Soil Brief *Nicaragua 1*

NICARAGUA

Reference soils of the Pacific Volcanic Cordillera

A.W. Vogel
E. Acuña Espinales

ISRIC

Universidad Nacional Agraria

International Soil Reference and Information Centre

The designations employed and the presentation of material in this document do not imply the expression of any opinion whatsoever on the part of the Universidad Nacional Agraria and the International Soil Reference and Information Centre concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries.

Reference citation

Vogel, A.W. and Acuña Espinales E., 1995. *Nicaragua: Reference Soils of the Pacific Volcanic Cordillera.* Soil Brief *Nicaragua 1*. Universidad Nacional Agraria, Managua, and International Soil Reference and Information Centre, Wageningen. pp 27.

ISSN: 1381-6950

Soil Brief *Nicaragua 1*

NICARAGUA

Reference soils of the Pacific Volcanic Cordillera

ISRIC Soil Monoliths:

Number	*FAO-Unesco*	*Soil Taxonomy*
NI 5	Vitric Andosol	Mollic Ustivitrand
NI 6	Mollic Andosol	Mollic Haplustand
NI 7	Haplic Phaeozem	Entic Durustoll

Issued in the framework of the National Soil Reference Collections and Databases project (NASREC).
Sponsored by the Directorate General of International Cooperation of the Government of the Netherlands.

A.W. Vogel
E. Acuña Espinales

April 1995

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

UNA
P.O. Box 453
Managua
Nicaragua

CONTENTS

FIGURES

TABLE

ABSTRACT

A study of three young volcanic reference soils in the Pacific Volcanic Cordillera of Nicaragua was carried out in the framework of the Central American Soil Reference Collection and Database (CASREC) as a joint effort between the "Centro Agronómico Tropical de Investigación y Enseñanza", Costa Rica, the "Universidad Nacional Agraría", Nicaragua and the International Soil Reference and Information Centre (ISRIC), The Netherlands.

The Pacific Volcanic Cordillera consists of a chain of volcanoes, which are relatively young and mostly still active. Large quantities of volcanic material are deposited on basalt. Some deposits are consolidated in a hard layer, called *"talpetate"*. The climate is characterised by high temperatures and marked wet and dry seasons. The distribution of rainfall defines the periods in which annual crops can be grown.

The first soil (NI 5) studied in the National Park "Volcan Masaya", is a shallow, young, (somewhat) excessively drained, black, loamy sandy soil mixed with fresh pyroclastic fragments. It is classified as a Vitric Andosol. The second soil (NI 6) near the village of Nindiri, is a deep, well drained, black to dark brown, loamy to sandy loam soil mixed with few manganiferous concretions. A buried profile can be found at depth. The soil is classified as a Mollic Andosol. The third soil (NI 7), studied on the Experimental station "El Plantel" along the main road from Masaya to Tipitapa, is a moderately deep, (moderately) well drained, very dark brown to brown, silty clay to silty loam soil mixed with fresh pyroclastic and "talpetate" fragments. Three different horizons are separated by two thin continuous but fragmented "talpetate" layers. The soil keys out as a Haplic Phaeozem.

In view of the severe erosion hazard, the most sustainable land use for NI 5 is the natural vegetation. Soil NI 6 has a high agricultural potential which does not correspond with its actual land use: cultivated pasture. Potential crop production for maize, calculated by a crop simulation model, appeared to be somewhat reduced for soil NI 7. The presence of the talpetate at shallow depth affects the rooting conditions, the soil moisture availability and the wind and water erosion hazard. Soil conservation measures are needed, before the talpetate layer is exposed to the surface and the soil will loose its agricultural potential.

RESUMEN

Un estudio de tres suelos volcanicos representativos para la Cordillera Volcánica del Pacífico de Nicaragua fue realizado en el marco de la "Central American Soil Reference Collection and Database (CASREC)" en la cual participan el "Centro Agronómico Tropical de Investigación y Enseñanza", Costa Rica, la "Universidad Nacional Agraria", Nicaragua y el "Centro Internacional de Referencia e Información en Suelos", Holanda.

La Cordillera Volcánica del Pacífico esta formado por una cadena de volcanes, los cuales son relativamente jóvenes y en su mayoría aún activos. Grandes cantidades de materiales volcanicos se encuentran depositados encima de basalto. Parte del material volcánico fue consolidado en forma de una capa dura, llamada "talpetate". 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.

El primer suelo (NI 5), estudiado en el Parque Nacional "Volcan Masaya", es un suelo superficial, joven, algo excesivamente drenado, de color negro y de textura areno francoso, mezclado con fragmentos piroclásticos frescos. Es clasificado como un Andosol vítrico. El segundo suelo (NI 6) fue estudiado cerca del pueblo Nindiri, y es un suelo profundo, bien drenado, de color negro a pardo oscuro y de textura franco a franco arenoso, mezclado con pocos concreciones manganesíferos. Un segundo suelo enterrado se encuentra a una profundidad mas grande. El suelo se clasifica como un Andosol mólico. El tercer suelo (NI 7), estudiado en la Estación Experimental "El Plantel" localizado sobre la carretera Masaya-Tipitapa, es moderadamente profundo, (moderadamente) bien drenado, de color pardo muy oscuro a pardo y de textura arcillo limoso a franco limoso, mezclado con fragmentos piroclásticos frescos y de talpetate. Tres secuencias de horizontes son separadas por dos capas angostas de talpetate continuo. El suelo se clasifica como Phaeozem háplico.

Por el alto riesgo de erosión se recomienda para el suelo NI 5 el mantenimiento de la vegetación natural existente. Suelo NI 6 tiene un potencial agrícola alto, lo cual no coincide muy bien con el uso actual: pasto. La producción potencial para maíz calculada con un modelo de simulación, es algo reducida para suelo NI 7. La presencia de un talpetate a poca profundidad limita las condiciones de enraizamiento, la disponibilidad de humedad y el riesgo de erosión hídrica y eólica. Se recomiendan medidas de conservación de suelo, antes que el talpetate se encuentre a la superficie y los suelos pierden su potencial agrícola.

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).

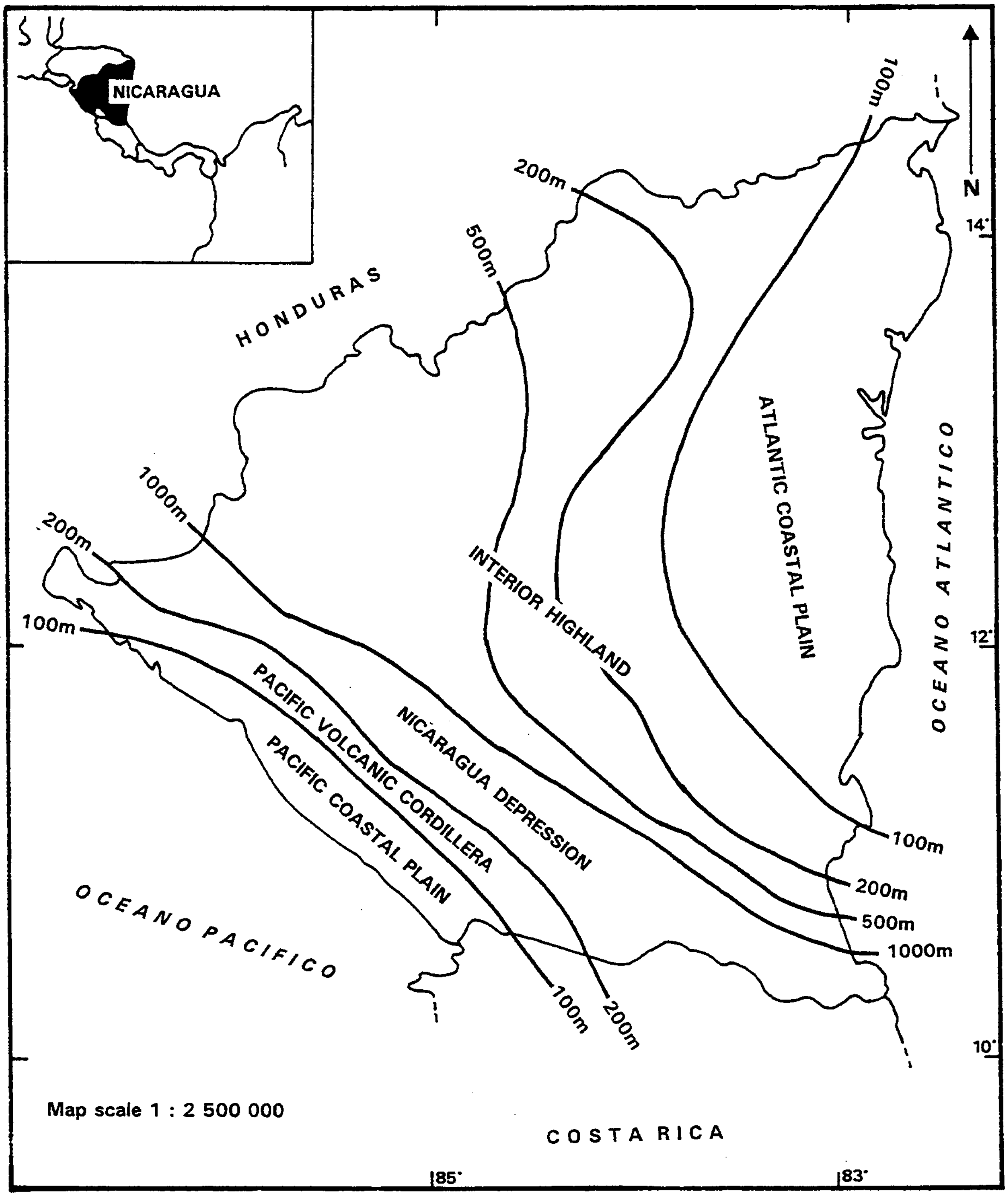


Figure 1 Major physiographic provinces of Nicaragua.

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 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

limited by the Volcanic Cordillera (province b). In the NE by the Interior Highlands Province (province d).
The lowest parts of the valley are occupied by lake Managua ("Lago de Xolotlán") and lake Nicaragua ("Lago de Cocibolca"), both drain via the Río San Juan into the Carribean Sea.

2 THE PACIFIC VOLCANIC CORDILLERA

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 "Masaya", located 2 km from site NI 5, at 9 km from site NI 6 and 20 km from site NI 7.

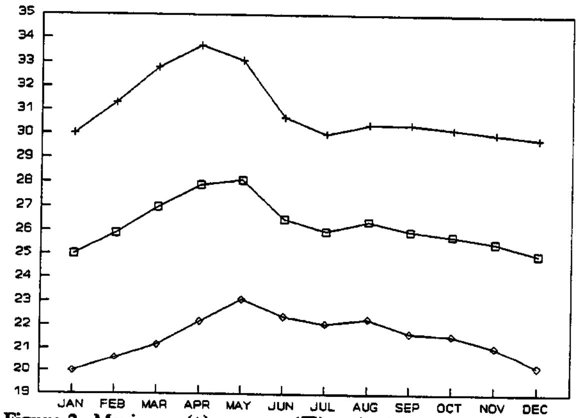


Figure 2 Maximum (+), average (□) and minimum (◊) temperature in °C at Masaya meteorological station.

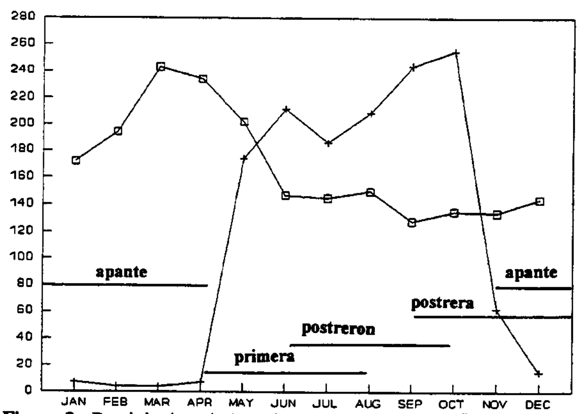


Figure 3 Precipitation (+) and evapotranspiration (□) in mm at Masaya meteorological station.

2.2 Geology, geomorphology and soils

In the province lavas of andesitic and basaltic composition, consolidated and semi-consolidated (tuff) pyroclastic materials, and alluvial deposits are found (Fenzl, 1989). The deposits as well as volcanic ash and lapilli from recent volcanic eruptions, were deposited on the basalt and are now sometimes consolidated in form of a hard layer, called "talpetate" (Catastro, 1971).
The "talpetate" consists of particles of volcanic glass, pieces of plagioclase, fragments of basaltic rocks and sporadically pyroxene and opaque minerals. All characteristics indicate that the layer has been developed from materials that were deposited after violent volcanic eruptions. For more details about this particular phenomena "talpetate", reference is made to Soil Brief *Nicaragua 3*.
The terrain forms are well pronounced with steep slopes close to the volcanoes. In the transition zone to the

Nicaraguan Depression, the topography is rolling to undulating with slopes from 2% to 16%, characteristic for a piedmont. The tops of the Cordillera divide the small Pacific watershed (9% of the national territory) and the Atlantic watershed.
As the parent material has mostly a volcanic origin, the major part of the soils in the Cordillera Province belongs to the Order of Andisols (Soil Survey Staff, 1990), which in the past were classified as Andepts (Soil Survey Staff, 1975). Catastro (1971) classified them during a soil survey of the Pacific Region. They are young soils with little development and locally a clearly defined stratification, as a result of volcanic deposits.
In other places they have a complex profile. They exhibit layering and other irregularities such as: (i) profiles partially rejuvenated by thin ash depositions that have only affected the surface horizon; (ii) profiles buried by an ash layer thick enough to enable development of a new profile; (iii) volcanic substratum consisting of a number of ash layers originating from one or more volcanoes. The recognition of genetic horizons and the tracing of the origin of parent materials is, therefore, very difficult (Martini, 1969).

3 THE REFERENCE SOILS

3.1 The relation between the studied sites

In this chapter, a selection of data and research information of reference soils NI 5, NI 6 and NI 7 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 two remaining reference soils are discussed in Soil Brief *Nicaragua 2*. The location of the profiles is presented in fig. 4.

Field and laboratory data of the soils are given in Annex 1: Soil and environmental data stored by ISRIC Soil Information System (Van Waveren and Bos, 1988).

3.2 Location and occurrence

Reference soil NI 5 is located in the National Park "Volcan Masaya", at about 20 km from the capital Managua (Fig. 4). The National Park consists of about 54 km^2 with two volcanoes of which one is active.

The soil was sampled on the middle slope of the volcano "Masaya", at about 1 km distance from the central crater. The soil represents a young volcanic soil frequently found near craters of volcanoes in the Pacific Region of Nicaragua.

Reference soil NI 6 is located near one of the agricultural cooperatives close to the village of Nindiri, at about 20 km from the capital Managua. The soil was sampled at almost 8 km from the volcano "Masaya". It represents a young volcanic soil and has a buried soil profile. Total area of this soil type is approximately 46 km^2 (Catastro, 1971). It has a large agricultural potential.

Reference soil NI 7 is located along the main road from Masaya to Tipitapa (km 42), at about 30 km from the capital Managua. The area belongs to the Agricultural University of Nicaragua, and is in use as experimental station where among others agro-forestry trials are carried out. The area presenting this kind of soil type covers approximately 132 km^2.

3.3 Landscape, geology, vegetation and landuse

The topography of the land surrounding the site of NI 5 is undulating to rolling. Slopes have a gradient of 6-15% and a concave form.

Parent material is volcanic ejecta and consists of lava, volcanic bombs and lapilli. Soil formation depends on the chemical weathering of the porous, permeable, fine-grained parent material containing "volcanic glass" in the presence of organic matter. Processes of weathering of the parent material, both physical and chemical, are clearly recognized in the subsoil as well as in the immediate neighbourhood of the profile where fresh volcanic materials were found at the surface.

The natural vegetation belongs to the ultimate phase (climax vegetation) of a vegetation sequence, which can be observed within the National Park. It is classified as "medium deciduous tropical forest", which means that many of the trees lose their leaves during the dry season. Typical tree species are "ceiba": *Ceiba pentadra* (L), "guarumo": *Cecropia peltata* (L), "quebracho": *Lysilomo seemannii* (B y R), "pochote": *Bombacopsis quinatum* (J), "guanacaste": *Enterolubium cyclocarpum* (J), "matapalo": *Ficus lapathifolia* (L), "laurel": *Cordia gerascanthus* (L), "jiñocuabo": *Bursera simarouba* (L), "talalate": *Gyrocarpus americanus* (J), and some palms: *Areca catechu* (L). Furthermore, orchids, "bromeliacias" and cetacean species occur.

The topography of the land surrounding NI 6 is undulating. Slopes have a gradient of up to 8% and a straight form.

The parent material is volcanic ejecta and consists of volcanic ash, lapilli and also tuff, originating from different eruptions. The origin of parent materials is too complicated to trace as being ejected by the volcano "Masaya", located nearby. Due to their small size, they are almost completely weathered (Medrano, 1989).

The original natural vegetation, belonging to the "Subtropical Moist Forest zone", has been removed for agricultural purposes. Major crops like maize, beans, ground nut and sorghum are rotated.

Soil NI 7 was sampled in an area with piedmont features, showing an undulating topography and straight slopes from 2- 8%.

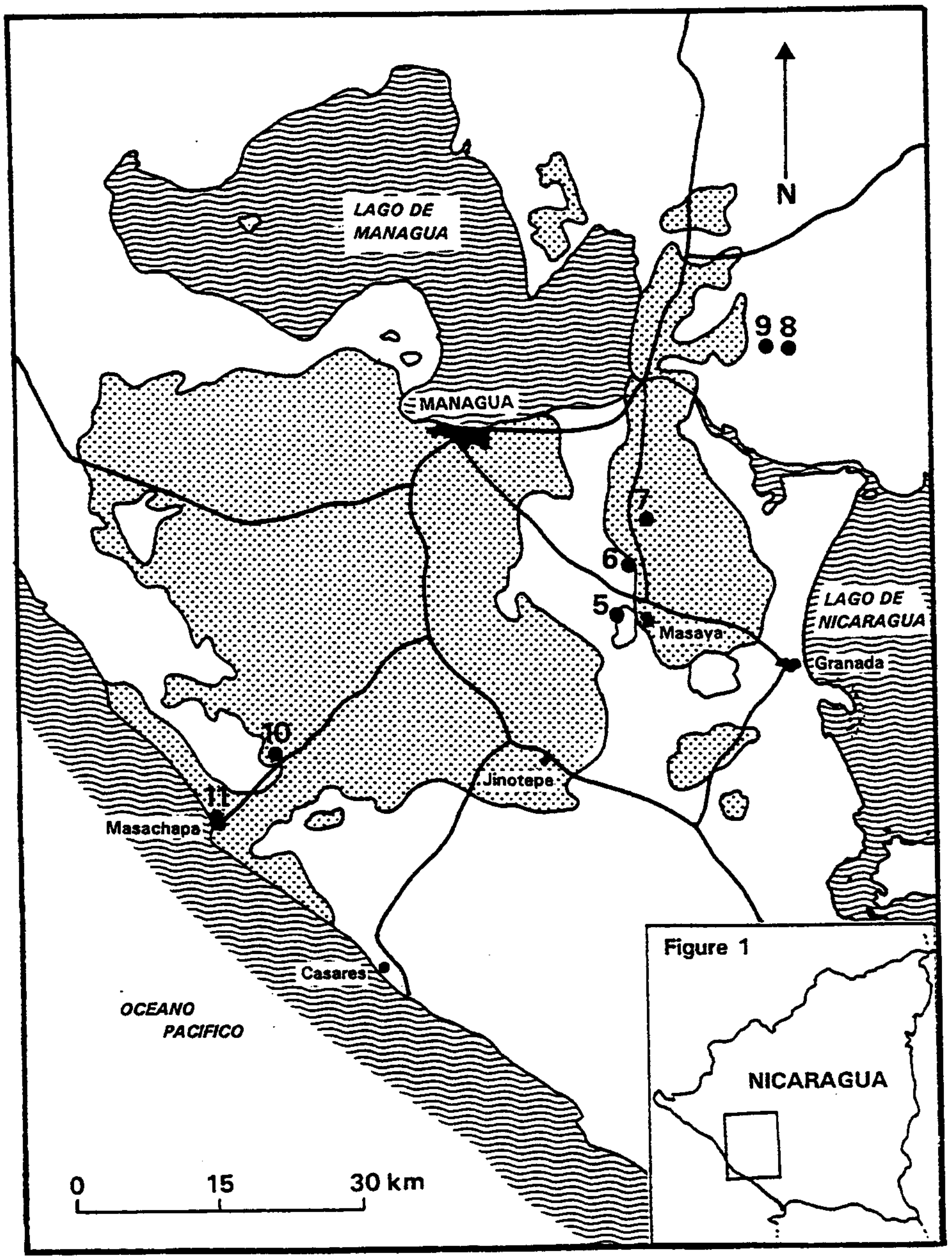


Figure 4 Distribution of soils with a talpetate layer and the number and location of the Reference Soils.

The parent material is volcanic ejecta and consists of (semi-) consolidated pyroclasts like tuff and (volcanic) alluvial deposits. Repeated deposition of fresh ashes caused superficial rejuvenation of the soil material with thin ash layers but also complete buried profiles. A new profile is then develop in the fresh deposit while soil formation in the buried A-horizon is affected by the sudden decrease in organic matter supply and a different soil solution (Driessen, 1989). In some parts, the ash can still be found in form of consolidated, hardened layers in the profile. They are locally called "talpetate".
The soil is located in the transitional life zones between Tropical Dry Forest and Subtropical Moist Forest. The original moderately dense forest has disappeared completely in 1950 and was replaced by sesame and later also cotton. The land use is semi natural grass and medium level arable farming. Sorghum and maize are common crops.

3.4 Soil characterisation

3.4.1 Brief field description

NI 5 is a shallow, young, (somewhat) excessively drained, black, loamy sandy soil mixed with fresh pyroclastic fragments; weakly structured and highly porous. At the surface, partly decomposed organic material has accumulated.
NI 6 is a deep, moderately developed, well drained, black to dark brown, loamy to sandy loam soil mixed with few manganiferous concretions; friable, moderately structured and highly porous and permeable.
Two soil profiles can be recognized, clearly separated by a small layer of partly weathered pyroclastic material which is sufficiently porous to permit roots to pass through. Originally this layer as a fresh deposit, must have been thick enough to influence all soil forming processes taking place in the older, lower profile.
NI 7 is a moderately deep, (moderately) well drained, very dark brown to brown, silty clay topsoil and silty loam subsoil mixed with fresh pyroclastic and "talpetate" fragments; moderately structured and permeable and highly porous.
The profile consists of three horizon sequences, separated by two thin continuous but fragmented, cemented "talpetate" layers with a duripan aspect (FAO, 1988; USDA, 1990) at a depth of 43 cm and 57 cm respectively. In the subsoil at 66 cm depth tuff is found with characteristics similar to "talpetate" (Marín *et al.*, 1971).

3.4.2 Brief analytical characterisation

Soil samples were analyzed at ISRIC's soil laboratory according the procedures as described by van Reeuwijk (1992). In Table 1 the classification of some key properties is given (Landon, 1991).

Fig. 5, 6 and 7 show the textural composition of the three soils at different depths. Soil NI 5 situated close to the volcano crater, has a high (coarse) sand content throughout the profile which indicates that the parent material is in an initial stage of weathering. This is confirmed by analysis of the clay mineralogy and most of the soil material is amorphous. A buried profile with a completely different textural composition causes the sand content of soil NI 6 to decrease sharply with depth. Soil NI 7 shows a sharp decrease of the clay content with depth.
Fig. 8, 9 and 10 present chemical properties of the profiles. The organic C content, the sum of the exchangeable bases (Ca, Mg, K and Na), and the soil acidity (pH-H_2O and pH-KCl). The three properties do not change very much with depth for soil NI 5. The soil shows a high organic C content, a neutral pH and it is high in exchangeable bases. Soil NI 6 has a much lower organic C content and the content of exchangeable bases is increasing rapidly with depth due to the increasing content of halloysite. The organic C content is high in the topsoil and moderate in the subsoil of NI 7. The pH is somewhat higher than in the other two profiles and the soil is well supplied with exchangeable bases, but the content decreases with depth.

Table 1 Key properties of soils NI 5, 6, 7

	NI 5	NI 6	NI 7
Texture	loamy sand throughout the profile	loamy to sandy loam in the most recent soil and clay loam to silty clay loam in the buried soil	silty clay loam in the topsoil and silt loam in the subsoil; increasing sand content with depth
Organic C	high throughout the profile	high in the most recent soil and medium in the buried soil	high in the upper 15 cm
pH	neutral (pH-H_2O 6.4)	neutral (pH-H_2O 7.1)	slightly alkaline (pH-H_2O 7.6)
Sum of bases	high (14.7 $cmol_c\ kg^{-1}$ soil) throughout the profile	very high (36 $cmol_c\ kg^{-1}$ soil) in the most recent soil and extremely high in the buried soil (75 $cmol_c\ kg^{-1}$ soil)	very high (about 55 $cmol_c\ kg^{-1}$ soil) throughout the profile
CEC	medium (17.6 $cmol_c\ kg^{-1}$ soil) throughout the profile	high (38 $cmol_c\ kg^{-1}$ soil) in the most recent soil and extremely high in the buried soil (58 $cmol_c\ kg^{-1}$ soil)	very high (about 55 $cmol_c\ kg^{-1}$ soil) throughout the profile
Phosphorus	extremely low (0.3 mg kg^{-1} soil)	very low (1.5 mg kg^{-1} soil) in the most recent soil and extremely low in the buried soil (0.1 mg kg^{-1} soil)	very low (1.1 mg kg^{-1} soil) in the topsoil and extremely low in the subsoil (0.2 mg kg^{-1} soil)
Nitrogen	medium (0.3%) throughout the profile	low (0.1%) throughout the profile	medium (0.2%) in the topsoil and very low in the subsoil (<0.1%)
Clay mineralogy	trace elements of halloysite	small quantity of halloysite increasing with depth	small quantity of halloysite in the topsoil which is replaced by smectite in the subsoil
Air capacity	very high (30%)	high (18%) throughout the profile	low (9%) in the whole soil profile
Available soil moisture	high in the topsoil (16%); low in the subsoil (8%)	high (18%) throughout the profile	medium (14%) in the topsoil and very high (24%) in the subsoil and buried soil
Bulk density	low (0.9 kg dm^{-3})	very low (0.82 kg dm^{-3}) in the topsoil and extremely low in the buried soil (0.70 kg dm^{-3})	low (1.0 kg dm^{-3}) in the topsoil and very low (0.8 kg dm^{-3}) in the subsoil

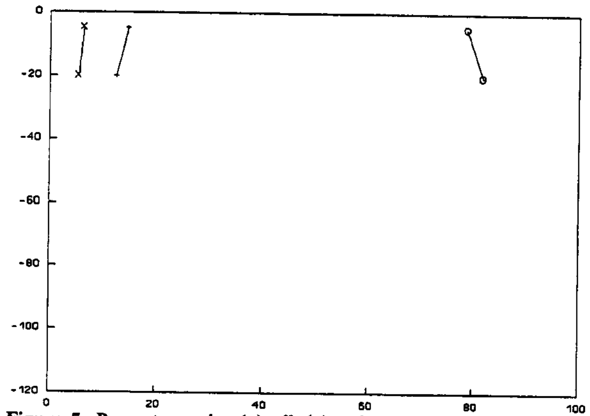


Figure 5 Percentages clay (x), silt (+) and sand (o) versus depth (cm) in profile NI 5.

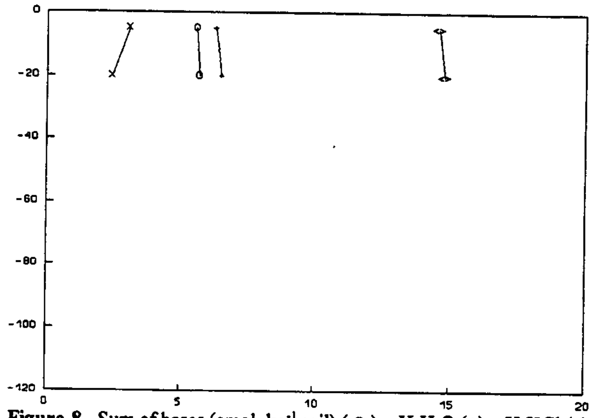


Figure 8 Sum of bases (cmol$_c$ kg^{-1} soil) (<>), pH-H_2O (+), pH-KCl (o) and organic carbon (x) versus depth (cm) in profile NI 5.

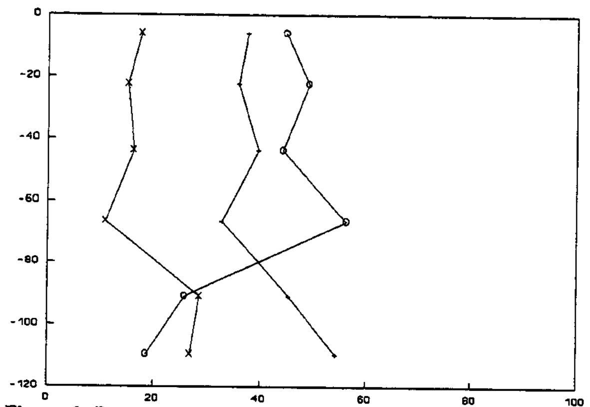


Figure 6 Percentages clay (x), silt (+) and sand (o) versus depth (cm) in profile NI 6.

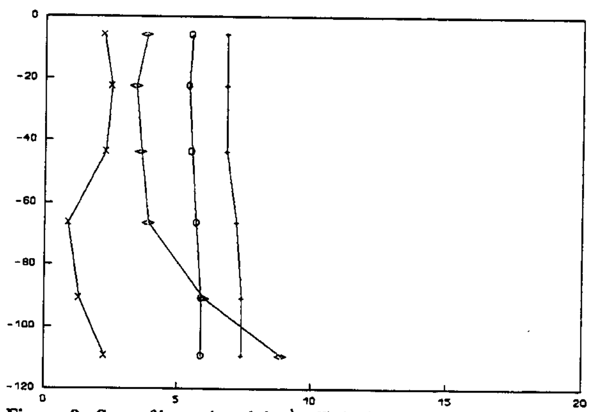


Figure 9 Sum of bases (cmol$_c$ kg^{-1} soil) (<>), pH-H_2O (+), pH-KCl (o) and organic carbon (x) versus depth (cm) in profile NI 6.

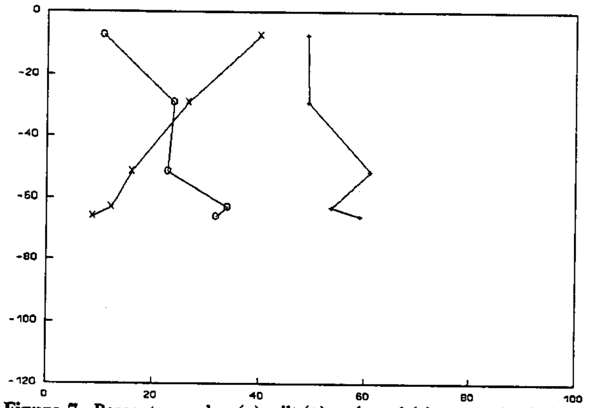


Figure 7 Percentages clay (x), silt (+) and sand (o) versus depth (cm) in profile NI 7.

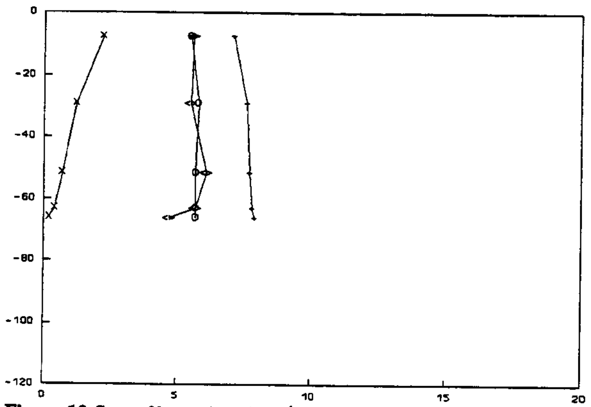


Figure 10 Sum of bases (cmol$_c$ kg^{-1} soil) (< >), pH-H_2O (+), pH-KCl (o) and organic carbon (×) versus depth (cm) in profile NI 7.

Figure 11, 12 and 13 present the moisture retention curves or pF graphs. The intersection point of each curve with the moisture content x-axis, at pF 0, gives the water content of the soils under saturated conditions, which means that this point indicates approximately the total pore-volume percentage. 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) for plant growth is the quantity of moisture between pF 2 (field capacity) and pF 4.2 (permanent wilting point).

The high air capacity of soil NI 5 indicates that there are many large pores. In the subsoil, the soil is less weathered than in the topsoil and therefore a lower percentage of moisture is available. Soil NI 6 shows a high available moisture capacity in each layer of the soil profile. Soil NI 7 shows an available moisture capacity that increases with depth. Large pores are not common in the profile which is expressed by the low air capacity.

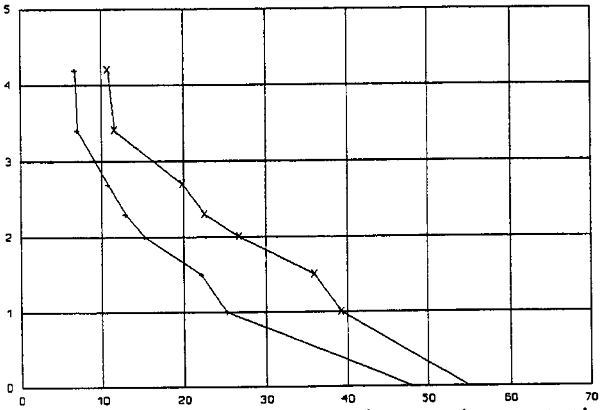


Figure 11 pF or moisture retention curves (water content in vol % versus suction) at depth 0-10 cm (x), 10-30 cm (+) in profile NI 5.

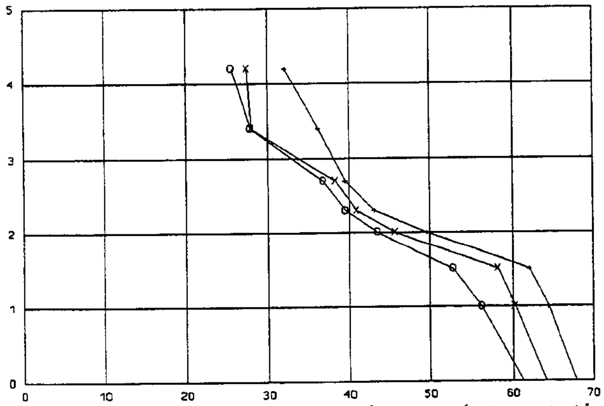


Figure 12 pF or moisture retention curves (water content in vol % versus suction) at depth 12-33 cm (x), 33-55 cm (+), 55-78 cm (o) in profile NI 6.

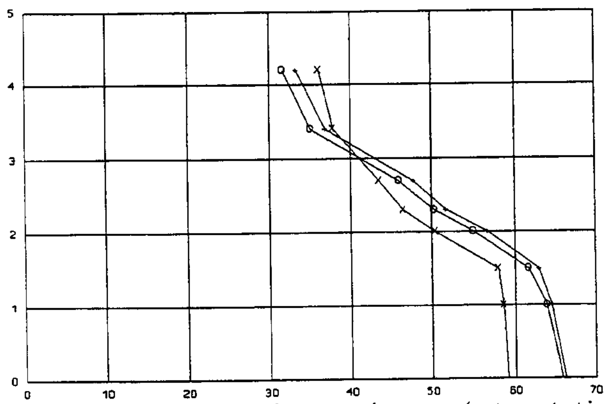


Figure 13 pF or moisture retention curves (water content in vol % versus suction) at depth 0-15 cm (x), 15-43 cm (+), 46-57 cm (o) in profile NI 7.

3.5 Soil classification

3.5.1 Soil classification of NI 5

FAO-Unesco (1988):
The soil is classified as a Vitric Andosol because it has andic properties (high Al and P, low bulk density (0.9 kg dm^{-3}) and high volcanic glass content). It should be noted, however, that the depth requisite of 35 cm is not met. The soil has a mollic A horizon (well structured and dark with moderately high organic matter and base saturation > 50%) and is lacking a smeary consistence, but does have a texture which is coarser than silt loam (loamy sand) on the weighted average for all horizons within 100 cm of the surface.

USDA Soil Taxonomy (1990):
The soil is classified as a Mollic Ustivitrands because it has andic soil properties, a water retention (at 1500 kPa or pF 4.2) of less than 15% and it has an ustic soil moisture regime and a mollic epipedon (surface horizon that contains 1% organic matter, colour values darker than 5.5 dry and 3.5 moist; structure cannot be massive and hard, base saturation > 50%).

3.5.2 Soil classification of NI 6

FAO-Unesco (1988):
The soil is classified as a Mollic Andosol because it has andic properties (high Al and P, low bulk density (0.82 kg/dm^3) and/or high volcanic glass content) for more than 35 cm, it has a mollic A-horizon (well structured and dark with moderately high organic matter and base saturation > 50%) overlying a cambic B-horizon. Because it has a smeary consistence it keys out as a Mollic Andosol, but the texture is loam and not fine enough (considering the weighted average for all horizons within 100 cm of the surface) to meet the requirements of this soil unit.

USDA Soil Taxonomy (1990):
The soil is classified as a Mollic Haplustands because it has andic soil properties, an ustic soil moisture regime and a mollic epipedon (surface horizon that, when mixed to a depth of 18 cm, contains 1% organic matter, colour values darker than 5.5 dry and 3.5 moist; the structure cannot be massive and hard, base saturation > 50%). Because the soil has a 1500 kPa (pF 4.2) water retention of more than 15% it does not key out as a Vitrands.

The soil is locally classified as Nindiri Series.

3.5.3 Soil classification of NI 7

FAO-Unesco (1988):
The soil is classified as a Haplic Phaeozem, because it has a mollic A horizon (well structured and dark with

moderately high organic matter content and base saturation > 50%) with a moist value of 2 or less to a depth of at least 15 cm, having a base saturation of more than 50% throughout within 125 cm of the surface. The soil has a duripan (silica cementation) within 100 cm of the soil surface; it is not calcareous from 20 to 50 cm of the surface and is lacking an argic B horizon, and gleyic and stagnic properties.

USDA Soil Taxonomy (1990):
The soil is classified as an Entic Durustoll, because the soil has a mollic epipedon (surface horizon that, when mixed to a depth of 18 cm, contains 1% organic matter, colour values darker than 5.5 dry and 3.5 moist; the structure cannot be massive and hard, base saturation > 50%). The soil moisture regime is ustic, the soil has a duripan (a subsurface horizon at least half-cemented by silica; air dried peds do not slake in water) with its upper boundary within 100 cm of the soil surface and lacks an argillic horizon above the duripan.

The soil is locally classified as Zambrano Series.

3.6 Soil suitability

3.6.1 Requirements and limitations for maize

A qualitative evaluation of relevant land qualities according to the Framework for Land Evaluation (FAO, 1983) was carried out. In this Soil Brief, the evaluation was only made for a traditional crop of great importance in this part of Nicaragua: maize.
Growth criteria for maize were taken from Zelaya (1990), ILACO (1981) and Landon (1991). Maize (*Zea mais*) needs about 500-800 mm of precipitation well distributed along the vegetative cycle. Grain ripening and harvesting should be completed during a dry period. Daily temperatures should be between 22°C and 27°C, while higher temperatures may cause damage to the pollen. It is a deep rooting (until 90 cm) crop and nutrient demanding (especially nitrogen; pH 6.6- 7.2). Maize presents a high erosion hazard due to the limited protection it offers to the soil surface. The soil, preferably of medium to fine texture, should be well drained and the tolerance to periods with water saturation of the soil is very low.
The results of the evaluation of soil NI 5, NI 6 and NI 7 are presented in a list of soil and land qualities in Annex 2.

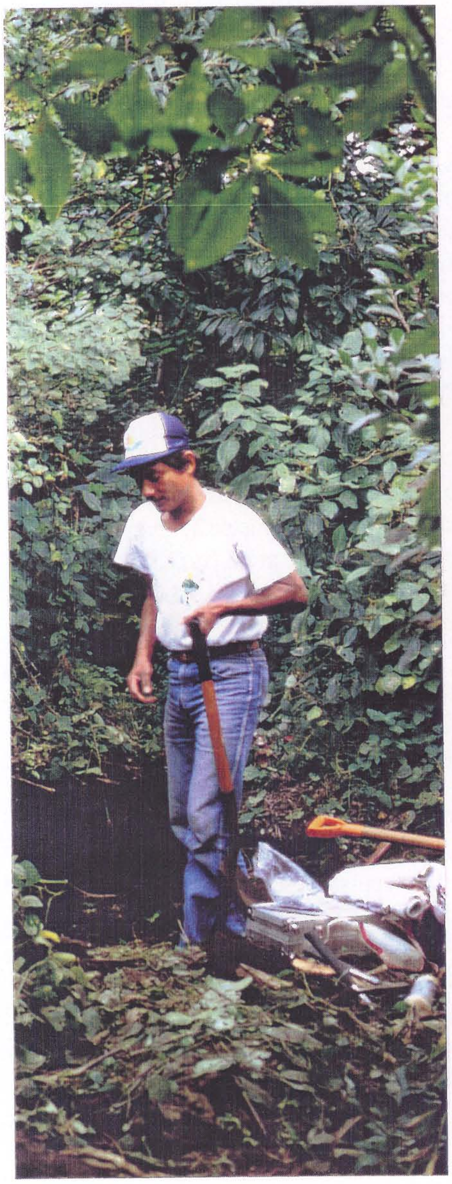
3.6.2 Evaluation of NI 5

The soil is well drained due to the high porosity, is easy to work at all moisture conditions and has sufficient natural fertility for moderate yields of traditional subsistence crops like maize (FAO, 1975).

Despite the high water permeability, the main limitation of the soil is the erosion hazard when the natural vegetation is removed. Due to inappropriate land use (crops which do not give enough soil protection), the steep slopes, and the small weight of the soil particles, the soil can be transported easily by water. The erosion hazard is more serious for dry soils as the soil particles are noncoherent.
The available soil moisture stored in the whole soil profile is low (AWC= 32 mm/30 cm of soil) due to the low capacity of the coarse soil particles to retain water and the shallowness of the soil. Furthermore, the allophane in these soils causes phosphorus deficiency as P is unavailable to plants. However, this deficiency is not very high, because research in other areas has shown that the highest phosphorus fixation is found in soils that are fine grained and have high Al/Si ratios (Buol *et al.*, 1989).
The potential for mechanization is limited due to the undulating and rolling topography and the shallowness of the soil. Soil depth also limits the rooting conditions for many crops.
In view of the severe erosion hazard, the most sustainable land use system is maintenance of the natural vegetation in areas with steep slopes. Other areas with a more undulating topography can be used for arable farming, taking into account a type of management and selection of crops focused on the danger for soil erosion. Care should be paid to the restriction of deforestation practices in areas where the primary vegetation is still present. In view of the growing population in this part of Nicaragua and its increasing need for firewood, especially such areas are under continuing pressure.

3.6.3 Evaluation of NI 6

The soil is deep, has a good rootability and very high moisture availability for plant growth (140 mm/78 cm of soil). It is freely drained due to the high porosity, is easy to cultivate at all moisture conditions, and has a proper fertility for high yields of traditional subsistence crops like maize (FAO, 1975).
Due to inappropriate land use (crops with low soil protection) and the small weight of the soil particles (low bulk density 0.8 kg dm^{-3}), the soil can be transported easily by water, especially where the topography is undulating. The erosion hazard is more serious for dry soils.
In view of the agricultural potential, the most suitable land use system is arable farming using of a high level of inputs, like mechanization, fertilizers (P) and pesticides. However, care should be paid to the danger of soil erosion. Use can be made of simple soil conservation practices, like contour tillage and mulching.
Cultivated pasture where the profile was sampled and studied, does not match very well with its potentials,



1

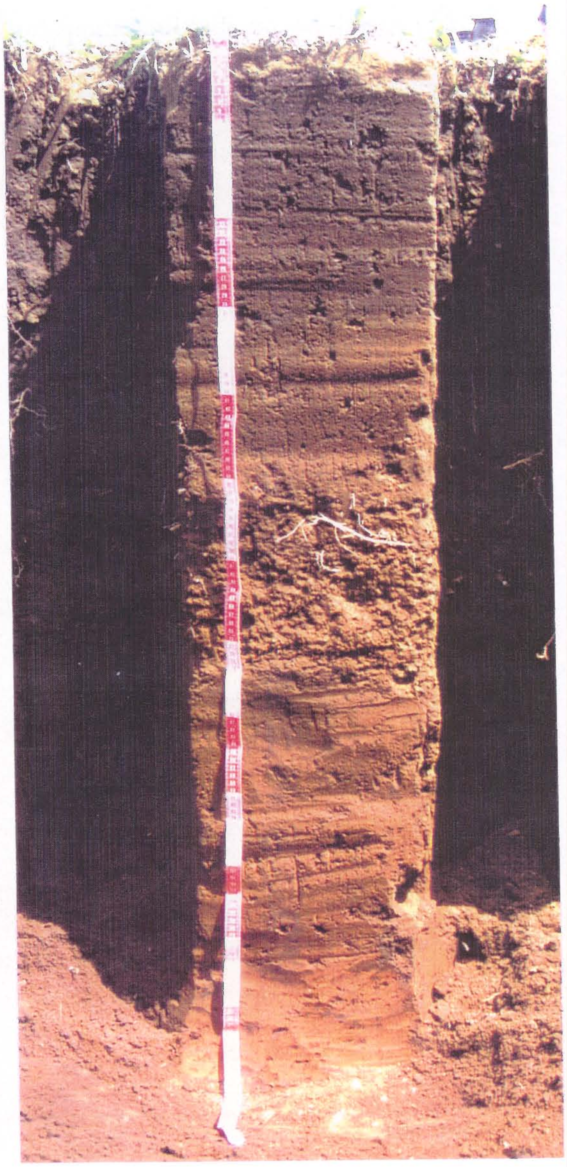
3

PROFILE NI 6

3. Landscape
4. Profile

PROFILE NI 5

1. Landscape
2. Profile



4

2

1

2

PROFILE NI 7

1. Landscape
2. Profile
3. Detail: "Talpetate"

3

which means that presently some parts are less productive than necessary.

3.6.4 Evaluation of NI 7

The soil is freely drained despite the talpetate layer at a depth of 43 cm. This layer is, however, broken. The soil is easy to work at all moisture conditions and has sufficient natural fertility for moderate yields of traditional subsistence crops like maize (FAO, 1975).
The main limitation of the soils is the erosion hazard. Due to inappropriate land use, the steep slopes and the small weight of the soil particles (bulk density is 0.8 kg dm^{-3}), the soil can be transported easily by water and also by wind. This effect is stronger when the soil is dry.
Rooting conditions are limited due to the "talpetate" layer at a depth of 43 cm. It is observed that despite its broken character, only few roots are able to pass.
The amount of soil moisture available for plant growth is moderate (AWC= 88 mm/43 cm of soil) due to the shallowness of the soil. The high allophane content in these soils causes that there is a P deficiency (Buol *et al.*, 1989).
Potential production is somewhat lower in comparison to similar soils without a talpetate layer. Calculations with the crop simulation model WOFOST (Van Diepen *et al.*, 1988; Pulles *et al.*, 1991) show 4% yield reduction for soils with a talpetate layer at 43 cm, no reduction for soils with a talpetate layer at 60 cm and 9% for soils which are eroded and have the talpetate layer at 30 cm.

3.7 Erosion and soil conservation of NI 7

The experimental station "El Plantel", has shown that the areas which present the highest rates of soil loss also have the shallowest soils (Somarriba, 1989). Data showed that these areas have the highest potential risk of erosion as well. Somarriba (1989) recommends the following soil conservation practices at short term, before complete degradation of the area will have taken place.
Parts that are less sloping can be used for arable farming (maize, cassava), but care should be paid to the danger of soil erosion. Use can be made of simple soil conservation practices, like contour tillage and mulching. Weed control should preferably be done by (mechanical) weeding and leaving the residues on the surface for soil protection (mulching).
In view of the severe erosion hazard for those areas that are undulating, the most sustainable land use system is pasture. Arable farming should be only permitted when strip-cropping with contour bunds is realized. An alternative is agro-forestry. The first trials at the experimental station "El Plantel", used maize and leucaena (*Leucaena leucocephalla*) and results are promising.
Parts that have no agricultural potential, because the talpetate layer is already exposed to the surface, will have to be planted as well with fruit trees and fuel wood trees. The soils should not be left fallow preferably, because of water and wind erosion hazard. Rigorous practices as breaking the layer requires high inputs and this can only be done by using heavy machinery.

REFERENCES

Buol, S.W., Hole, F.D. and McCracken, R.J., 1989. *Soil genesis and classification (3rd ed.).* Iowa State University Press, Ames.

Cardaso, C.F.S. and H. Pérez Brignoli, 1986. Centroamérica y la Economía Occidental. In: *Geografía y estructura económicas de Nicaragua.* En el contexto Centroamericano y de America Latina (ed. R. Solá Monserrat, 1990.) Universidad Centroamericana, Managua.

Catastro e Inventarios de Recursos Naturales de Nicaragua, 1971. *Levantamiento de suelos de la Región Pacífica de Nicaragua.* Vol. II, partes I, II y III. Ministerio de Agricultura y Ganadería. Managua.

Corrales Rodríguez, D., 1983. *Impacto ecologico sobre los recursos naturales renovables de Centroamerica (caso particular de Nicaragua).* IRENA, Managua.

Driessen, P.M. and Dudal, R. (Eds.), 1989. *Lecture notes on the geography, formation, properties and use of the major soils of the world.* Wageningen Agricultural University.

FAO, 1975. *FAO-Unesco soil map of the world 1:5.000.000. Volume III Mexico and Central America.* Unesco, Paris.

FAO, 1977. *Guidelines for soil profile description (2nd ed.).* FAO, Rome.

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

FAO, 1988. *FAO-Unesco Soil Map of the World, revised Legend.* World Resources Report 60. FAO, Rome, Italy. Also reprinted as Technical Paper 20, 1989. ISRIC, Wageningen.

Fenzl, N., 1989. *Nicaragua: geografía, clima, geología y hidrogeología.* Texto más suplemento. UFPA/INETER/INAN, Belém.

Forsythe, W.M., 1974. Soil-water relations in soils derived from volcanic ash in Central America. In: *Soil management in Tropical America* (eds E. Bornemisza and A. Alvarado, 1975). Proceedings of a seminar held at CIAT, Cali. February 10-14, 1974.

ILACO, 1981. *Agricultural compendium for rural development in the tropics and subtropics.* Elsevier, Amsterdam.

Landon, J.R. (ed.), 1991. *Booker tropical soil manual.* A handbook for soil survey and agricultural land evaluation in the tropics and subtropics. Longman Scientific and Technical and John Wiley, New York.

Marín, E.J., Ubeda, E. and Viramontes, J. 1971. *Contribución al conocimiento de la genésis del talpetate.* Catastro e Inventarios de Recursos Naturales, Managua.

Martini, J.A., 1969. Geographic distribution and properties of ash-derived soils in Central America. In: *Volcanic ash soils in Latin America.* Proceedings of a panel held at the Training and Research Centre of the IAAIS, Turrialba, Costa Rica. July 6-13, 1969.

Medrano X., 1989. *Una toposecuencia de suelos formados a partir de materiales volcánicos en la Región del Pacífico de Nicaragua (Volcán Masaya-Planicies de Tipitapa).* Informe preliminar. Instituto Superior de Ciencias Agropecuarias, Managua, Nicaragua.

Prat, C., 1991. *Etude du "talpetate" horizon volcanique indure de la region Centre-Pacifique du Nicaragua.* Genèse, caractérisation morphologique, physico-chimique et hydrodynamique, son rôle dans l'érosion des sols. Université Paris VI, Sciences de la Terre, Paris.

Pulles, J.H.M., Kauffman, J.H. and Wolf, J. 1991. *A user friendly menu and batch facility for the crop simulation model WOFOST v4.3* (Supplement to WOFOST v4.1 User's Guide). ISRIC Working Paper and Preprint 91/09. ISRIC, Wageningen.

Soil Survey Staff, 1975. *Soil Taxonomy.* Agricultural Handbook 436. Soil Conservation Service, USDA, Washington D.C.

Soil Survey Staff, 1990. *Keys to Soil Taxonomy (4th edition).* SMSS Technical Monograph no.19. Pacohontas Press, Blacksburg, VA.

Solá Monserrat, R., 1990. *Geografía y estructura económicas de Nicaragua.* En el contexto Centroamericano y de America Latina. Universidad Centroamericana, Managua.

Somarriba Chang, M., 1989. *Planificación conservacionista de la finca El Plantel.* Trabajo de Diploma, Instituto Superior de Ciencias Agropecuarias, Managua.

Taylor, B.W., 1963. An outline of the vegetation of Nicaragua. *Journal of Ecology*, 5: 27-54.

Van Diepen, C.A., Rappoldt, C., Wolf, J. and van Keulen, H., 1988. *CWFS Crop Growth Simulation Model WOFOST Documentation Version 4.1.* Staff working paper SOW-88-01. Centre for World Food Studies, Wageningen.

Van Reeuwijk, L.P., 1992. *Procedures for soil analysis. Technical Paper 9 (3rd ed.).* ISRIC, Wageningen.

Van Waveren, E.J. and Bos, A.B., 1988a. *Guidelines for the description and coding of soil data. Revised edition.* Technical Paper no. 14. ISRIC, Wageningen.

Van Waveren, E.J. and Bos, A.B., 1988b. *ISRIC Soil Information System, user manual and technical manual.* Technical Paper no. 15. ISRIC, Wageningen.

Zelaya Martinez, C.R., 1990. *Los suelos y sus aptitudes agrícolas de la finca El Plantel.* Trabajo de Diploma, Instituto Superior de Ciencias Agropecuarias, Managua.

Annex 1A ISIS Data Sheet NI 5

ISIS 4.0 data sheet of monolith NI 5 Country : NIGARAGUA Print date (dd/mm/yy) : 06/06/94

FAO/UNESCO (1988) : Vitric Andosol (1974 : Vitric Andosol)
USDA/SCS SOIL TAXONOMY (1992) : Mollic Ustivitrand, ashy, halloysitic, isohyperthermic (1975 : mollic vitrandept)

DIAGNOSTIC CRITERIA
FAO (1988) : Diagnostic horizons : mollic A
: Diagnostic properties : andic properties
USDA/SCS (1992) : Diagnostic horizons : mollic epipedon
: Diagnostic properties : andic soil properties
: Soil moisture regime : ustic

LOCATION : National Parc "Volcan Masaya", road to laguna, about halfway
Latitude : 11°58′ 0′′ N Longitude : 86° 8′ 0′′ W Altitude : 250 (m.a.s.l.)
AUTHOR(S) : Vogel, Jimenez Date (mm.yy) : 11.92

GENERAL LANDFORM : caldera Topography : rolling
PHYSIOGRAPHIC UNIT : Pacific Volcanic Cordillera
SLOPE Gradient : 15% Aspect : W Form : concave
POSITION OF SITE : middle slope
MICRO RELIEF Kind : level Pattern : none
SURFACE CHAR. Rock outcrop : nil Stoniness : nil
Cracking : nil Slaking/crusting : nil
Salt : nil Alkali : nil
SLOPE PROCESSES Soil erosion : nil Aggradation : nil

PARENT MATERIAL 1 : volcanic ejecta derived from : unconsol. pyroclastic rocks
Texture : gravelly
Weathering degree : slight Resistance : low
Depth lithological boundary (cm): 30
Remarks : Origin about 1770

EFFECTIVE SOIL DEPTH(cm) : 30

WATER TABLE Depth(cm) : Kind : no watertable observed
DRAINAGE : (somewhat) excessive
PERMEABILITY : high No slow permeable layer(s) cm
FLOODING Frequency : nil Run off : medium
MOISTURE CONDITIONS PROFILE : 0 - 30 cm moist

VEGETATION Type : semi deciduous forest Status : primary
Landuse/vegetation remarks : Ultimate phase prim. vegetation success.

ADDITIONAL REMARKS :
Shallow, young, (somewhat) excessively drained, black loamy sand soil developed from volcanic ejecta, derived from unconsolidated pyroclastic rock (ash, lapilli, volcanic bombs). The soil contains fresh pyroclastic fragments, is weakly structured, highly porous and highly erodable. At the surface an accumulation of about 2 cm of organic material is found. The densily closed natural vegetation prevents soil erosion. The profile forms part of the NIC05 to NIC09 toposequence.

CLIMATE : Köppen: Aw"
Station: MASAYA 11 59 N/ 86 6 W 250 m a.s.l 2 km E of site Relevance: very good

		No. years of record	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
EP Penman	mm		172	194	243	234	202	147	145	150	128	135	134	144	1923
relative humidity	%		71	67	64	61	67	80	81	81	82	82	80	75	74
precipitation	mm		7	4	4	7	174	212	186	209	244	255	62	15	1295
T mean	°C		25.0	25.9	27.0	27.9	28.1	26.5	26.0	26.4	26.0	25.8	25.5	25.0	26.3
T max	°C		30.0	31.3	32.8	33.7	33.1	30.7	30.0	30.4	30.4	30.2	30.0	29.8	31.1
T min	°C		20.0	20.6	21.2	22.2	23.1	22.4	22.1	22.3	21.7	21.6	21.1	20.2	21.6

PROFILE DESCRIPTION :

Ah	0 - 10 cm.	black (10YR 2.0/1.0, moist) loamy sand; leaves, moderately decomposed; weak fine to medium granular structure;, very friable, soft; many fine continuous exped tubular pores and many medium random continuous exped tubular pores; highly porous; many very fine to coarse roots throughout; frequent fine fresh pyroclastic fragments and few medium fresh pyroclastic fragments; clear smooth boundary to
AC	10 - 30 cm.	very dark grayish brown (10YR 3.0/2.0, moist) loamy sand; weakly coherent structure;, loose; many fine continuous exped tubular pores; highly porous; common fine roots throughout and common medium roots throughout; frequent fine fresh pyroclastic fragments and few medium fresh pyroclastic fragments; abrupt wavy boundary to
R	30 - cm.	;

ANALYTICAL DATA :

Hor. no.	Top - Bot	>2 mm	2000 1000	1000 500	500 250	250 100	100 50	TOT SAND	50 20	20 2	TOT SILT	<2 µm	DISP	BULK DENS	pF- 0.0	1.0	1.5	2.0	2.3	2.7	3.4	4.2
1	0 - 10	-	34	22	9	11	4	79	9	6	15	6	-	0.90	55	39	36	27	23	20	12	11
2	10 - 30	-	29	27	11	10	5	82	6	6	13	6	-	0.94	48	25	22	15	13	11	7	7

Hor. no.	pH- H2O	KCl	CaCO3 %	ORG- C %	MAT. N %	EXCH CAT. Ca	Mg	K	Na	sum	EXCH AC. H+Al	Al	CEC soil	clay	OrgC	ECEC	BASE SAT %	Al SAT %	EC 2.5 mS cm^{-1}
						cmol$_c$ kg^{-1}													
1	6.3	5.6	0.0	3.07	0.36	12.4	1.7	0.5	0.0	14.6	-	-	18.0	281	10.7	14.6	81	-	0.00
2	6.5	5.7	1.3	2.42	0.24	12.7	1.7	0.4	0.0	14.8	-	-	17.0	309	8.5	14.8	87	-	0.05

remarks (hor. 1) : P-Olsen= 2
remarks (hor. 2) : P-Olsen= 1

CLAY MINERALOGY (1 very weak,.., 8 very strong) / EXTRACTABLE Fe Al Si Mn (by AMM. OXALATE(o), Na DITHIONITE(d) & PYROPHO(p)

Hor. no.	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
1	-	-	-	-	-	1	-	-	-	-	-	-	1.23	0.79	0.50	-	-	-	-	-	-
2	-	-	-	-	-	1	-	-	-	-	-	-	1.25	0.86	0.51	-	-	-	-	-	-

Annex 1B ISIS Data Sheet NI 6

ISIS 4.0 data sheet of monolith NI 6 Country : NIGARAGUA Print date (dd/mm/yy) : 06/06/94

FAO/UNESCO (1988) : Mollic Andosol (1974 : Mollic Andosol)
USDA/SCS SOIL TAXONOMY (1992) : Typic Haplustand, loamy, halloysitic, isohyperthermic (1975 : typic eutrandept)
LOCAL CLASSIFICATION : Series "Nindiri"

DIAGNOSTIC CRITERIA
FAO (1988) : Diagnostic horizons : mollic A, cambic B
USDA/SCS (1992) : Diagnostic horizons : mollic epipedon, cambic horizon
: Soil moisture regime : ustic

LOCATION : Cooperative "J.Arias Lopez", Altos Sur de Masaya, 200m farm St. Juana
Latitude : 12° 2'30'' N Longitude : 86° 7' 0'' W Altitude : 190 (m.a.s.l.)
AUTHOR(S) : Vogel, Jimenez Date (mm.yy) : 11.92

GENERAL LANDFORM : piedmont Topography : flat or almost flat
PHYSIOGRAPHIC UNIT : Pacific Volcanic Cordillera
SLOPE Gradient : 2% Aspect : NNE Form : straight
POSITION OF SITE : lower slope
MICRO RELIEF Kind : level
SURFACE CHAR. Rock outcrop : nil Stoniness : nil
Cracking : nil Slaking/crusting : nil
Salt : nil Alkali : nil
SLOPE PROCESSES Soil erosion : slight sheet Aggradation : nil
Slope stability : stable

PARENT MATERIAL 1 : volcanic ejecta derived from : unconsol. pyroclastic rocks
Texture : sandy
Weathering degree : slight Resistance : moderate
Depth lithological boundary (cm): 115
Remarks :

EFFECTIVE SOIL DEPTH(cm) : 115

WATER TABLE Depth(cm) : Kind : no watertable observed
DRAINAGE : well
PERMEABILITY : slow Slow permeable layer from : 115 to 0 cm
FLOODING Frequency : nil Run off : very slow
MOISTURE CONDITIONS PROFILE : 0 - 115 cm moist

LAND USE : cultivated pasture; no irrigation; Rotation : crop - grass rotation,lay
Landuse/vegetation remarks : In the past used for maize and root crop

---

ADDITIONAL REMARKS :
Deep, well drained, black to dark brown loamy to sandy loam soil developed from volcanic ejecta, derived from unconsolidated pyroclastic materials (ash, lapilli). The soil contains few manganiferous concretions, is friable, moderately structured and highly porous and permeable. A recent profile (A-Bw-C) is found upon a buried profile (2Ab-2Bb-R) derived from older pyroclastic materials. The profile forms part of the NIC05 to NIC09 toposequence.

CLIMATE : Köppen: Aw"
Station: MASAYA 11 59 N/ 86 6 W 250 m a.s.l 9 km S of site Relevance: very good

		No. years of record	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
EP Penman	mm		172	194	243	234	202	147	145	150	128	135	134	144	1923
relative humidity	%		71	67	64	61	67	80	81	81	82	82	80	75	74
precipitation	mm		7	4	4	7	174	212	186	209	244	255	62	15	1295
T mean	°C		25.0	25.9	27.0	27.9	28.1	26.5	26.0	26.4	26.0	25.8	25.5	25.0	26.3
T max	°C		30.0	31.3	32.8	33.7	33.1	30.7	30.0	30.4	30.4	30.2	30.0	29.8	31.1
T min	°C		20.0	20.6	21.2	22.2	23.1	22.4	22.1	22.3	21.7	21.6	21.1	20.2	21.6

PROFILE DESCRIPTION :

A11 0 - 12 cm. black (10YR 2.0/1.0, moist) loam; moderate medium granular structure;, friable; few medium distinct clear mottles (10YR 4.0/4.0); many fine continuous inped pores; highly porous; many fine roots; few spherical manganiferous concretions; clear smooth boundary to

A12 12 - 33 cm. black (10YR 2.0/1.0, moist) loam; moderate medium granular structure;, friable; few fine continuous inped pores and few very fine random continuous inped pores; highly porous; few fine roots and few very fine roots; few irregular hard manganiferous concretions; clear smooth boundary to

Bw 33 - 55 cm. dark brown (7.5YR 3.0/2.0, moist) loam; moderate medium to coarse subangular blocky structure; friable; few fine continuous inped pores and few very fine random continuous inped pores; highly porous; few fine roots and few very fine roots; few irregular hard manganiferous concretions; few termite channels; abrupt smooth boundary to

C 55 - 78 cm. dark brown (7.5YR 3.0/4.0, moist) sandy loam; weak medium angular blocky structure;, loose; many fine continuous inped pores and many medium continuous inped pores; many fine roots and many medium roots; frequent irregular hard manganiferous inclusions; frequent fine fresh pyroclastic fragments; clear wavy boundary to

2Ab 78 - 104 cm. dark brown (7.5YR 3.0/4.0, moist) clay loam; moderate coarse angular blocky structure;, friable; many fine continuous inped pores and many medium continuous inped pores; many fine roots and many medium roots; few irregular manganiferous concretions; frequent mycelium and termite channels; clear wavy boundary to

2Bb 104 - 115 cm. dark brown (7.5YR 3.0/2.0, moist) silty clay loam; moderate coarse angular blocky structure;, firm; many coarse pores and many medium pores; many fine roots and many medium roots; few spherical manganiferous concretions; abrupt wavy boundary to

R 115 - cm. ;

ANALYTICAL DATA :

Hor. no.	Top - Bot	>2 mm	2000 1000	1000 500	500 250	250 100	100 50	TOT SAND	50 20	20 2	TOT SILT	<2 µm	DISP	BULK DENS	pF- 0.0	1.0	1.5	2.0	2.3	2.7	3.4	4.2
1	0 - 12	-	4	6	10	18	7	45	23	15	38	18	-	-	-	-	-	-	-	-	-	-
2	12 - 33	-	3	5	11	20	10	49	14	22	36	15	-	0.82	64	60	58	46	41	38	28	28
3	33 - 55	-	3	6	10	18	7	44	16	23	40	16	-	0.69	68	65	62	50	43	40	36	32
4	55 - 78	-	12	11	10	16	8	56	14	19	33	11	-	0.70	61	56	53	44	40	37	28	26
5	78 - 104	-	2	2	4	12	5	26	11	34	45	29	-	-	-	-	-	-	-	-	-	-
6	104 - 115	-	0	1	2	8	8	19	11	43	54	27	-	-	-	-	-	-	-	-	-	-

Hor. no.	pH- H2O	KCl	CaCO3 %	ORG- C %	MAT. N %	EXCH CAT. Ca	Mg	K	Na	sum	EXCH AC. H+Al	Al	CEC soil	clay	OrgC	ECEC	BASE SAT %	Al SAT %	EC 2.5 mS cm^{-1}
						cmol$_c$ kg^{-1}													
1	6.8	5.5	2.2	2.18	0.19	27.3	7.5	3.0	0.3	38.1	-	-	42.6	242	7.6	38.1	89	-	0.06
2	6.8	5.4	2.1	2.47	0.22	23.5	6.2	4.0	0.2	33.9	-	-	37.5	248	8.6	33.9	90	-	0.06
3	6.8	5.5	2.3	2.26	0.19	24.1	6.4	5.4	0.2	36.1	-	-	39.9	246	7.9	36.1	90	-	0.06
4	7.2	5.7	2.2	0.89	0.08	29.6	7.6	0.8	0.6	38.6	-	-	39.3	357	3.1	38.6	98	-	0.05
5	7.4	5.9	3.2	1.31	0.09	40.9	18.1	0.2	0.9	60.1	-	-	58.0	202	4.6	60.1	104	-	0.06
6	7.4	5.9	3.8	2.25	0.16	49.6	38.6	0.1	0.9	89.2	-	-	58.3	216	7.9	89.2	153	-	0.06

remarks (hor. 1) : P-Olsen= 8
remarks (hor. 2) : P-Olsen= 11
remarks (hor. 3) : P-Olsen= 3
remarks (hor. 4 - 5): P-Olsen= 1
remarks (hor. 6) : P-Olsen= 0

CLAY MINERALOGY (1 very weak,.., 8 very strong) / EXTRACTABLE Fe Al Si Mn (by AMM. OXALATE(o), Na DITHIONITE(d) & PYROPHO(p)

Hor. no.	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
1	-	-	-	-	-	4	-	-	-	-	-	-	3.45	1.31	0.79	-	-	-	-	-	-
2	-	-	-	-	-	3	-	-	-	-	-	-	3.32	1.18	0.73	-	-	-	-	-	-
3	-	-	-	-	-	5	-	-	-	-	-	-	3.84	1.43	0.93	-	-	-	-	-	-
4	-	-	-	-	-	5	-	-	-	-	-	-	4.34	1.40	0.84	-	-	-	-	-	-
5	-	-	-	-	-	5	-	-	-	-	-	-	4.05	1.50	1.07	-	-	-	-	-	-
6	-	-	-	-	-	4	-	-	-	-	-	-	5.50	3.07	1.88	-	-	-	-	-	-

Annex 1C ISIS Data Sheet NI 7

ISIS 4.0 data sheet of monolith NI 7 Country : NIGARAGUA Print date (dd/mm/yy) : 06/06/94

FAO/UNESCO (1988) : Haplic Phaeozem, duripan phase
(1974) : Haplic Phaeozem, duripan phase
USDA/SCS SOIL TAXONOMY (1992) : Entic Durustoll, fine silty, mixed, isohyperthermic (1975 : durustoll)
LOCAL CLASSIFICATION : Series "Zambrano"

DIAGNOSTIC CRITERIA
FAO (1988) : Diagnostic horizons : mollic A
USDA/SCS (1992) : Diagnostic horizons : mollic epipedon, duripan
: Soil moisture regime : ustic

LOCATION : Finca "El Plantel", Km 42 Road Masaya-Tipitapa; 100 m south of source
Latitude : 12° 6′ 0′′ N Longitude : 86° 5′ 0′′ W Altitude : 130 (m.a.s.l.)
AUTHOR(S) : Vogel, Rodriguez Date (mm.yy) : 11.92

GENERAL LANDFORM : piedmont Topography : undulating
PHYSIOGRAPHIC UNIT : Pacific Volcanic Province
SLOPE Gradient : 2% Aspect : WNW Form : straight
POSITION OF SITE : middle slope
MICRO RELIEF Kind : ripples Pattern : linear Height (cm) : 10
SURFACE CHAR. Rock outcrop : nil Stoniness : fairly stony
Form : angular blocky Av.Size (cm) : 1
Cracking : nil Slaking/crusting : nil
Salt : nil Alkali : nil
SLOPE PROCESSES Soil erosion : slight rill Aggradation : nil
Slope stability : stable

PARENT MATERIAL 1 : volcanic ejecta derived from : tuff
Texture : silty
Weathering degree : partial or moderate Resistance : moderate
Depth lithological boundary (cm): 66
Remarks :

EFFECTIVE SOIL DEPTH(cm) : 66

WATER TABLE Depth(cm) : Kind : no watertable observed
DRAINAGE : well
PERMEABILITY : Slow permeable layer from : 66 to 0 cm
FLOODING Frequency : nil Run off : medium
MOISTURE CONDITIONS PROFILE : 43 - 66 cm dry 0 - 43 cm moist

LAND USE : medium level arable farming; Crops : sorghum; no irrigation; Rotation : crop rotation continuous
Landuse/vegetation remarks : Actual landuse treatened by erosion

ADDITIONAL REMARKS :
Moderately deep, (moderately) well drained, very dark brown to brown silty clay loam to silty loam soil developed from volcanic ejecta, derived from tuff. The soil contains fresh pyroclastic and talpetate fragments, is moderately structured and permeable and highly porous. The profile consists of three different horizon sequences separated by two thin cemented layers, in Nicaragua called "talpetate" (Bm horizon). In this part of Nicaragua the talpetate is probably of geogenetic origin (Bm horizon becomes C horizon). Due to the high erosion hazard, the area urgently needs some soil conservation measures, because otherwise the talpetate layer will outcrop at the surface and the soil will loose its agricultural potential. The profile forms part of the NIC05 to NIC09 toposequence.

CLIMATE : Köppen: Aw"
Station: MASAYA 11 59 N/ 86 6 W 250 m a.s.l 20 km S of site Relevance: good

		No. years of record	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
EP Penman	mm		172	194	243	234	202	147	145	150	128	135	134	144	1923
relative humidity	%		71	67	64	61	67	80	81	81	82	82	80	75	74
precipitation	mm		7	4	4	7	174	212	186	209	244	255	62	15	1295
T mean	°C		25.0	25.9	27.0	27.9	28.1	26.5	26.0	26.4	26.0	25.8	25.5	25.0	26.3
T max	°C		30.0	31.3	32.8	33.7	33.1	30.7	30.0	30.4	30.4	30.2	30.0	29.8	31.1
T min	°C		20.0	20.6	21.2	22.2	23.1	22.4	22.1	22.3	21.7	21.6	21.1	20.2	21.6

PROFILE DESCRIPTION :

Ap	0 - 15 cm.	very dark brown (10YR 2.0/2.0, moist)dark grayish brown (10YR 4.0/2.0, dry) slightly gravelly silty clay loam; moderate medium subangular blocky to moderate medium wedge-shaped ang.bl. structure;, hard; few very fine pores; highly porous; many fine roots throughout and many medium roots throughout; few fine fresh pyroclastic fragments and very few medium fresh talpetate fragments; abrupt smooth boundary to
Bw	15 - 43 cm.	dark brown (10YR 4.0/3.0, moist)yellowish brown (10YR 5.0/6.0, dry) slightly gravelly loam; weak to moderate medium subangular blocky to weak to moderate medium wedge-shaped ang.bl. structure; slightly hard; many medium pores and few medium pores; highly porous; few fine roots throughout; very few medium fresh talpetate fragments; abrupt smooth boundary to
Bm	43 - 46 cm.	light olive brown (2.5Y 5.0/4.0, moist)yellow (2.5Y 7.0/6.0, dry); strongly cemented broken platy duripan; abrupt smooth boundary to
2Bb	46 - 57 cm.	dark yellowish brown (10YR 3.0/4.0, moist)dark yellowish brown (10YR 4.0/4.0, dry) gravelly silt loam; weak medium subangular blocky structure;, slightly hard; many medium pores; highly porous; few very fine roots throughout; frequent fine fresh pyroclastic fragments and frequent fine fresh talpetate fragments; abrupt smooth boundary to
2Bm	57 - 60 cm.	light olive brown (2.5Y 5.0/4.0, moist)yellow (2.5Y 7.0/6.0, dry); strongly cemented broken platy duripan; abrupt smooth boundary to
3Bb	60 - 66 cm.	dark brown (10YR 3.0/3.0, moist)brown (10YR 5.0/3.0, dry) silt loam; weak medium subangular blocky structure;, slightly hard; many medium pores; highly porous; few very fine roots throughout; frequent fine fresh pyroclastic fragments and frequent fine fresh talpetate fragments; abrupt smooth boundary to
R	66 - cm.	;

ANALYTICAL DATA :

Hor. no.	Top - Bot	>2 mm	2000 1000	1000 500	500 250	250 100	100 50	TOT SAND	50 20	20 2	TOT SILT	<2 µm	DISP	BULK DENS	pF- 0.0	1.0	1.5	2.0	2.3	2.7	3.4	4.2
1	0 - 15	-	2	2	2	3	2	11	9	40	49	40	-	1.01	59	59	58	50	47	44	38	36
2	15 - 43	-	5	5	4	6	4	24	10	39	49	27	-	0.80	66	65	63	57	52	48	37	33
3	46 - 57	-	4	5	4	7	4	23	16	45	61	16	-	0.83	66	64	62	55	50	46	35	32
4	60 - 66	-	5	7	6	10	7	34	18	36	54	12	-	-	-	-	-	-	-	-	-	-
5	66 - 66	-	5	7	5	7	8	32	21	38	59	9	-	-	-	-	-	-	-	-	-	-

Hor. no.	pH- H2O	KCl	CaCO3 %	ORG- C %	MAT. N %	EXCH CAT. Ca	Mg	K	Na	sum	EXCH AC. H+Al	Al	CEC soil	clay	OrgC	ECEC	BASE SAT %	Al SAT %	EC 2.5 mS cm^{-1}
						cmol$_c$ kg^{-1}													
1	7.1	5.5	2.2	2.21	0.23	38.0	15.8	2.3	0.1	56.2	-	-	53.3	133	7.7	56.2	105	-	0.06
2	7.6	5.8	2.4	1.22	0.12	38.9	15.5	0.6	0.3	55.3	-	-	58.1	218	4.3	55.3	95	-	0.06
3	7.7	5.7	2.6	0.70	0.09	36.7	22.7	0.9	0.4	60.7	-	-	64.2	399	2.5	60.7	95	-	0.07
4	7.8	5.7	2.7	0.42	0.06	36.6	18.8	0.6	0.5	56.5	-	-	60.2	489	1.5	56.5	94	-	0.05
5	7.9	5.7	2.6	0.19	0.03	31.8	14.5	0.3	0.7	47.3	-	-	42.9	488	0.7	47.3	110	-	0.04

remarks (hor. 1) : P-Olsen= 8
remarks (hor. 2 - 3): P-Olsen= 2
remarks (hor. 4) : P-Olsen= 1
remarks (hor. 5) : P-Olsen= 0

CLAY MINERALOGY (1 very weak,.., 8 very strong) / EXTRACTABLE Fe Al Si Mn (by AMM. OXALATE(o), Na DITHIONITE(d) & PYROPHO(p)

Hor. no.	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
1	-	-	-	-	-	4	-	-	-	-	-	-	1.69	0.69	0.39	-	-	-	-	-	-
2	-	-	-	-	-	5	-	-	-	-	-	-	1.80	0.80	0.41	-	-	-	-	-	-
3	-	-	-	5	-	2	-	-	-	-	-	-	2.11	0.78	0.36	-	-	-	-	-	-
4	-	-	-	6	-	2	-	-	-	-	-	-	1.63	0.61	0.33	-	-	-	-	-	-
5	-	-	-	6	-	-	-	-	-	-	-	-	1.17	0.53	0.29	-	-	-	-	-	-

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

			NI 5	NI 6	NI 7
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.

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 $cmol_c\ kg^{-1}$)
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.
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*
1	Cuba	22
2	P.R. of China	51
3	Turkey	15
4	Côte d'Ivoire	7
5	Thailand	13
6	Colombia	18
7	Indonesia	48
8	Ecuador	in prep.
9	Brazil	28
10	Peru	21
11	Nicaragua	11
12	Costa Rica	12
13	Zambia	11
14	Uruguay	10

No.	Country	No. of soils*
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