordillera.

The Depression is situated at an altitude which varies from 50 to 100 m a.s.l. and shows a light inclination of about 3 to 4° to the south-east (Ferrey Ortega, 1971).

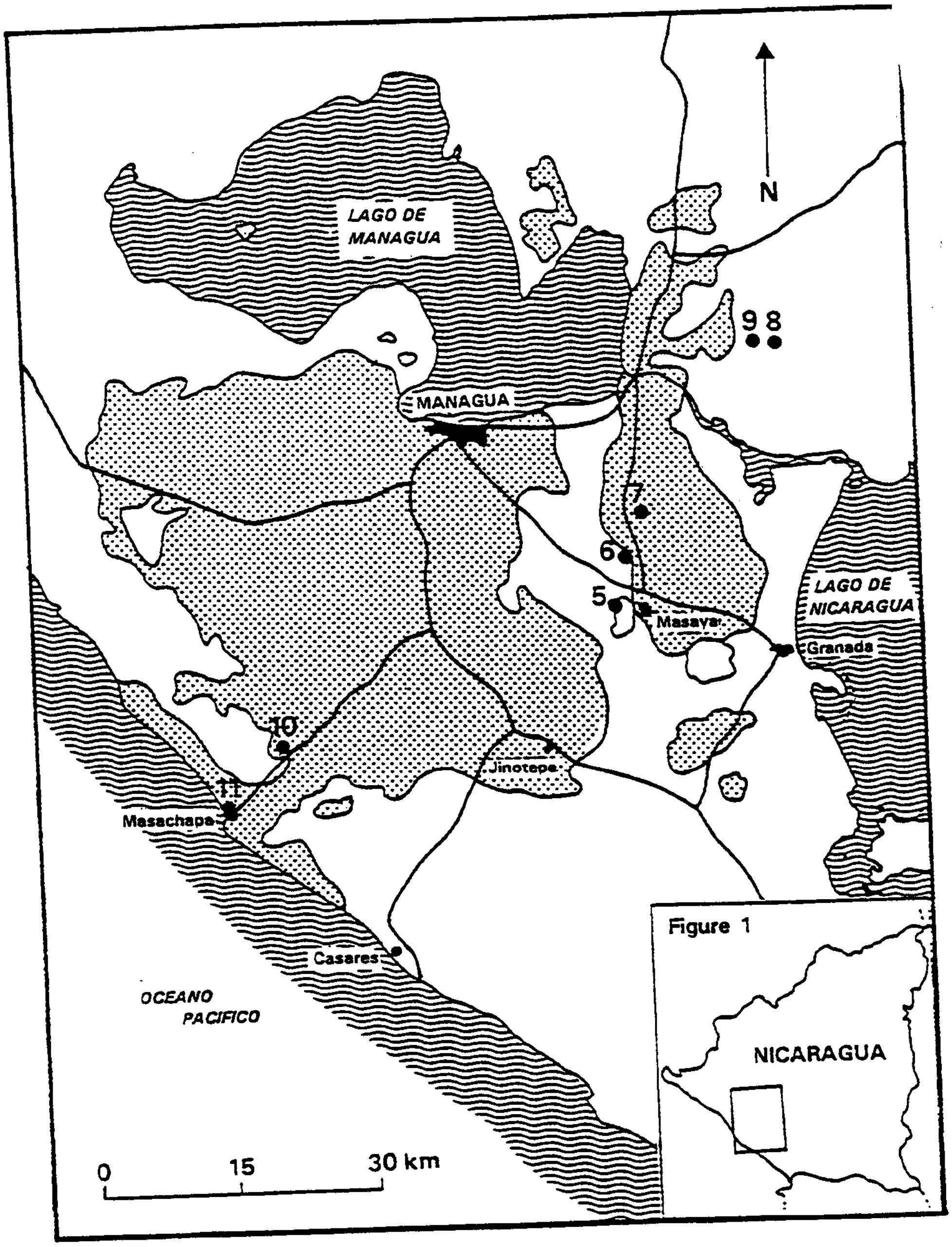



**Figure 4** Distribution of soils with a talpetate layer and the number and location of the Reference Soils. (Dotted area is Talpetate zone).

# 3 THE REFERENCE SOILS

## 3.1 The relation between the studied sites

In this Soil Brief, a selection of data and research information of reference soils NI 8 and NI 9 is discussed. The soils are part of a sequence of 5 soil profiles originally selected and identified in 1989 (Medrano, 1989). Detailed description and sampling and the taking of monoliths of each soil was carried out in november 1992 by scientists of ISRIC, CATIE and UNA. The original objective to select these sites was to show students of the Agricultural University of Nicaragua during a one day field trip different soil types developed from the same volcanic parent material. This sequence of five different soils clearly demonstrates the influence of soil forming factors: time, relief, climate and organisms. The three remaining reference soils are discussed in Soil Brief *Nicaragua 1*. The location of the profiles are presented in Fig. 4.
Reference soil NI 8 is located at very short distance from reference soil NI 9. Both soil types have completely different characteristics, qualities and limitations and are therefore suitable for different types of land use. The characteristic that differs most, is the colour of the soil: NI 8 is red and NI 9 almost black.
Field and laboratory data of both soils are given in Annex 1A and 1B: Soil and environmental data, stored by ISRIC Soil Information System (Van Waveren and Bos, 1988).

## 3.2 Location and occurrence

Reference soils NI 8 and NI 9 are both located along the main road passing through the area belonging to the sugar cane factory "Ingenio Victoria de Julio" (Fig. 4). The area is about 10 km from the small village Tipitapa and about 35 km from the capital Managua. The distance between both sites is 5 km. The soils were located in an alluvial plain with a terrain gradient of less than 2%.

## 3.3 Landscape, geology, vegetation and landuse

Resorted admixtures of volcanic ash, tuff and basalt form the majority of the lacustrine and alluvial deposits. The primary volcanic minerals are now weathered to clay soils, with montmorillonite as the dominant mineral (FAO, 1975).
The soils are located in the subtropical Dry Forest zone. Most of the forests have been removed and the land is used by the industrial Sugar Project Tipitapa-Malacatoya. Arable farming with a moderate input of fertilizers, pesticides and mechanization is common. The major crop is sugar cane, although this crop is increasingly replaced by sorghum, semi- natural grassland and forest. A considerable part of the area is left fallow, because of the low price for sugar and also because of irrigation problems. Water supply is not fully guaranteed and the soils are very sticky so that applied irrigation techniques do not function properly.

## 3.4 Soil characterisation

### 3.4.1 Brief field description

NI 8 is a deep, well drained, (dark) reddish brown, clay to silty clay soil mixed with few pyroclastic fragments; friable, strongly to moderately structured, moderately to slowly permeable and moderately porous.
The profile has a layer with clay illuviation. In the deeper subsoil, the colour of the soil becomes yellowish brown in the transition horizon to the parent material (tuff). The biological activity in the soil is high.

NI 9 is a deep, imperfectly drained, very dark grey to black, heavy clay soil mixed with few pyroclastic fragments; moderately to strongly structured and moderately to slightly porous. The B horizon has a well developed wedge structure with slickensides (polished and grooved surfaces that are produced by one mass sliding past another (FAO, 1989)). Deep and wide cracks are common during the dry season. The profile is homogeneous with little horizon differentiation. Soil colour and texture do not change very much, but the structural elements are coarser in the sub-soil. In the deeper subsoil at about 90 cm, there is a clear transition to the parent material (tuff), which is of the same composition as that of profile NI 8.

Detailed descriptions of the soils according to FAO Guidelines for Soil Profile Description (FAO, 1977) are presented in Annex 1A (NI 8) and Annex 1B (NI 9).

### 3.4.2 Brief analytical characterisation

Soil samples were analyzed at ISRIC's soil laboratory according to the procedures described by van Reeuwijk (1992).
Fig. 5 and 6 show the textural composition of both soils. Soil NI 8 has a small increase of the clay content in the subsoil, which is however difficult to observe in the field. The textural gradient is sufficiently pronounced to distinguish an argic horizon. Soil NI 9 has a very high clay content throughout the profile consisting of expanding lattice clays.
Fig. 7 and 8 present chemical properties with depth. The organic C content, the sum of exchangeable bases (Ca, Mg, K and Na), and the soil acidity (pH-$H_2O$ and pH-

KCl). The organic C content of soil NI 8 is high in the surface and moderately to low in the subsoil. The soil is high in exchangeable bases and has a neutral pH. The organic C content of soil NI 9 is much lower but the content of exchangeable bases is extremely high throughout the profile.
Fig. 9 and 10 present the moisture retention curves (pF graphs). The intersection point of each curve with the x-axis, gives the water content of the soils under saturated conditions, which indicates the total pore-volume. The quantity of soil moisture between pF 0 and pF 2 is expressed by the air capacity which is a measure for the drainage and aeration conditions of a soil. The available soil moisture (ASM) is the quantity of moisture between pF 2 (field capacity) and pF 4.2 (permanent wilting point).
Soil NI 8 has a moderate to low quantity of available soil moisture and the amount of large soil pores decreases with depth possibly due to the increase in clay. The quantity of pores in soil NI 9 is high (total porosity is 60%), but large pores are not very common (air capacity is 3%). The available soil moisture increases with depth.

**Table 1** Key properties of soils NI 8 and 9

| | NI 8 | NI 9 |
|---|---|---|
| Texture | clay; clay content increases with depth and at 50 cm a higher clay content is found than the overlying topsoil and subsoil (silty clay) | heavy clay (80%) throughout the profile |
| Organic C | high in the upper 33 cm | medium in the upper 15 cm |
| pH | neutral (pH-$H_2O$ 6.3) | neutral (pH-$H_2O$ 6.5) |
| Sum of bases | very high (>40 $cmol_c$ $kg^{-1}$ soil) with higher values in the topsoil than in the subsoil | extremely high (about 80 $cmol_c$ $kg^{-1}$ soil) throughout the profile |
| CEC | very high (about 40 $cmol_c$ $kg^{-1}$ soil) throughout the profile | extremely high (about 75 $cmol_c$ $kg^{-1}$ soil) throughout the profile |
| Phosphorus | extremely low (<1 mg $kg^{-1}$ soil) throughout the profile | extremely low (<1 mg $kg^{-1}$ soil) throughout the profile |
| Nitrogen | medium (0.2%) in the topsoil and very low in the subsoil (<0.1%) | very low (< 0.1%) throughout the profile |
| Clay mineralogy | low content of smectite and medium content of halloysite | very high, dominant content of smectite |
| Air capacity | medium (14%) in the topsoil and low (8%) in the subsoil | very low (3%) |
| Available soil moisture | medium to low (13 to 7%) | medium (11%) in topsoil to high (20%) in subsoil |
| Bulk density | low (0.9 kg $dm^{-3}$) | low (1.0 kg/$dm^3$) |

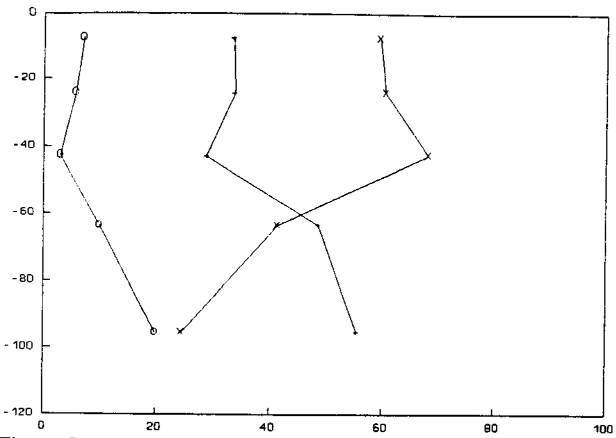



**Figure 5** Percentages clay (×), silt (+) and sand (o) versus depth (cm) in profile NI 8.

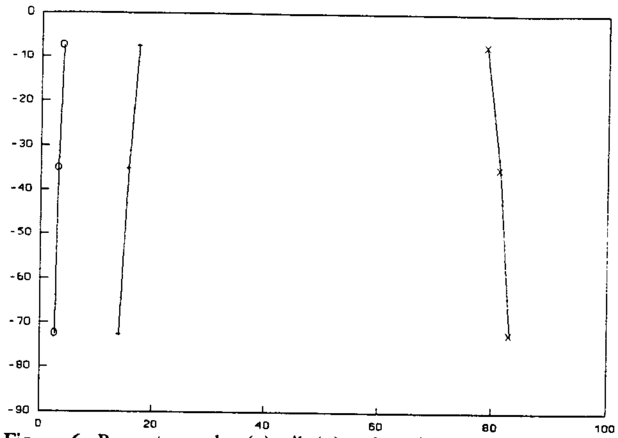



**Figure 6** Percentages clay (×), silt (+) and sand (o) versus depth (cm) in profile NI 9.

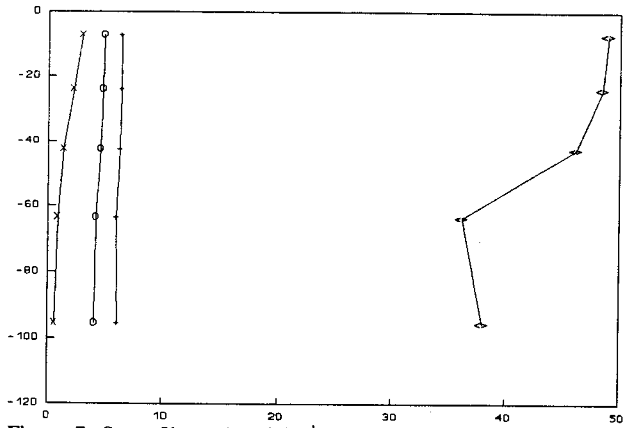



**Figure 7** Sum of bases ($cmol_c$ $kg^{-1}$ soil) (<>), pH-$H_2O$ (+), pH-KCl (o) and organic carbon (×) versus depth (cm) in profile NI 8.

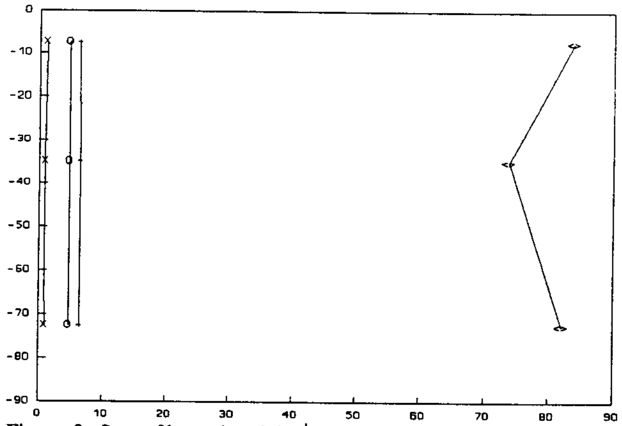



**Figure 8** Sum of bases ($cmol_c$ $kg^{-1}$ soil) (<>), pH-$H_2O$ (+), pH-KCl (o) and organic carbon (×) versus depth (cm) in profile NI 9.

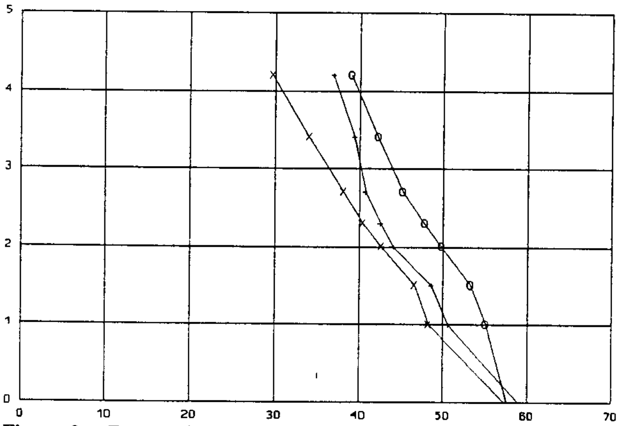



**Figure 9** pF or moisture retention curves (water content in vol % versus suction) at depth 15-33 cm (×), 33-52 cm (+), 52-75 cm (o) in profile NI 8.

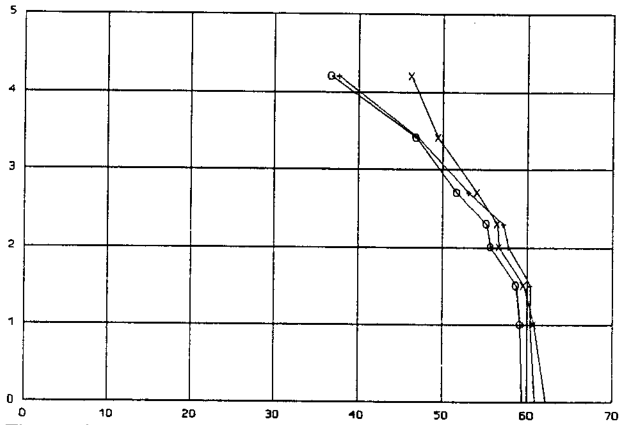
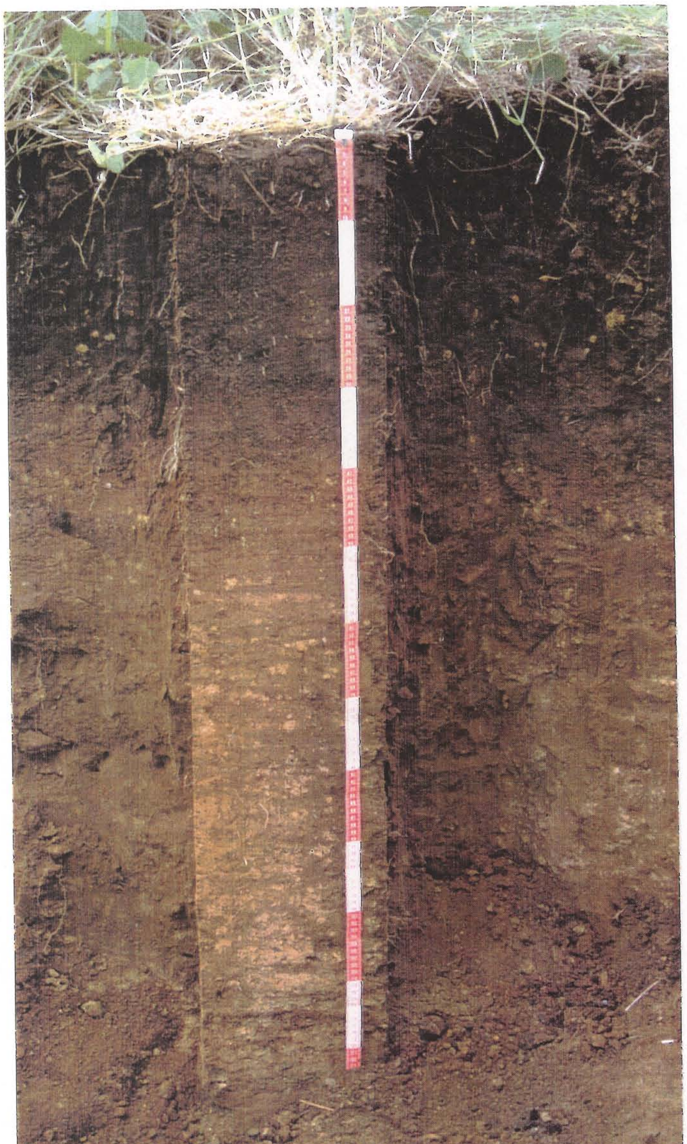



**Figure 10** pF or moisture retention curves (water content in vol % versus suction) at depth 0-15 cm (×), 15-55 cm (+), 55-90 cm (o) in profile NI 9.

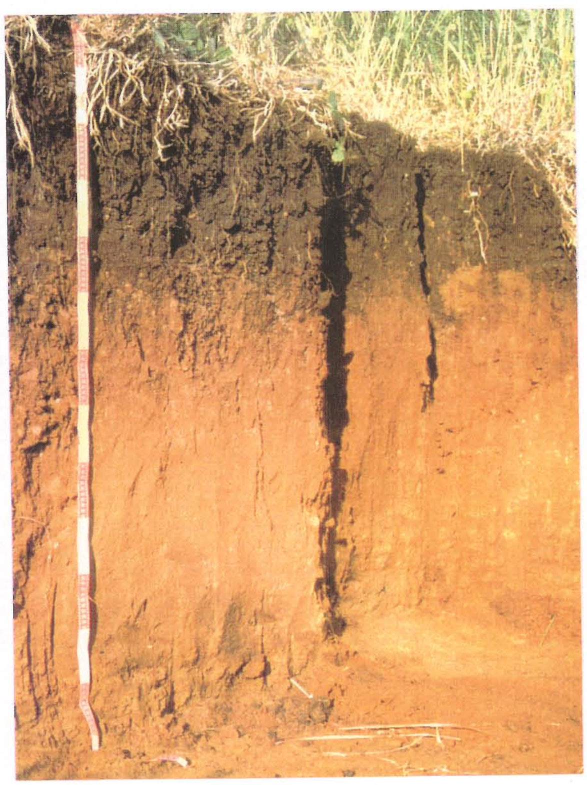
1



2

**PROFILE NI 8**

1. Landscape
2. Profile
3. Profile



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1

**PROFILE NI 9**

1. Landscape
2. Profile

2

## 3.5 Soil classification

### 3.5.1 Soil classification of NI 8

FAO-Unesco (1988)
The soil classifies as a Chromic Luvisol, having a strong brown to red argic B horizon (a subsurface horizon which has a distinctly higher clay content than the overlying horizon), having a base saturation of 50% or more and a cation exchange capacity equal to or more than 24 cmol(+)/ kg clay throughout the profile to a depth of 125 cm.

USDA Soil Taxonomy (1990)
The soil classifies as a Typic Rhodustalf, because an accumulation of clay is found in the subsoil, high enough to classify the layer as an argillic horizon (it has at least 1.2 times as much clay as the eluvial horizon). The soil has an ustic soil moisture regime. The colour of the argillic horizon is in some places redder than 5 YR and a colour value, moist, of 3 or less.
Clay illuviation is confirmed by micromorphological interpretation of some thin layers. These show very clearly clay coatings on the walls of the channels of the B horizon, in such a quantity that the requirements of an argillic B-horizon are met.

### 3.5.2 Soil classification of NI 9

FAO-Unesco (1988)
The soil classifies as a Eutric Vertisol, because the soil is more than 50 cm thick and has more than 35% clay in all horizons during the dry period. The cracks are more than 1 cm wide to a depth of 50 cm. In addition, slickensides are observed in the subsurface. Because of a base saturation of 50% or more, the soils keys out as an Eutric Vertisol.

USDA Soil Taxonomy (1990)
The soil classifies as a Typic Pellustert, because the soil is more than 50 cm thick and has more than 30% clay in all horizons. The cracks of more than 1 cm wide to a depth of 50 cm, open and close more than once a year but remain open for 90 or more days a year but not more than 305 days in most years. The moist colour chroma is less than 1.5 in some horizon within 30 cm and because there are no other special features, it keys out as a Typic Pellustert.
According to the proposed revision of the great groups, the Typic Pellustert can be classified as an Eutrustert having a high base status and no gilgai and/or wavy horizons (FitzPatrick, 1983).

The soil is locally classified as San Nicolas Series.

## 3.6 Soil suitability

### 3.6.1 Requirements and limitations for sugar cane

A qualitative evaluation of relevant land qualities according to the Framework for Land Evaluation (FAO, 1983) was carried out. The evaluation was made for sugar cane, a cash crop of great importance in Nicaragua.
Growth criteria were taken from Ilaco (1981) and Landon (1984) and are summarized below. Sugar cane (*Saccharum officinarum*) needs about 1600 mm of rain with emphasis on the late maturing stage during the vegetative cycle. Adequate ripening should be completed in a dry period of 4-5 months. Drought resistance is low. Optimum average daily temperature is about 28°C, but mean daily temperature optimums are 22°C- 30°C. Growth is retarded at temperatures below 15°C. Wind may cause lodging of the cane, especially when it is not properly banked. It is a deep rooting crop (until 90 cm), and nutrient demanding (especially nitrogen; optimum pH 6.0- 7.5). Water requirements are high (1500- 2500mm/ year). The soil should be well drained, although an imperfect drainage is tolerated. The tolerance to periods with water saturation is medium in a young stage but there is even a low resistance to water-logging. Preferably the soil must have a good structure and be heavy to medium textured. On heavy clay soils, sugar-cane responds well to deep-ripping. Before full canopy development the erosion hazard is high.
The results of the evaluation of soil NI 8 and NI 9 are presented in a comprehensive list of soil/land qualities in Annex 2.

### 3.6.2 Evaluation of NI 8

The soil is moderately to highly productive under a wide range of crops, due to high amounts of nutrients. It has a high aggregate stability and a high porosity, so the soil is not susceptible to erosion. In the dry period, soil material shrinks and cracks may develop. The high porosity (total porosity is 58%) and deep solum allow deep rooting. The internal drainage is good due to the high permeability and this favours the workability of the soil (Driessen and Dudal, 1989).

The available moisture is moderately low due to the somewhat limited capacity of the soil particles to retain moisture (AWC= 82 mm/75 cm soil). Irrigation is required for a water demanding crop like-sugar cane. Erosion might present a serious hazard to future productivity of the soil in more undulating areas. Stagnic properties develop where a dense B-horizon obstructs downward percolation and the surface soil becomes saturated with water for long periods.
The soil is suitable for the actual large-scale mechanised agriculture as long as it is well drained. In those parts

were the soil has a high silt content, structure deterioration may occur if the soil is tilled under wet conditions and/or with heavy machinery. A wide range of traditional crops will grow, like sorghum, maize, sesame, ground nut and beans. The precipitation in this part of Nicaragua is not sufficient for high water consuming crops like sugar-cane, and irrigation is required.

### 3.6.3 Evaluation of NI 9

The soil has a high natural fertility although the use of nitrogen and phosphorus is beneficial. The high chemical fertility and the location of the soil in an area with no slopes, where reclamation and mechanical cultivation are relatively easy is favourable (Driessen and Dudal, 1989). It has a high water holding capacity (AWC= 163 mm/90cm soil), due to its large quantity of fine pores. However, a large proportion of water is retained at high tensions and generally unavailable to plants, so seasonal irrigation is needed. This is done with the help of self-propelled pivot sprinklers, which can irrigate most of the land in a quarter section. The rate of water can be controlled, which is more difficult with other types of irrigation.
The soil is imperfectly drained and has a high clay content, which account for the poor workability and limited potential for mechanization of the soil. In the rainy period, the hydraulic conductivity of the soil is very low and the soil becomes sticky and plastic, which causes that the soil material adheres to the machinery. Consequently problems arise with the self-propelled pivot sprinklers which fail at the moment their wheels get blocked. The water infiltrates very slowly and in depressions even ponding may occur. Most crops do not develop well due to an oxygen deficiency, sugar cane can however tolerate short periods (1 or 2 weeks) of waterlogging or even flooding.
In the dry period the soil becomes very hard and unmanageable (FitzPatrick, 1983). Due to the dominance of lattice clay (smectite) in the clay fraction, the soil shrinks and cracks are formed resulting in a high infiltration rate in the beginning of the rainy season. Roots of most crops, also sugar cane, can be damaged and the cracks are wide enough to present hazardous footing for grazing animals (Buol *et al.*, 1989). Also the trafficability of the land is affected which can cause transport problems at the moment of harvesting.
The low organic C content as well as the typical structure of the soil can sometimes account for unfavourable germination conditions.
The soil is suitable for the actual large-scale mechanised forms of agriculture and is less suited to low-technology farming with hand tools, due to its poor workability (Driessen and Dudal, 1989). Specific management practices are required to secure sustainable production. It is most important that the soil is worked when soil moisture conditions are optimum in order to prevent smearing and soil structural damage, and artificial drainage can be helpful (Medrano, 1989).

## 3.7 Soil formation

Presently, insufficient field and analytical data exist to formulate a theory on the formation of the studied soils. Analytical data of the highest soil (NI 8= red soil: Luvisol) and lowest (NI 9= black soil: Vertisol) of a "red-black" soil catena, as were described in the foregoing chapter are presented in Table 2 to demonstrate the clear differences between both soil types.
Driessen and Dudal (1989) present concepts based on data from Africa (Kantor *et al.*, 1974), India and Australia: "In the semi-arid to sub-humid tropics, smectite is the first secondary mineral that forms upon rock weathering. It retains most of the ions that have been liberated from the primary silicates, like Ca and Mg. Iron, contained as $Fe^{2+}$ in primary minerals, is preserved in the smectite crystal lattice as $Fe^{3+}$. As weathering proceeds, smectites become unstable. The clay minerals decompose, and the released cations and part of the silica are removed by leaching. $Fe^{3+}$-compounds remain in the soil, lending it a reddish colour; aluminium is retained in kaolinite and Al-oxides. The leached soil components accumulate at the lower terrain positions where they precipitate and form smectites. Smectites in these poorly drained positions are stable as long as the pH is above neutral.
There are some additional reasons why there is a relative dominance of smectite in the lower members of the catena:
- lateral physical transport of clay, particularly of fine clay in which the proportion of smectites is greater than in the coarse clay.
- decreasing drainage and leaching of soluble compounds from high to low terrain positions. Internal drainage is impeded by the formation of smectite. (It is increased when kaolinite forms: ferric ion, released from the smectite lattice, cements soil particles to stable structural peds and maintains a permanent system of pores in the soil).
The processes of rock weathering, breakdown of primary and formation of secondary minerals, and the transport of soil components result in the catenary differentiation: reddish well-drained soils on higher positions, and black, poorly drained soil in depressions".

**Table 2** Selected analytical data of soils NI 8 and 9

| Profile | Horizon designation | Depth (cm) | Clay (%) | pH-H2O | CEC ($cmol_c\ kg^{-1}$) | BS (%) | Org. C (%) | extr.Fe (%) | extr.Al (%) | extr.Si (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| Red soil | A | 0-15 | 59 | 6.4 | 44.0 | >100 | 3.0 | 1.0 | 0.6 | 0.3 |
| NI 8 | AB | 15-33 | 61 | 6.4 | 42.7 | >100 | 2.2 | 1.1 | 0.6 | 0.3 |
| | Bt | 33-52 | 68 | 6.3 | 47.6 | 97 | 1.4 | 1.1 | 0.6 | 0.2 |
| | BC | 52-75 | 41 | 6.0 | 41.8 | 87 | 0.9 | 1.4 | 0.7 | 0.2 |
| | C | 75-116 | 25 | 6.1 | 44.2 | 86 | 0.6 | 1.4 | 0.6 | 0.2 |
| Black soil | | | | | | | | | | |
| NI 9 | A | 0-15 | 79 | 6.4 | 77.2 | >100 | 1.1 | 1.0 | 0.2 | 0.2 |
| | Bw | 15-55 | 81 | 6.5 | 74.2 | 99 | 0.9 | 0.8 | 0.2 | 0.2 |
| | C | 55-90 | 83 | 6.5 | 74.6 | >100 | 0.9 | 0.8 | 0.2 | 0.2 |
| | R | 90-> | | | | | | | | |

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## Annex 1A ISIS Data Sheet NI 8

Reference soil NI 8, NICARAGUA — Print date: 6 October 1995

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FAO/UNESCO (1988) : Orthi-Chromic Luvisol
(1974) : Chromic Luvisol
USDA/SCS SOIL TAXONOMY (1992) : Typic Rhodustalf, fine, mixed, isohyperthermic
(1975) : -do-

DIAGNOSTIC CRITERIA FAO (1988) : ochric A, argic B
USDA/SCS (1992) :
Soil moisture regime : ustic
Soil temperature regime : isohyperthermic

---

LOCATION : Main road to "Ingenio Victoria de Julio", 2 Km westwards of sugar mill
Latitude / Longitude : 12°15'0"N / 86°0'0"W — Altitude : 80 m a.s.l.
AUTHOR(S) : Vogel, Rodriguez — Date : November 1992

---

GENERAL LANDFORM : plain — Topography : flat or almost flat
PHYSIOGRAPHIC UNIT : Nicaragua Depression
SLOPE Gradient, Aspect, Form : 0%, S , straight, — Position of site : flat
MICRO RELIEF Kind : ripples — Pattern (height) : linear (30 cm)
SURFACE CHAR. Rock outcrop : little rocky — Cracking : nil
Size, Form : 2 cm, , angular irregular — Salt : nil
Slaking/crusting : nil — Alkali : nil
SLOPE PROCESSES Soil erosion : no
Slope stability : stable

---

PARENT MATERIAL 1 type, texture : alluvium derived from pyroclastic, consolidated, silty
Weathering degree, resistance : slight, low
PARENT MATERIAL 2 type, texture :
Depth to lithological boundary : 116 cm
Remarks :

---

EFFECTIVE SOIL DEPTH : 116 cm
WATER TABLE Kind, Depth : no watertable observed, -
DRAINAGE : well
PERMEABILITY : slow, slowly permeable layer from 116 to 0 cm
FLOODING Frequency : nil — Run off : ponded

MOISTURE CONDITIONS PROFILE : 0-116 cm moist

---

LAND USE : high level arable farming (sugar cane), seasonal irrigated, monoculture
Land use/vegetation remarks : Profile at border sugar cane field

---

CLIMATE Köppen : Aw"
MET. STATIONS Name, Location : MANAGUA, 12°7'N / 86°11'W, 40 m a.s.l
Distance to site (relevance) : MANAGUA lays 35 km WSW of the site (moderate)

| MANAGUA | | No. years of record | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EP Penman | mm | | 138 | 147 | 181 | 181 | 176 | 136 | 146 | 148 | 133 | 119 | 118 | 123 | 1746 |
| precipitation | mm | | 3 | 1 | 3 | 11 | 147 | 211 | 136 | 110 | 216 | 292 | 44 | 10 | 1184 |
| tot.glob.rad. | MJ $m^{-2}$ | | 17.4 | 20.5 | 21.8 | 22.7 | 22.2 | 19.2 | 19.9 | 20.5 | 19.9 | 16.0 | 17.2 | 15.9 | 0.0 |
| T mean | °C | | 26.3 | 27.2 | 28.6 | 29.3 | 29.4 | 27.2 | 26.9 | 27.2 | 26.9 | 26.5 | 26.3 | 26.1 | 27.3 |
| T max | °C | | 31.6 | 33.0 | 34.6 | 35.2 | 34.7 | 31.4 | 31.1 | 31.7 | 31.5 | 30.9 | 31.2 | 31.5 | 32.4 |
| T min | °C | | 21.0 | 21.5 | 22.7 | 23.5 | 24.1 | 23.0 | 22.8 | 22.7 | 22.4 | 22.2 | 21.5 | 20.7 | 22.3 |
| windspeed(at 2m) | m $s^{-1}$ | | 3.1 | 3.4 | 3.3 | 2.9 | 2.2 | 2.5 | 2.4 | 1.9 | 1.6 | 2.0 | 2.5 | 2.6 | 2.6 |
| bright sunshine | % | | 65 | 75 | 73 | 73 | 70 | 53 | 57 | 60 | 59 | 47 | 60 | 57 | 62 |

# ISIS Data Sheet NI 9

Reference soil NI 9, NICARAGUA — Print date: 6 October 1995

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```
FAO/UNESCO (1988)                : Pelli-Eutric Vertisol
           (1974)                : Pellic Vertisol
USDA/SCS SOIL TAXONOMY (1992)    : Typic Haplustert, very fine, montmorrilonitic (calc.), isohyperthermic
                       (1975)    : Typic Pellustert
LOCAL CLASSIFICATION             : Series "San Nicolas"

DIAGNOSTIC CRITERIA  FAO (1988)  : ochric A, cambic B, slickensides
                USDA/SCS (1992)  : ochric epipedon, cambic horizon
                                   Soil moisture regime    : ustic
                                   Soil temperature regime : isohyperthermic
```

---

```
LOCATION                         : Timal, Main road to "Ingenio Victoria de Julio", Km 30, Excavation pit
        Latitude / Longitude     : 12°15'0"N / 86°2'0"W                      Altitude : 80 m a.s.l.
AUTHOR(S)                        : Vogel, Jimenez                                Date : November 1992
```

---

```
GENERAL LANDFORM                 : plain                              Topography : flat or almost flat
PHYSIOGRAPHIC UNIT               : Nicaragua Depression
SLOPE          Gradient, Aspect  : 0%, ESE,                      Position of site : flat
MICRO RELIEF               Kind  : gilgai                        Pattern (height) : none (20 cm)
SURFACE CHAR.      Rock outcrop  : nil                                   Cracking : large cracks
                     Stoniness   : nil                                       Salt : nil
              Slaking/crusting   : nil                                     Alkali : nil
SLOPE PROCESSES    Soil erosion  : no
               Slope stability   : stable
```

---

```
PARENT MATERIAL 1 type, texture  : alluvium derived from tuff, silty
  Weathering degree, resistance  : slight, moderate
 Depth to lithological boundary  : 90 cm
                        Remarks  :
```

---

```
EFFECTIVE SOIL DEPTH             : 90 cm
WATER TABLE         Kind, Depth  : no watertable observed, -
DRAINAGE                         : imperfectly
PERMEABILITY                     : slow, slowly permeable layer from 55 to 90 cm
FLOODING              Frequency  : irregular                             Run off : ponded

MOISTURE CONDITIONS PROFILE      : 0-90 cm moist
```

---

```
LAND USE                         : semi-natural grassland, grazed, no irrigation, not relevant
VEGETATION                 Type  : medium tall grassland                  Status : secondary
   Land use/vegetation remarks   : Intended to use for sugar cane
```

---

```
CLIMATE                  Köppen  : Aw"
MET. STATIONS    Name, Location  : MANAGUA, 12°7'N / 86°11'W, 40 m a.s.l
  Distance to site (relevance)   : MANAGUA lays 30 km WSW of the site (moderate)
```

| MANAGUA | | No. years of record | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EP Penman | mm | | 138 | 147 | 181 | 181 | 176 | 136 | 146 | 148 | 133 | 119 | 118 | 123 | 1746 |
| precipitation | mm | | 3 | 1 | 3 | 11 | 147 | 211 | 136 | 110 | 216 | 292 | 44 | 10 | 1184 |
| tot.glob.rad. | $MJ\ m^{-2}$ | | 17.4 | 20.5 | 21.8 | 22.7 | 22.2 | 19.2 | 19.9 | 20.5 | 19.9 | 16.0 | 17.2 | 15.9 | 0.0 |
| T mean | °C | | 26.3 | 27.2 | 28.6 | 29.3 | 29.4 | 27.2 | 26.9 | 27.2 | 26.9 | 26.5 | 26.3 | 26.1 | 27.3 |
| T max | °C | | 31.6 | 33.0 | 34.6 | 35.2 | 34.7 | 31.4 | 31.1 | 31.7 | 31.5 | 30.9 | 31.2 | 31.5 | 32.4 |
| T min | °C | | 21.0 | 21.5 | 22.7 | 23.5 | 24.1 | 23.0 | 22.8 | 22.7 | 22.4 | 22.2 | 21.5 | 20.7 | 22.3 |
| windspeed(at 2m) | $m\ s^{-1}$ | | 3.1 | 3.4 | 3.3 | 2.9 | 2.2 | 2.5 | 2.4 | 1.9 | 1.6 | 2.0 | 2.5 | 2.6 | 2.6 |
| bright sunshine | % | | 65 | 75 | 73 | 73 | 70 | 53 | 57 | 60 | 59 | 47 | 60 | 57 | 62 |

PROFILE DESCRIPTION :

| | | |
|---|---|---|
| A | 0 - 15 cm | very dark gray (10YR 3/1, moist) clay; moderate to strong fine to medium granular and weak to moderate medium wedge-shaped angular blocky; slightly sticky, plastic; few medium distinct clear mottles (7.5YR 4.0/6.0); common fine pores and common very fine oblique pores; moderately porous; common fine roots between peds and common very fine roots between peds; very few fine fresh pyroclastic fragments; clear wavy boundary to |
| Bw | 15 - 55 cm | very dark gray (10YR 3/1, moist) clay; strong medium columnar; slightly sticky, plastic; broken slickensides cutans on pedfaces; few fine pores and few very fine oblique pores; slightly porous; few fine roots between peds and few very fine roots between peds; very few fine fresh pyroclastic fragments; clear wavy boundary to |
| C | 55 - 90 cm | very dark gray (10YR 3/1, moist) clay; strongly coherent; non sticky, very plastic; few fine pores and few very fine oblique pores; slightly porous; few fine roots between peds; clear smooth boundary to |
| R | 90 - cm | dark brown (10YR 4/3, moist) silt loam;; |

ADDITIONAL REMARKS

Moderately deep, imperfectly drained, very dark grey to black heavy clay developed from alluvium derived from tuff. The soil contains few pyroclastic fragments, is moderately to strongly structured (columnar) and moderately to slightly porous.
This typical Vertisol with a very high clay content and poor internal drainage shows great problems in workability and management (central pivot irrigation system). This profile forms part of the NIC05 to NIC09 toposequence. NIC09 ("black soils") and NIC08 ("red soils") are both found at short distances in an irregular pattern, as a consequence of differences in drainage conditions (imperfectly c.q. well drained).

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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 0 - | 15 | - | 1 | 1 | 1 | 1 | 1 | 4 | 1 | 16 | 17 | 79 | 69.2 | 1.06 | 62 | 61 | 60 | 57 | 57 | 54 | 50 | 46 |
| Bw | 15 - | 55 | - | 0 | 1 | 1 | 1 | 1 | 3 | 1 | 15 | 16 | 81 | 71.8 | 1.08 | 61 | 60 | 60 | 58 | 57 | 53 | 47 | 38 |
| C | 55 - | 90 | - | 0 | 0 | 0 | 1 | 1 | 3 | 1 | 14 | 14 | 83 | 64.1 | 1.04 | 59 | 59 | 59 | 56 | 55 | 52 | 47 | 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 6.4 | 4.7 | - | 1.1 | 0.10 | 48.2 | 34.8 | 0.2 | 0.6 | 83.8 | - | - | 77.2 | 98 | 3.9 | 83.8 | 100 | - | 0.08 | |
| Bw | 6.5 | 4.7 | - | 0.9 | 0.07 | 43.8 | 29.0 | 0.2 | 0.8 | 73.8 | - | - | 74.2 | 91 | 3.0 | 73.8 | 99 | - | 0.06 | |
| C | 6.5 | 4.7 | - | 0.9 | 0.08 | 46.5 | 30.6 | 3.8 | 1.2 | 82.1 | - | - | 74.6 | 90 | 3.2 | 82.1 | 100 | - | 0.09 | |

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

| Hor. | MI | VE | CH | SM | KA | HA | ML | QU | FE | GI | GO | HE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 0 | 0 | 0 | 8 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bw | 0 | 0 | 0 | 8 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 |
| C | 0 | 0 | 0 | 8 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 |

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 | 1.0 | 0.2 | 0.2 | - | - | - | - | - | - |
| Bw | 0.8 | 0.2 | 0.2 | - | - | - | - | - | - |
| C | 0.8 | 0.2 | 0.2 | - | - | - | - | - | - |

## Annex 2 Evaluation of Soil/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

| | | NI008 | | | | | NI009 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **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$^0$ 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 $\mu$m 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.

# Annex 4 Units, Glossary, Classes and Acronyms

## UNITS

| | |
|---|---|
| $cmol_c\ kg^{-1}$ | centimol charge per kilogram (formerly meq/100 g; 1 meq/100 g = 1 $cmol_c\ kg^{-1}$) |
| $\mu m$ | micro-metre: 1/1000[th] 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 (< 2$\mu$m) 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. |
| ESP | Exchangeable sodium percentage, ratio of exchangeable sodium to the CEC, expressed as percentage. |
| 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. |
| SAR | Sodium adsorption ratio of the soil solution, indicative of sodication hazard. |
| 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. |
| Water soluble salts | Salts more soluble in water than gypsum. |

## 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 Agricultural Organization of the United Nations |
| ISIS | ISRIC Soil Information System |
| ISRIC | International Soil Reference and Information Centre |
| SCS | Soil Conservation Service |
| UNA | Universidad Nacional Agraria |
| UNESCO | United Nations Educational, Scientific and Cultural Organization |
| USDA | United States Department of Agriculture |

## Soil Briefs of Nicaragua

(ISSN: 1381-6950)

| No. | Title | No. of soils* |
|---|---|---|
| *Nicaragua 1* | Reference soils of the Pacific Volcanic Cordillera | 3 |
| *Nicaragua 2* | Reference soils of the Nicaragua Depression | 2 |
| *Nicaragua 3* | Reference soils of the Pacific Coastal Plain with a hardpan (Talpetate) | 2 |

## Country Reports

(ISSN: 1381-5571)

| No. | Country | No. of soils* |
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| 2 | P.R. of China | 51 |
| 3 | Turkey | 15 |
| 4 | Côte d'Ivoire | 7 |
| 5 | Thailand | 13 |
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| 7 | Indonesia | 48 |
| 8 | Ecuador | in prep. |
| 9 | Brazil | 28 |
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| 11 | Nicaragua | 11 |
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| 13 | Zambia | 11 |
| 14 | Uruguay | 10 |
| 15 | Gabon | 6 |
| 16 | Ghana | in prep. |
| 17 | Philippines | 6 |
| 18 | Zimbabwe | 13 |
| 19 | Spain | 20 |
| 20 | Italy | 17 |
| 21 | Greece | in prep. |
| 22 | India | in prep. |
| 23 | Kenya | in prep. |
| 24 | Mali | in prep. |
| 25 | Nigeria | in prep. |
| 26 | Mozambique | in prep. |
| 27 | Botswana | in prep. |

* State of reference collections as of January 1995