Soil Brief *Nicaragua 3*

NICARAGUA

Reference soils of the Pacific Coastal Plain with a hardpan (Talpetate)

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Reference soils of the Pacific Coastal Plain with a hardpan (Talpetate)

ISRIC Soil Monoliths:

Number	*FAO-Unesco*	*Soil Taxonomy*
NI 10	Haplic Phaeozem	Entic Durustoll
NI 11	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.

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ABSTRACT

Two representative soils with "talpetate" (Duripan), located in the Pacific Coastal Plain of Nicaragua 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 Pacific Coastal Plain consists of Cretaceous and Tertiary sediments covered by pyroclastic deposits and re-deposited sediments. 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.

The first soil (NI 10), located near "Los Rizos" along the main road from El Crucero to Masachapa, is a shallow, (moderately) well drained, dark yellowish brown to (dark) brown, silty clay loam to silt loam soil mixed with fresh "talpetate" fragments. The second soil (NI 11) near Montelimar is a deep, (moderately) well drained, dark brown to dark reddish brown, loamy soil, also mixed with fresh talpetate fragments. Both soils are derived from pyroclastic materials and have in the subsoil a thick strongly cemented broken platy, hardened layer, in Nicaragua called "talpetate". Such soils occupy about 15% of the Pacific Region of Nicaragua. The soils key out as a Haplic Phaeozem, duripan phase.

Potential crop production for maize and sugar-cane calculated by a simulation model appeared to be limited. The presence of a talpetate affects the rooting conditions, the nutrients and moisture availability and the potential for mechanization of the soils.

Aluminium and silicon contents in the "talpetate" are higher than in the overlying and underlying horizons. The Al: Si ratio indicates that the silicon is bound by the allophane which after irreversible dehydrating, acts as the main cementing agent. There is no micromorphological evidence of silica cementation and therefore the talpetate does not meet all the criteria for a duripan.

RESUMEN

Dos suelos representativos, ubicados en la Planicie Costera del Pacífico de Nicaragua 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 Planicie Costera del Pacífico esta formado por sedimentos del Cretáceo y Terciario cubiertos por depósitos piroclásticos muy gruesos y sedimentos mas recientes que fueron re-depositados. 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 10) ubicado cerca "Los Rizos" sobre la carretera El Crucero- Masachapa, es superficial, (moderadamente) bien drenado, de color pardo amarillento oscuro y de textura franco arcillo limoso a franco limoso, mezclado con fragmentos de talpetate frescos. El segundo suelo (NI 11) cerca de Montelimar es profundo, (moderadamente) bien drenado, de color pardo oscuro a pardo rojizo oscuro y de textura franco, mezclado con fragmentos de talpetate. Ambos suelos son derivados de materiales piroclásticos y muestran a una profundidad de 25 cm y 42 cm, respectivamente una capa fuertemente cementada, quebrada lo cual se llama en Nicaragua "talpetate". Los suelos con talpetate ocupan en Nicaragua aproximadamente un 15% de la Región Pacífica. Ambos suelos fueron clasificados como Phaeozem háplico, fase duripan.

La producción potencial para maíz y caña de azúcar calculadas por medio de un modelo de simulación parecen ser limitados. La presencia de un talpetate a poca profundidad afecta las condiciones de enraizamiento, la disponibilidad de nutrientes y de humedad y el potencial de mecanización de ambos suelos.

Los contenidos de óxidos de aluminino y de silicio en el talpetate son más altos que en la capa superior e inferior. La relación Al:Si indica que el sílice está retenido por la alófana que después de una deshidratación irreversible, actúa como cementante principal. Ninguna evidencia micromorfológica existe de una cementación de sílice y por lo tanto el talpetate no cumple con los criterios de un duripan.

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).

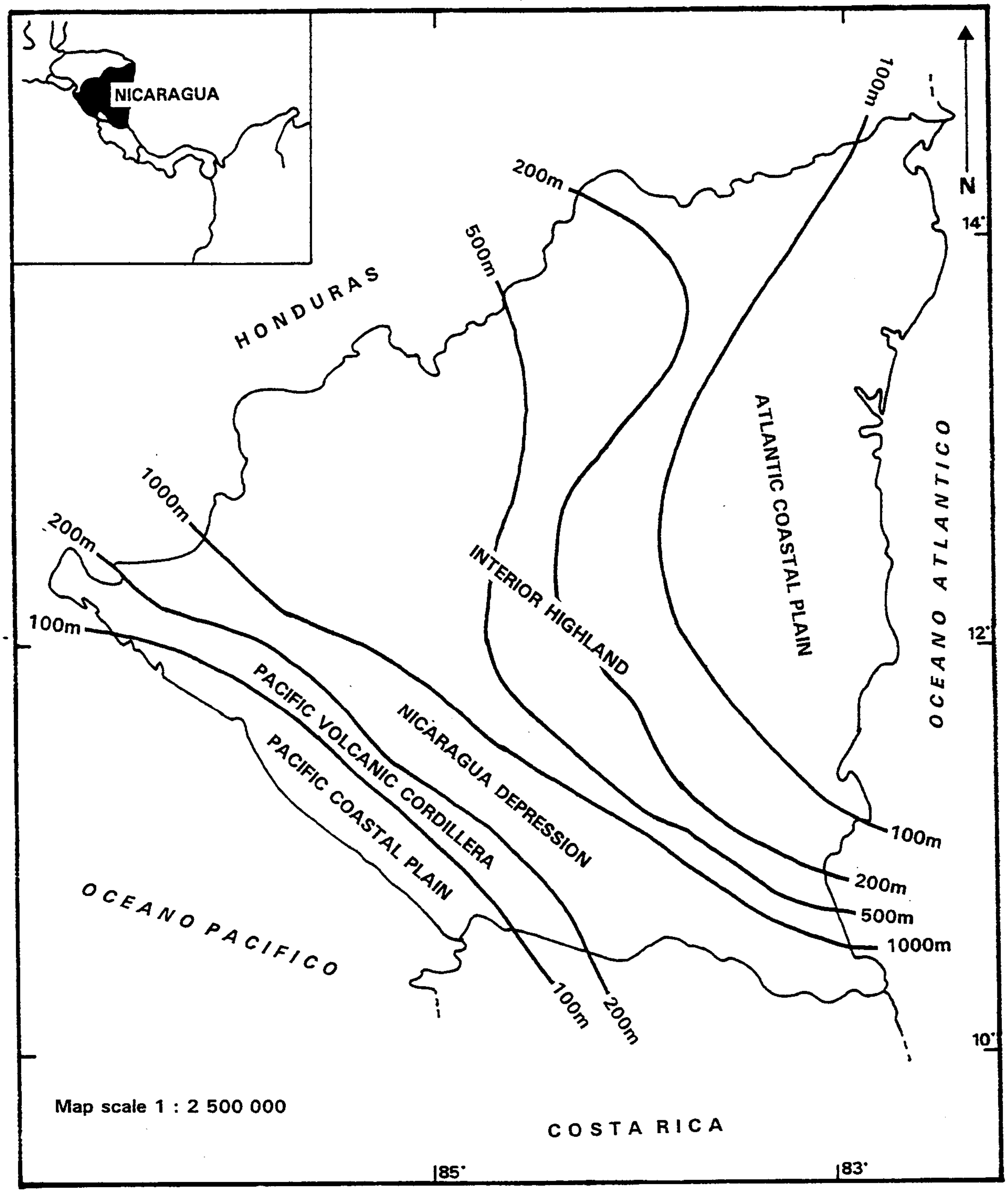


Figure 1 Major physiographic provinces of Nicaragua.

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 COASTAL PLAIN

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, mean precipitation and evapotranspiration, from the meteorological station "Managua Airport", located at 41 km from NI 10 and 60 km from NI 11.

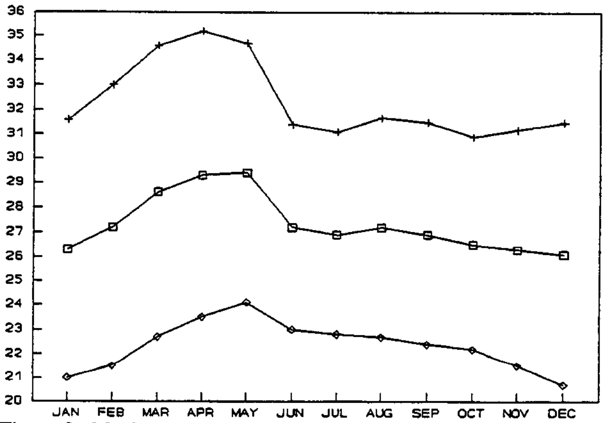


Figure 2 Maximum (+), average (◇) and minimum (◇) temperature in °C at Managua meteorological station.

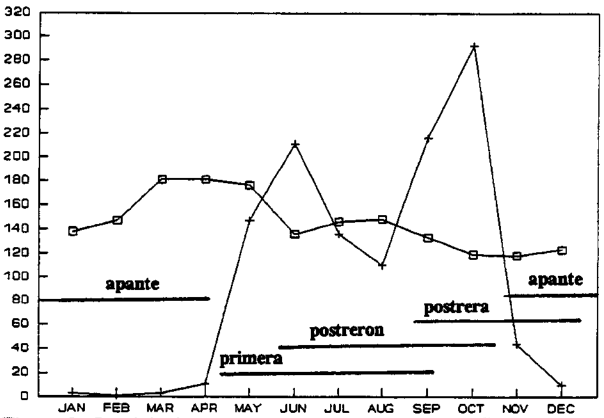


Figure 3 Precipitation (+) and evapotranspiration (□) in mm at Managua meteorological station.

2.2 Geology and geomorphology

The Western coastal range of Nicaragua consists of Cretaceous and Tertiary sediments, mostly sandstones with tuffaceous schists, limestones and breccia, as well as some Quaternary rocks. They are covered by deposits of pyroclastics and re-deposited sediments (Weyl, 1980). During the Miocene, the deposits of the Pacific sedimentation watersheds have been folded, forming a large anticline oriented NW-SE. The formation of this tectonic structure was accompanied by the emergence of a system of faults parallel and perpendicular to the direction of the anticline (Fenzl, 1989). During the Pleistocene, the Nicaraguan Depression and the emergence of the Pacific Cordillera with its volcanoes took place.

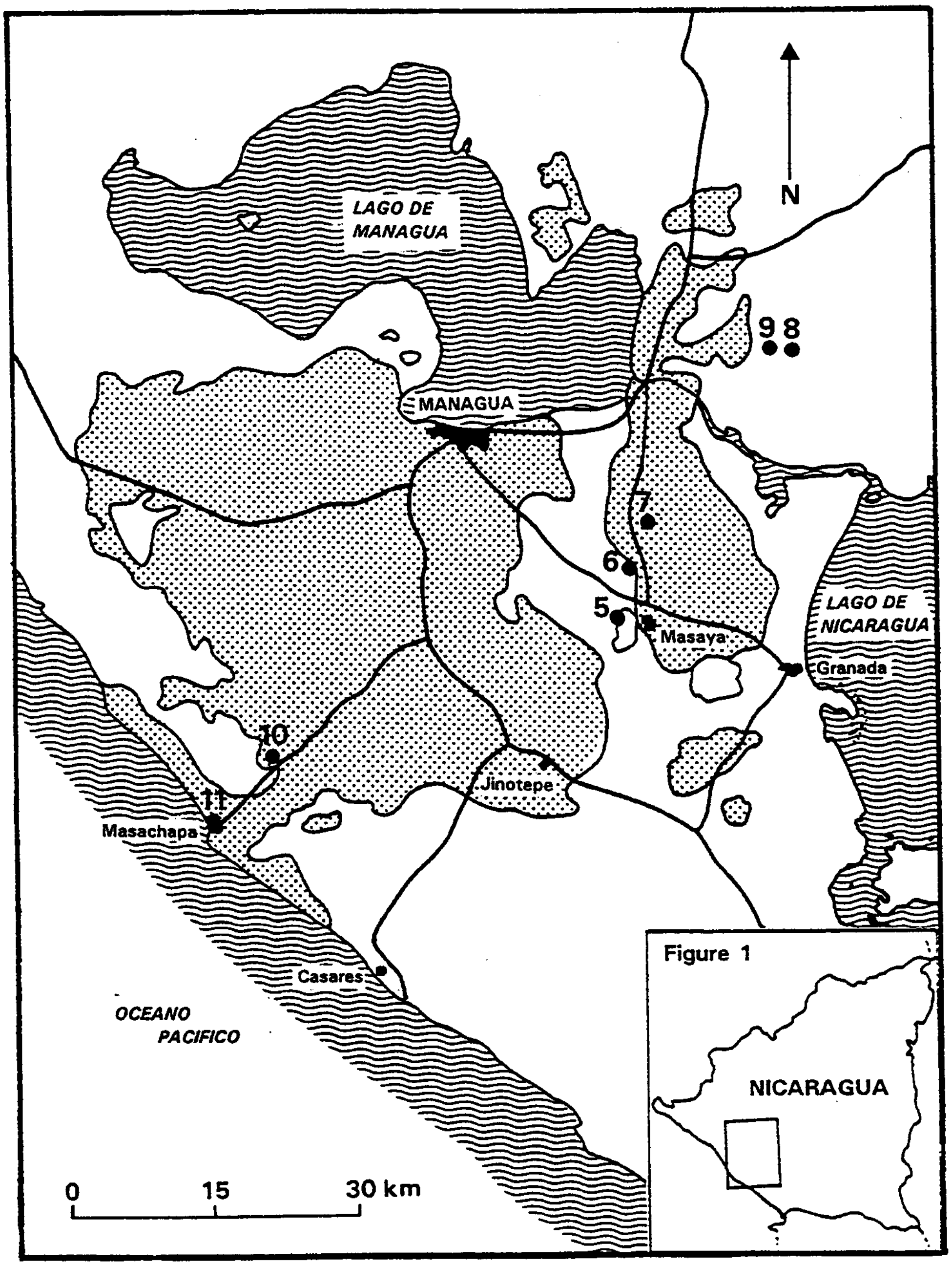


Figure 4 Distribution of soils with a talpetate layer and the number and location of the Reference Soils.

3 THE REFERENCE SOILS

3.1 The relation between the studied sites

In this chapter, a selection of data and research information of reference soil NI 10 and NI 11 is discussed. The soils are part of a sequence of 8 soils originally studied in 1991 as part of a research on soils derived from volcanic deposits with a hardened layer, in Nicaragua called "talpetate" (Rodriguez *et al.*, 1991; Marín *et al.*, 1971; Prat, 1991). This layer is classified as a duripan, silica being the main cementing agent. Detailed description and sampling and the taking of monoliths of two reference soils was carried out in 1992 by scientists of ISRIC, CATIE and UNA.
Field and laboratory data are given in Annex 1A and 1B: Soil and environmental data, stored by ISRIC Soil Information System (Van Waveren and Bos, 1988).
Detailed descriptions of both soils with their different soil horizons, according to FAO Guidelines for Soil Profile Description (FAO, 1977) are presented in Annex 1A (NI 10) and Annex 1B (NI 11).

3.2 Location and occurrence

Reference soil NI 10 is located near "Los Rizos", along the main road from El Crucero to Masachapa near the Pacific coast (Fig. 4). It is 41 km from the capital Managua and 17 km from the coast. The soils cover a major part of the nearly level to strongly sloping plains west of San Rafael del Sur, and on the rolling plains between San Rafael and El Crucero to the east.
Reference soil NI 11 is located near the sugar mill "Ingenio Julio Buitrago" in Montelimar, at 60 km from the capital Managua and 2 km from the coast. Total area presenting this kind of soil equals approximately 7.6 square kilometres (Catastro, 1971).

3.3 Landscape, geology, vegetation and landuse

The topography of the land surrounding the site where reference soil NI 10 was studied, is undulating to rolling. Slopes gradients vary from 4-16%. The parent material is volcanic ejecta.
The current land use involves grazing land. The natural vegetation is a grassed shrub land with scattered trees. In the past, the land was used for maize, beans and tomatoes, but its production was low.
As part of a fluvio lacustrine plain, the topography of the land surrounding the site where reference soil NI 11 was studied, is level to very gently sloping. Slopes have a gradient of less than 2%. Parent material is unconsolidated and has a mixed composition of igneous and sedimentary rocks, which have been resorted.
The soil occurs in the moist transition of the Subtropical Dry Forest zone. Forests have been removed and the current land use is arable farming, making use of a medium level of inputs, like fertilizers, pesticides and mechanization. The cultivated crop is sugar-cane, seasonally irrigated. In this part of Nicaragua sugar-cane has been cultivated for a long period (Rodriguez *et al.*, 1991).

3.4 Soil characterisation

3.4.1 Brief field description

Soil NI 10 is a shallow, (moderately) well drained, dark yellowish brown to (dark) brown, silty clay loam to silt loam soil mixed with fresh talpetate fragments; weak to moderately structured and moderately porous. At about 25 cm there is a thick strongly cemented broken platy, hardened layer, which does not meet all the criteria for a duripan. In Nicaragua this layer is called "talpetate". In the subsoil, at about 70 cm, another "talpetate" layer is found.
Soil NI 11 is a deep, developed, (moderately) well drained, dark brown to dark reddish brown, loamy soil mixed with fresh talpetate fragments; strong to moderately structured, moderately permeable and highly porous. At about 42 cm, a strongly cemented discontinuous platy duripan ("talpetate") is found of variable thickness.
In the subsoil, below the "talpetate" layer, the soil shows evidence of high biological activity and has strong thixotropic characteristics. Thixotropic soil material changes under pressure or by rubbing from a plastic solid into a liquefied stage and back to the solid condition. In the liquefied stage the material skids or smears between the fingers (FAO, 1989). The thixotropy is caused by allophane, a non-cristalline, amorphous clay mineral.

3.4.2 Brief analytical characterisation

Fig. 5 and 6 show the texture of the two soils with depth. The sand content increases in both soils, at talpetate depth and is a prominent feature. Above and below the talpetate layer, the soil increase in silt and clay content. Fig. 7 and 8 present chemical properties with depth. 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 sum of the exchangeable bases of soil NI 10 is very high, although the talpetate layer has a distinct lower content. The topsoil has a high organic C content compared to the lower layers in the profile. The organic C content of the topsoil of NI 11 is also high. The soil is high in exchangeable bases especially in the talpetate layer due to the high Ca content.

Fig. 9 and 10 present the moisture retention curves or 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).
The available moisture in the topsoil of NI 10 is very high due to the many fine soil pores which retain water. Large pores are more frequent in the topsoil than in the deeper profile but the overall porosity of the soil is high. Soil NI 11 has a very high amount of available moisture (22%) in each horizon, above and below the talpetate layer.

3.5 Soil classification

Both soils are similarly classified.

FAO-Unesco (1988)
The soil classifies as a Haplic Phaeozem, because the soil has a mollic A horizon (well structured and dark with moderately high organic C content and a 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, is not calcareous from 20 to 50 cm of the surface and is lacking an argic B horizon, as well as gleyic and stagnic properties.

USDA Soil Taxonomy (1990)
The soil classifies as a 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 doesn't have an argillic horizon above the duripan.

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. The evaluation was made for maize, a traditional crop of great importance of Nicaragua.

Table 1 Key properties of soils NI 10 and 11

	NI 10	NI 11
Texture	silty clay loam in topsoil; small increase in silt and clay content below sandy loam talpetate layer	loam to clay loam in the subsoil with sandy loam talpetate layer
Organic C	high in the upper 23 cm	high above the talpetate
pH	neutral (pH-H_2O 6.2)	slightly alkaline (pH-H_2O 7.6)
Sum of bases	very high (29.5 $cmol_c$ kg^{-1} soil) throughout the profile	topsoil very high (22.6 $cmol_c$ kg^{-1} soil), subsoil high (14.9 $cmol_c$ kg^{-1} soil)
CEC	very high (about 40 $cmol_c$ kg^{-1} soil)	medium (about 14 $cmol_c$ kg^{-1} soil) throughout the profile
Phosphorus	extremely low (0.1 mg kg^{-1} soil) throughout the profile	low (4 mg kg^{-1} soil) in the topsoil to very low (0.5 mg kg^{-1} soil) in the subsoil
Nitrogen	medium (0.4%) in the topsoil and very low (<0.1%) in the subsoil	medium (0.3%) in the topsoil and very low (<0.1%) in the subsoil
Clay mineralogy	low content of halloysite, increasing below the talpetate layer	low contents of halloysite increasing below the talpetate layer
Air capacity	high (16%) in topsoil; slightly decreasing with depth	high (16%) in the topsoil; low (6%) in the subsoil
Available soil moisture	very high (22%) in topsoil to medium (13%) in subsoil	very high (22%) in the topsoil to medium (11%) in the subsoil
Bulk density	low (0.9 kg dm^{-3})	low (1.0 kg dm^{-3}) throughout the profile

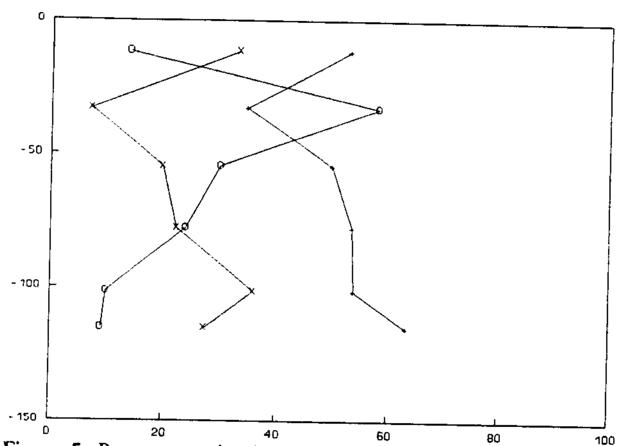


Figure 5 Percentages clay (x), silt (+) and sand (o) versus depth (cm) in profile NI 10.

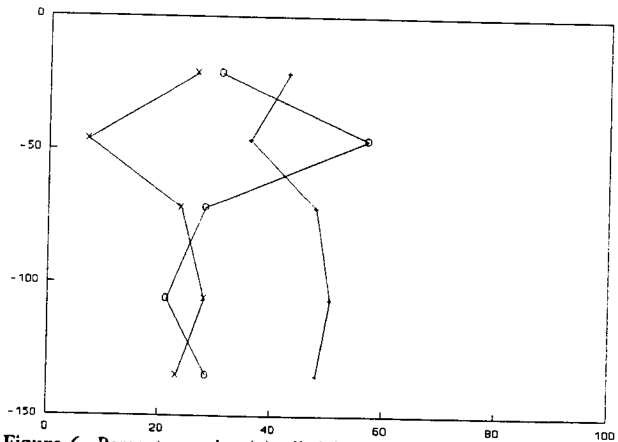


Figure 6 Percentages clay (x), silt (+) and sand (o) versus depth (cm) in profile NI 11.

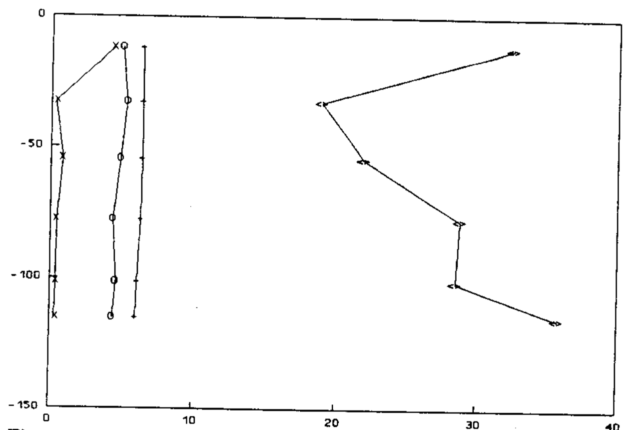


Figure 7 Sum of bases (cmol$_c$ kg^{-1} soil) (<>), pH-H_2O (+), pH-KCl (o) and organic carbon (x) versus depth (cm) in profile NI 10.

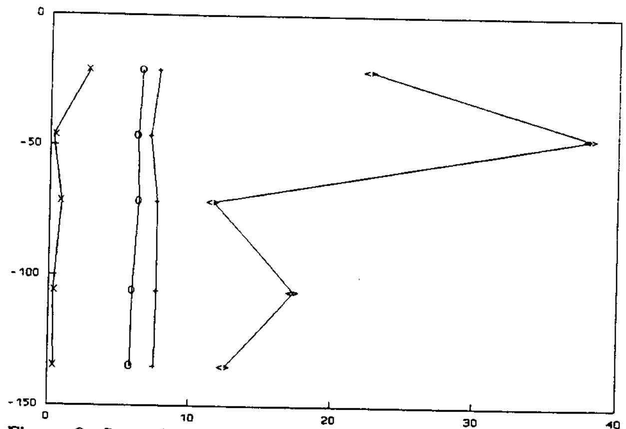


Figure 8 Sum of bases (cmol$_c$ kg^{-1} soil) (<>), pH-H_2O (+), pH-KCl (o) and organic carbon (x) versus depth (cm) in profile NI 11.

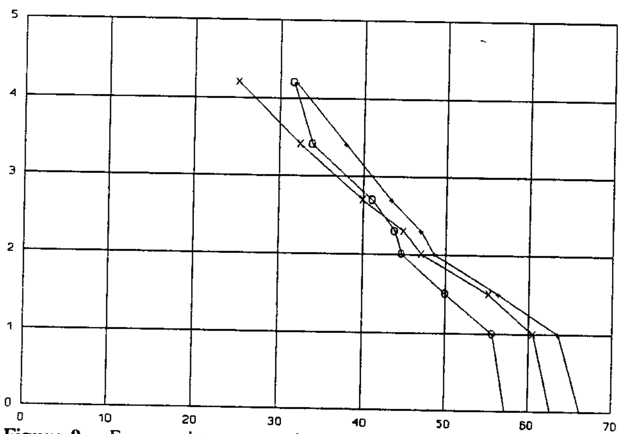


Figure 9 pF or moisture retention curves (water content in vol % versus suction) at depth 0-23 cm (x), 42-67 cm (+), 88-115 cm (o) in profile NI 11.

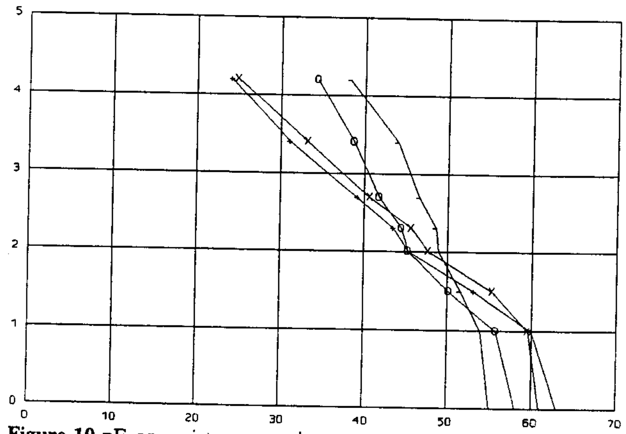


Figure 10 pF or moisture retention curves (water content in vol % versus suction) at depth 0-42 cm (x), 51-92 cm (+), 92-120 cm (o), 120-150 (< >) in profile NI 11.

Crop growth criteria of maize were taken from Zelaya (1990), ILACO (1981) and Landon (1991) and are summarized below. Maize (*Zea mais*) needs 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 cause damage to the pollen. It is a deep rooting (90 cm), nutrient demanding crop (especially nitrogen; pH 6.6-7.2), which presents a high erosion hazard due to the limited soil protection. The soil, preferably of medium to fine texture must be well drained and the tolerance to periods with water saturation is very low.

1

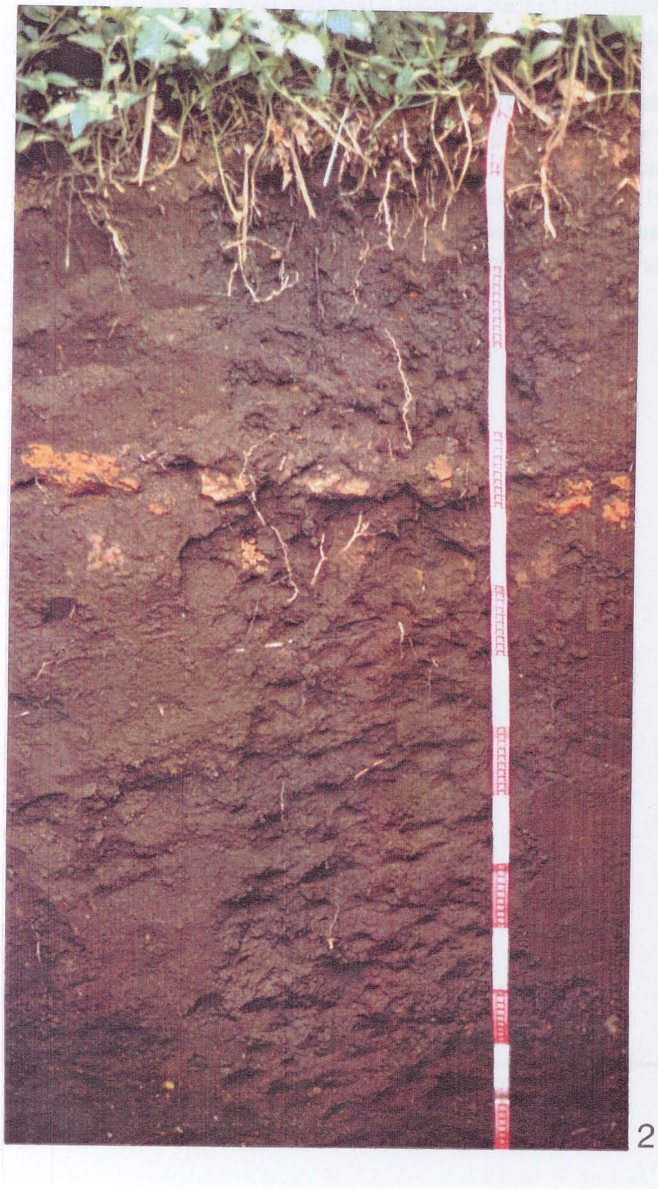
2

PROFILE NI 10

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

3

1



2

3

PROFILE NI 11

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

The results of the evaluation of soil NI 10 and NI 11 are presented in a list of soil/land qualities in Annex 2.

3.6.2 Evaluation of NI 10

The soil has sufficient natural fertility for moderate yields of traditional subsistence crops (FAO, 1975).
An almost continuous hard layer at shallow depth (23 cm) limits the potential for mechanization. Damage can occur to machinery when for instance deep ploughing of the soil is done without taking into account the proximity of the layer. In addition, the layer restricts root penetration. Roots can only pass through fissures in the hardened layers. Therefore, hardly any root is found below the layer and no use can be made of the nutrient rich subsoil.
The talpetate layer also impedes that crops can make use of the humidity stored in the subsoil. For most crops, the amount of water stored above the talpetate layer is not sufficient for high and sustainable yields (Available Water Capacity is 51 mm/23 cm soil). This means that extra water is required by irrigation. However, irrigation is difficult due to the undulating topography, the lack of surface water and the deep groundwater level.
Potential agricultural production is somewhat reduced in comparison to soils without a talpetate layer. Calculations with the crop simulation model WOFOST (Van Diepen *et al.*, 1988; Pulles *et al.*, 1991) show 10% yield reduction for soils with a talpetate layer at 23 cm, no reduction for soils with a talpetate layer at 40 cm and 25% for soils which are extremely eroded and have a talpetate layer at 10 cm.
There is a risk for erosion, especially when crops are cultivated without covering the soil surface, in combination with the undulating topography.
The soil is suitable for low-input farming on account of its poor rooting conditions and poor moisture availability. It is marginally suitable for high input mechanised agriculture unless, special management practices are applied like breaking of the talpetate layer and irrigation.

3.6.3 Requirements and limitations for sugar cane

Crop growth criteria for sugar-cane were taken from Ilaco (1981) and Landon (1984). 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 during a dry period of 4-5 months. Drought resistance is low. Optimum average daily temperatures are 28°C, optimum mean daily temperature for growth 22°C- 30°C. Growth is low at temperatures below 15°C. Wind may cause lodging of the cane, especially when it is not properly banked. It is a deep rooting (90 cm), nutrient demanding crop (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 but in a young stage there is a low resistance to water logging. Preferably the soil must be well-structured and heavy to medium textured. On heavy clay soils sugar-cane responds well to deep-ripping. Before full canopy development the erosion hazard is high.

3.6.4 Evaluation of NI 11

The soil is easy to work at all moisture conditions using a high degree of mechanization, which is also favourable due to the flat topography. The soil as a product of reworked parent material of mixed composition, has a moderate level of natural fertility.
The relative shallowness of the soil due to the talpetate layer at a depth of 42 cm, is not favourable. The layer is discontinuous and fine roots can pass. The amount of water stored in the topsoil above the talpetate layer is limited (Available Water Capacity is 97 mm/42 cm soil) so crops have to make use of water stored in deeper layers. Taking into account the high water needs of sugar-cane, additional irrigation has to be provided mainly in the dry season in order to guarantee sustainable yields.
Potential agricultural production is somewhat reduced in comparison to soils without a talpetate layer. Calculations with the crop simulation model WOFOST (Van Diepen *et al.*, 1988; Pulles *et al.*, 1991) show 11% yield reduction for soils with a talpetate layer at 42 cm, 6% for soils with a talpetate layer at 60 cm and 16% for soils which are eroded and have a talpetate layer at 30 cm. Soil depth is, however, not the most yield determining factor and the yield reductions calculated with WOFOST may be lower than the actual reductions.

4 DISTRIBUTION, MORPHOLOGY and GENESIS of "TALPETATE" SOILS

In different soils of Central America and Mexico a process of cementation within the soil profile has been active, which is important because these soils are frequently very erodable. As soon as the surface soil has been removed by erosion and the hardened layer emerges, the soil looses its agricultural potential. By breaking the layer it becomes possible to recuperate it. In cases when soil degradation has not proceeded, rooting conditions, soil drainage and the potential for mechanization of the soil is negatively affected, especially when the layer is continuous and is covered by a very shallow soil only.

Controversion exists on the genesis of the hardened layer, presenting the disjunction between a pedogenetic horizon and a geological material (a.o. tuff). In case the layer has silica as a cementing agent, it is called "silcrete" by the geologists and "duripan" by the pedologists who also use it as a concept within the taxonomy of soils. Also carbonates can act as cementing agent giving a completely different morphology of the hardened layer, while layers cemented by sesquioxides are not very common in Central America and Mexico (Nimlos, 1987).

In Nicaragua the duripan like layer is usually called "talpetate". The word is derived from the Aztec, who called it in their native language (Nahuatl) "tepetatl", which means stone matting (Gary *et al.*, 1974). The term "tepetate" used in Mexico, refers to the same phenomena, while others speak of "talpatate". In some cases volcanic tuff is also defined as a talpetate.

Talpetate soils are common in Nicaragua. They occupy about 2 500 km^2, 15% of the total Pacific region of Nicaragua (Marín *et al.*, 1971). In Fig. 4 an impression is given of the distribution of the soils with a talpetate layer. Prat (1991) presented evidence that the talpetate is a kind of volcanic tuff layer deposited about 2 000 years ago by the Masaya volcano. One or various violent explosions which led to the transformation of the volcano in the actual caldera, were followed by surges of pyroclastic materials. After deposition, the tuff was transformed by different weathering processes. Prat (1991) proposes to change the name of talpetate into "tuff of Masaya".

From a morphological point of view the talpetate layer consists of very light material with a variable hardness depending on its state of weathering. The colour may change from light yellowish brown to pale red. In general, small yellow and red mottles are observed. Within the soil profile, the layer is normally localized at a depth of 20 to 70 cm. In general, the layer is discontinuous or broken and has a platy structure. The thickness of the layer can fluctuate from a few centimetres to some decimeters (Marín *et al.*, 1971).

Examination of thin sections of soil NI 10 and soil NI 11 confirms the volcanic origin of the talpetate. The material is compact and there are very few pores, except in a few restricted zones where burrowing soil fauna has disturbed the material, which resulted in the discontinuity of the layer. The micromass of the talpetate layer consists of light to very light reddish yellow clay. It is optically isotropic with common inclusions of very fine crystalline minerals. Most of them have a fibrous habit (maximum length 6 μm), presumably aggregates of newly formed layer-lattice silicate clay minerals produced by weathering of the ash. X-ray diffraction analysis confirms the presence of halloysite. The larger particles (coarse silt, and coarser) are identified as volcanic glass (ϕ up to 5 mm), feldspars, pyroxenes and fragments of volcanic rock. The reddish yellow colour of the isotropic micromass is the result of extremely finely divided ferric oxides/hydroxides released through weathering. High percentages of oxalate extractable aluminium and silicon (Fig. 11 and 12), and high percentages of aluminium as measured by SEM-EDAX were found. The ratio of extracted amounts of Al and Si of the talpetate is 1.2 and therefore all Si is bound by the allophane (Mizota and Van Reeuwijk, 1989).

It is assumed that the isotropic (=amorphous) micromass consists dominantly of allophane. This constituent is thought to be responsible for the cementation of the layer, allophane acting as a cementing agent after irreversible dehydration. It does not coincide with the findings of Prat (1989) who presents data of talpetates formed in a relative allophane poor environment.

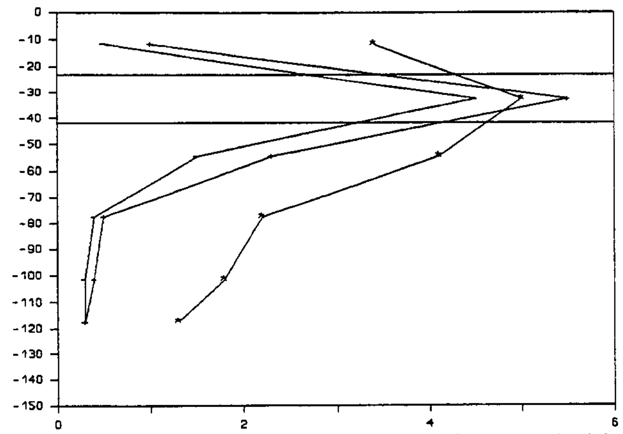


Figure 11 Oxalate-extractable Fe (*), Al (+) and Si (-) versus depth in profile NI 10.

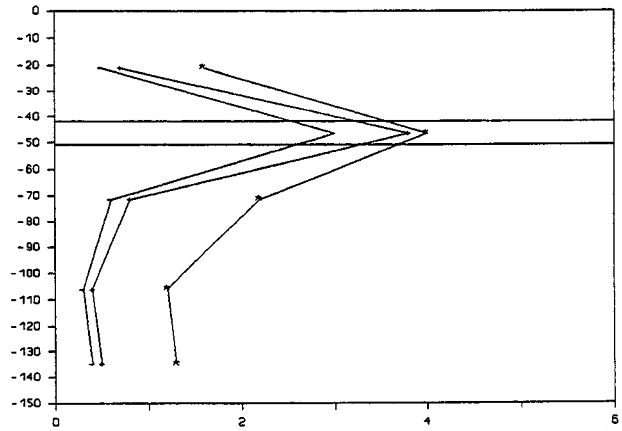


Figure 12 Oxalate-extractable Fe (*), Al (+) and Si (-) versus depth in profile NI 11.

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ISIS 4.0 data sheet of monolith NI 10   Country : NICARAGUA   Print date (dd/mm/yy) : 09/06/94

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

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

LOCATION : Los Rizos, road El Crucero-Masachapa,Km 41; 50 m from electricity post
Latitude : 11°54′ 0′′ N   Longitude : 86°27′ 0′′ W   Altitude : 0 (m.a.s.l.)
AUTHOR(S) : Vogel, Gutierrez   Date (mm.yy) : 11.92

GENERAL LANDFORM : piedmont   Topography : undulating
PHYSIOGRAPHIC UNIT : Pacific Coastal Plain
SLOPE Gradient : 4%   Aspect : W   Form : convex
POSITION OF SITE : middle slope
MICRO RELIEF Kind : level
SURFACE CHAR. Rock outcrop : little rocky   Stoniness : nil
Form : angular irregular   Av.Size (cm) : 1
Cracking : nil   Slaking/crusting : nil
Salt : nil   Alkali : nil
SLOPE PROCESSES Soil erosion : nil   Aggradation : nil
Slope stability : stable

PARENT MATERIAL 1 : volcanic ejecta   derived from : pyroclastic,consolidated
Texture : loamy
Weathering degree : partial or moderate   Resistance : moderate
Depth lithological boundary (cm): 115
Remarks :

EFFECTIVE SOIL DEPTH(cm) : 23

WATER TABLE Depth(cm) :   Kind : no watertable observed
DRAINAGE : moderately well to well
PERMEABILITY : slow   Slow permeable layer from : 23 to 42 cm
FLOODING Frequency : nil   Run off : medium
MOISTURE CONDITIONS PROFILE : 0 - 115 cm moist

LAND USE : shrubland,grazed; no irrigation; Rotation : not relevant; Improvements : none
VEGETATION Type : semi deciduous shrub   Status : modified
Landuse/vegetation remarks : In past used for maize, beans, tomatoes

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ADDITIONAL REMARKS :
Shallow, (moderately) well drained, dark yellowish brown to (dark) brown silty clay loam to silt loam soil developed from volcanic ejecta, derived from unconsolidated pyroclastic materials. The soil contains fresh talpetate fragments, is weakly to moderately structured and moderately porous. The strongly cemented layers at 23 and 67 cm depth, called "talpetate" (Bm horizon) are in this part of Nicaragua probably of geogenetic and pedogenetic origin. The shallowness of the soil and the drought hazard due to the semi-dry climate determine the selected land use type. The profile forms part of a toposequence (El Crucero- Montelimar) of soils with "talpetate", studied by the Department of Soil Science of the Nicaraguan Agricultural University.

CLIMATE :   Köppen: Aw"
Station: MANAGUA   12 7 N/ 86 11 W   0 m a.s.l   41 km NE of site   Relevance: moderate

	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/m2		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		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 4.0 data sheet of monolith NI 10 Country : NICARAGUA Print date (dd/mm/yy) : 09/06/94

PROFILE DESCRIPTION :

A 0 - 23 cm. dark yellowish brown (10YR 4.0/4.0, dry) silty clay loam; moderate medium subangular blocky to moderate medium angular blocky structure;, slightly hard; common fine continuous inped tubular pores and common very fine random continuous inped tubular pores; moderately porous; common very fine to coarse roots throughout; very few fine fresh "talpetate" fragments; abrupt smooth boundary to

Bm 23 - 42 cm. strong brown (7.5YR 5.0/8.0, dry); strongly cemented broken platy duripan; abrupt smooth boundary to

BC 42 - 67 cm. dark yellowish brown (10YR 3.0/6.0, dry) loam; weak to moderate fine to medium subangular blocky structure;, slightly hard; common very fine continuous inped tubular pores; moderately porous; few medium roots throughout and few coarse roots throughout; very frequent medium fresh "talpetate" fragments; clear broken boundary to

C 67 - 88 cm. strong brown (7.5YR 4.0/6.0, dry) silt loam;; clear broken boundary to

2Bw 88 - 115 cm. brown (7.5YR 4.0/4.0, dry) silty clay loam; moderate medium subangular blocky structure;, hard; common fine to coarse continuous inped tubular pores; moderately porous; few coarse roots between peds; very few very fine fresh pyroclastic fragments; clear wavy boundary to

2C 115 - cm. 5.0YR 4.0/4.0, dry silty clay loam; strong prismatic and strong medium angular blocky structure;, hard; few fine continuous inped tubular pores; slightly porous;; few small spherical manganiferous concretions; few fine weathered pyroclastic fragments;

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 - 23	-	1	1	2	7	4	14	9	44	53	33	-	0.94	63	61	55	47	45	40	33	25
2	23 - 42	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	42 - 67	-	1	3	7	12	8	30	14	36	50	20	-	0.81	66	64	56	49	47	43	38	32
4	67 - 88	-	1	2	5	11	6	24	15	38	54	22	-	-	-	-	-	-	-	-	-	-
5	88 - 115	-	0	0	1	4	5	10	13	41	54	36	-	1.07	57	56	50	45	44	41	34	32
6	115 - 115	-	0	0	1	4	4	9	16	47	63	28	-	-	-	-	-	-	-	-	-	-

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}													
0	6.0	4.4	0.0	0.27	0.05	20.3	14.6	0.7	0.2	35.8	-	-	38.7	141	0.9	35.8	93	-	0.07
1	6.4	5.0	0.0	4.41	0.42	25.5	5.2	1.7	0.1	32.5	-	-	46.6	140	15.4	32.5	70	-	0.06
2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	6.4	4.9	0.0	0.86	0.10	15.0	6.3	0.4	0.2	21.9	-	-	33.7	169	3.0	21.9	65	-	0.06
4	6.3	4.4	0.0	0.44	0.05	18.1	10.2	0.2	0.3	28.8	-	-	43.0	192	1.5	28.8	67	-	0.06
5	6.1	4.6	0.0	0.40	0.07	17.1	11.0	0.2	0.2	28.5	-	-	34.9	97	1.4	28.5	82	-	0.06

remarks (hor. 0) : P-Olsen= 0
remarks (hor. 1) : P-Olsen= 1
remarks (hor. 3 - 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	-	4	-	-	-	-	-	-	3.38	0.98	0.54	6.50	0.90	-	-	-	8.9
2	-	-	-	-	-	4	-	-	-	-	-	-	5.01	0.98	0.54	8.50	1.90	-	-	-	10.2
3	-	-	-	2	-	6	-	-	-	-	-	-	4.13	2.34	1.46	7.50	1.10	-	-	-	9.8
4	-	-	-	3	-	5	-	-	-	-	-	-	2.20	0.53	0.38	6.30	0.50	-	-	-	9.0
5	-	-	-	4	-	3	-	-	-	-	-	-	1.77	0.39	0.29	5.40	0.50	-	-	-	9.0
6	-	-	-	4	-	4	-	-	-	-	-	-	1.27	0.34	0.28	4.30	0.30	-	-	-	9.0

Annex 1B ISIS Data Sheet NI 11

ISIS 4.0 data sheet of monolith NI 11 Country : NICARAGUA Print date (dd/mm/yy) : 09/06/94

FAO/UNESCO (1988) : Haplic Phaeozem, duripan phase
(1974) : Haplic Phaeozem, duripan phase
USDA/SCS SOIL TAXONOMY (1992) : Entic Durustoll, fine loamy, halloysitic, isohyperthermic (1975 : durustoll)

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

LOCATION : Montelimar, "Ingenio Julio Buitrago", 40 m west of offices sugar mill
Latitude : 11°50′ 0′′ N Longitude : 86°31′ 0′′ W Altitude : 50 (m.a.s.l.)
AUTHOR(S) : Vogel, Gutierrez Date (mm.yy) : 11.92

GENERAL LANDFORM : plain Topography : flat or almost flat
PHYSIOGRAPHIC UNIT : Pacific Coastal Plain
SLOPE Gradient : -% Aspect : E Form : straight
POSITION OF SITE : flat
MICRO RELIEF Kind : ripples Pattern : linear Height (cm) : 20
SURFACE CHAR. Rock outcrop : fairly rocky Stoniness : nil
Form : angular irregular Av.Size (cm) : 3
Cracking : nil Slaking/crusting : nil
Salt : nil Alkali : nil
SLOPE PROCESSES Soil erosion : nil Aggradation : nil
Slope stability : stable

PARENT MATERIAL 1 : unconsolidated derived from : igneous and sedimentary
Texture : mixed
Weathering degree : partial or moderate Resistance : moderate
Depth lithological boundary (cm): 120
Remarks : Mix.alluvial,volcan.

EFFECTIVE SOIL DEPTH(cm) : 120

WATER TABLE Depth(cm) : Kind : no watertable observed
DRAINAGE : moderately well to well
PERMEABILITY : slow Slow permeable layer from : 42 to 51 cm
FLOODING Frequency : nil Run off : ponded
MOISTURE CONDITIONS PROFILE : 0 - 120 cm moist

LAND USE : medium level arable farming; Crops : sugar cane; seasonal irrigated; Rotation : monoculture; Improvements : none
Landuse/vegetation remarks : In the past used for fruit trees

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ADDITIONAL REMARKS :
Deep, (moderately) well drained, dark brown to dark reddish brown loam soil developed from unconsolidated materials, derived from igneous and sedimentary rocks as well as volcanic ejecta. The soil contains fresh talpetate fragments, is strongly to moderately structured, moderately permeable and highly porous. The strongly cemented layer at a depth of 42 cm, called "talpetate" (Bm horizon) is in this part of Nicaragua probably of geogenetic and pedogenetic origin. The talpetate at shallow depth affects the rooting conditions, the nutrients and moisture availability and the potential for mechanization of the soil. The profile forms part of a toposequence (El Crucero- Montelimar) of soils with "talpetate", studied by the Department of Soil Science of the Nicaraguan Agricultural University.

CLIMATE : Köppen: Aw"
Station: MANAGUA 12 7 N/ 86 11 W 0 m a.s.l 60 km NE of site Relevance: moderate

	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/m2		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		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 4.0 data sheet of monolith NI 11   Country : NICARAGUA   Print date (dd/mm/yy) : 09/06/94

PROFILE DESCRIPTION :

Ap 0 - 42 cm. dark brown (7.5YR 3.0/2.0, moist) loam; strong medium granular structure;, firm; common fine continuous exped tubular pores and common very fine random continuous exped tubular pores; moderately porous; common fine roots throughout and common very fine roots throughout; frequent fine fresh "talpetate" fragments; frequent worm channels; abrupt smooth boundary to

Bm 42 - 51 cm. strong brown (7.5YR 5.0/6.0, moist); strongly cemented discontinuous platy duripan; abrupt smooth boundary to

BC 51 - 92 cm. 5.0YR 3.0/4.0, moist loam; moderate medium subangular blocky structure;, very friable; many micro to very coarse continuous exped-inped tubular pores; highly porous; common fine roots throughout; very few medium fresh "talpetate" fragments; frequent worm channels; gradual smooth boundary to

C 92 - 120 cm. 5.0YR 3.0/4.0, moist clay loam; moderate medium to coarse subangular blocky to moderate medium to coarse prismatic structure;, very friable; many micro to very coarse continuous exped-inped tubular pores; highly porous;; dominant fine fresh "talpetate" fragments; frequent worm channels; clear smooth boundary to

2C 120 - cm. strong brown (7.5YR 4.0/6.0, moist) loam; moderate medium to coarse subangular blocky structure;, friable; few very fine continuous inped tubular pores; slightly porous;;

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 - 42	-	1	3	6	13	8	31	11	32	43	27	-	1.02	61	60	55	48	46	41	33	25
2	42 - 51	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	51 - 92	-	1	2	4	14	7	28	12	36	48	24	-	0.85	63	60	53	45	44	39	31	24
4	92 - 120	-	0	1	2	10	9	21	15	36	51	28	-	1.06	58	56	50	45	45	42	39	34
5	120 - 150	-	2	4	6	12	5	29	14	35	48	23	-	1.17	55	54	52	49	49	47	44	38

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	7.7	6.5	2.0	2.73	0.25	10.8	2.1	9.6	0.1	22.6	-	-	15.2	57	9.6	22.6	149	-	0.13
2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	7.6	6.3	2.1	0.02	0.13	8.8	1.7	0.9	0.2	11.6	-	-	11.8	50	0.1	11.6	98	-	0.11
4	7.6	5.9	1.9	0.33	0.06	12.1	3.8	1.2	0.2	17.3	-	-	18.4	65	1.2	17.3	94	-	0.12
5	7.5	5.8	1.8	0.41	0.06	8.9	2.9	0.6	0.1	12.5	-	-	13.4	58	1.4	12.5	93	-	0.11

remarks (hor. 1) : P-Olsen= 31
remarks (hor. 3) : P-Olsen= 4
remarks (hor. 4) : P-Olsen= 1
remarks (hor. 5) : P-Olsen= 3

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	-	-	-	-	-	-	1.56	0.70	0.46	5.20	0.60	-	-	-	9.3
2	-	-	-	-	-	4	-	-	-	-	-	-	4.02	3.83	2.96	6.30	1.40	-	-	-	10.1
3	-	-	-	-	-	5	-	-	-	-	-	-	2.21	0.84	0.64	6.30	0.80	-	-	-	9.6
4	-	-	-	-	-	6	-	-	-	-	-	-	1.24	0.36	0.31	4.20	0.30	-	-	-	9.5
5	-	-	-	-	-	6	-	-	-	-	-	-	1.27	0.49	0.40	4.20	0.40	-	-	-	9.6

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 10					NI 11				
		1	2	3	4	5	1	2	3	4	5
CLIMATE											
Radiation regime - total radiation	1	X					X				
- day length	1	X					X				
Temperature regime	1	X					X				
Climatic hazards (hailstorm, wind, frost)	2	X					X				
Conditions for ripening	1	X					X				
Length growing season	1		X					X			
Drought hazard during growing season	2		X					X			

		NI 10					NI 11				
		1	2	3	4	5	1	2	3	4	5
SOIL											
Potential total soil moisture	1				X				X		
Oxygen availability	1		X					X			
Nutrient availability	1		X					X			
Nutrient retention capacity	1	X						X			
Rooting conditions	1					X				X	
Conditions affecting germination	1		X					X			
Excess of salts - salinity	2	X					X				
- sodicity	2	X					X				
Soil toxicities (e.g. high Al sat.)	2	X					X				

		NI 10					NI 11				
		1	2	3	4	5	1	2	3	4	5
LAND MANAGEMENT											
Initial land preparation	2	X					X				
Workability	1	X					X				
Potential for mechanization	1			X				X			
Accessibility - existing	1	X					X				
- potential	1	X					X				
Erosion hazard - wind	2	X					X				
- water	2		X					X			
Flood hazard	2	X					X				
Pests and diseases	2	X					X				

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 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)

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25	Nigeria	in prep.
26	Mozambique	in prep.
27	Botswana	in prep.

* State of reference collections as of January 1995