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Original article

Diagnosis and classification of Ferrallic soils in Mayabeque province, Cuba

Diagnóstico y clasificación de suelos Ferrálicos en la provincia de Mayabeque, Cuba

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ABSTRACT: The objective of this work is to show for the first time the diagnostic data of ferric soils in Mayabeque province and criteria on their formation and distribution. For this purpose, the characterization of soils located in two regions, San Nicolás de Bari and Nueva Paz, was carried out. However, in the soil map scale 1:25 000, according to the cartographic sheet, these soils are classified as Ferrallitic. In the first region, a soil profile was studied in the "Roma" farm and, in the second region, the characteristics of the cumulative humic horizons of the soils in two farms were studied. The morphological characteristics of the soils and the analytical results show that these soils are not classified as Ferrallitic, although they are deep and red in color, but Ferrallitic, since they have a content of exchangeable bases greater than 20 $cmol^{+}$ kg^{-1}. In addition, these soils are characterized by the presence of an argillic horizon. Although these soils have been classified as Ferrallitic on the map, they are not Ferrallitic, but rather Ferrallitic, which has a more favorable productive value for agricultural production.

Key words: Edaphology, soil taxonomy, ferralsol, soil profile, leaching.

RESUMEN: El objetivo de este estudio es presentar por primera vez datos sobre el diagnóstico de suelos Ferrálicos en la provincia de Mayabeque, así como criterios sobre su formación y distribución. Se llevó a cabo la caracterización de suelos en dos regiones: San Nicolás de Bari y Nueva Paz. En el mapa de suelos a escala 1:25 000, estos suelos están clasificados como Ferralíticos según la hoja cartográfica. Sin embargo, en San Nicolás de Bari se estudió un perfil de suelo en la finca "Roma", y en Nueva Paz se estudiaron las características de los horizontes húmico acumulativos en dos fincas. Los resultados morfológicos y analíticos indican que estos suelos, aunque profundos y de color rojo, no deben clasificarse como Ferralíticos, sino como Ferrálicos, ya que tienen un contenido en bases cambiables superior a 20 $cmol^{+}$ kg^{-1}. Además, presentan un horizonte argílico. Aunque en el mapa están clasificados como Ferralíticos, los resultados indican que son Ferrálicos, lo que les otorga un valor productivo más favorable para la producción agrícola.

Palabras Clave: Edafología, taxonomía de suelos, ferralsol, perfil del suelo, lixiviación.

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INTRODUCTION

The classification of Ferrallic soils in Cuba was established for the first time in the version elaborated in 2004 and published in 2009 (1). In this classification, the Ferrallic Soil Grouping is defined, which includes two main genetic types: Ferrallic Red and Ferrallic Yellowish, each with several subtypes. This grouping is characterized by the presence of a main horizon of ferrallic diagnosis, which is identified by the presence of clay minerals of the 1:1 type mixed with clays of the 2:1 type, with a content of the latter between 10 and 40 %. These soils are found in regions associated with Ferrallitic soils.

In the most recent version of the Cuban Soil Classification (2), it is also indicated that Ferrallitic soils have a cation exchange capacity between 20 and 30 $cmol^{+}\ kg^{-1}$ in clay. Specifically, for the Red Ferrallic soils, it is established that they have a pH in water between 6 and 7. However, to date, detailed data on these soils have not been published, nor has their diagnosis and distribution been studied in depth.

Taking into account these considerations, the objective of this work is to present, for the first time, data on the diagnosis of Ferrallic soils in Mayabeque province, as well as to offer criteria on their formation and distribution.

MATERIALS AND METHODS

In order to meet the objectives, soil studies were carried out in the contact areas between the Red Ferrallitic soils and Vertisols in the regions of San Nicolás de Bari and Nueva Paz, in Mayabeque province. In addition, the results of the soil mapping previously carried out in this region were taken into account. In the soil map at a scale of 1:250,000 (3), these soils are classified as plastic Red Latosolic, formed by transported materials and hard limestone rock. In contrast, the 1:25,000 scale soil map (4) classifies them as compacted Red Ferrallitic, formed from hard limestone rock.

Investigations were carried out in two sites of the denudative plain ecosystem of Ferrallitic soils that borders to the south with the cumulative plain ecosystem with Vertisols, Gleysols and Fluvisols soils (5). A soil profile was made and studied in the "Roma" farm of producer Nelbis Díaz, in the "José Luis García" Credit and Services Cooperative (CCS), located one kilometer northeast of San Nicolás de Bari, and the cumulative humic horizons of soils in two farms (San Antonio and 2 de Mayo) of producers in the municipality of Nueva Paz were analyzed. Two farms in Nueva Paz municipality, mapped and classified as Ferrallitic Red according to the 1:25 000 soil map (4), were visited. Located in the Cartographic Sheet (1:25 000): San Nicolás de Bari.

Each farm was sampled at a depth of 30 cm. The soil profile in Roma farm was described according to the norms of the Manual for the Description of Soil Profiles of Cuba (6). The soil samples were analyzed at the chemical analysis laboratory of the National Institute of Agricultural Sciences (INCA) and the Institute of Animal Science (ICA) for the following parameters:

- Mechanical composition by the modified Bouyoucos method, applying sodium pyrophosphate to eliminate organic matter and sodium hydroxide as a dispersant.
- Texture according to the mechanical composition of the soil particles (sands, silts and clays) using the textural triangle.
- Organic matter by wet combustion method (7).
- pH by potentiometry in the soil/water ratio 1:2.5.
- Exchangeable calcium and magnesium by the ammonium acetate extraction method and EDTA titration. The Ca/Mg ratio was calculated.
- Phosphorus and potassium by Oniani's method.
- Soil color was determined by the Munsell Color Chart (8).

RESULTS AND DISCUSSION

Morphological characteristics of the soil profile

Table 1 shows the profile description format. According to the diagnosis, the profile is of type A-Bfral-B3R, the formation process is Ferrallitization, the diagnostic horizons are, main: Ferrallitic and, secondary: Argillic; the diagnostic characteristics are red. It is proposed for the next update of the Cuban Soil Classification to include the Ferrallitic Red Lixiviated pedocutanic (it is not in the classification).

Field diagnosis by profile shows that it is of the ABtR type, leached with many cutans, underlain by limestone rock (Figure 1). It is a deep red soil on limestone, with argillic Bt horizon, but it is remarkable the presence of small dark gravels apparently of ultrabasic rock in the A horizon and the presence of abundant cutans in the Bt horizon, which seem more of pressure than of leaching. On the other hand, the structure of the A horizon (Figure 2), is not typical of Red Ferrallitic Leached soils under pastures such as those of the Municipality of San José de Las Lajas. Likewise, the structure of Horizon Bt (Figure 3) is different, here it is of angular wedge-shaped blocks different from the polyhedral structure typical of Red Ferrallitic Leached soils (Table 1).

On the other hand, Figure 4 shows the polyhedral structure typical of the leached Red Ferrallitic soils of the San José de las Lajas municipality.

The morphological characteristics of the studied profile are not Red Ferrallitic Leached soils, they characterize a Red Ferrallitic Leached soil. This soil type is not in the 2015 version of the Cuban Soil Classification (11), so it is recommended to include it in the next revision and also with the pedocutanic subtype.

Mechanical composition of the profile

In the mechanical composition of the profile, the amount of clay is remarkable, which reaches in the Bt horizon up to 80 % (Table 2). The increase in clay content coincides with what the Soil Taxonomy defines as argillic horizon (9); adopted in our Cuban soil classification (2) but the amount of sand in the soil is even more notable, especially in the upper part of the profile where it reaches up to 25.37 %. By the textural triangle, the soil texture is calculated to be clayey in the whole profile, increasing up to 15 % in the leached Bt horizon.

Table 1. Template for profile description

Profile No.: Cary 1
Date: February 22, 2022
Described by: Alberto Hernández, María Caridad González y Rodolfo Guillama

Soil classification

Cuban [2] : Red Ferrallic Soil Taxonomy [9] : Udic Rhodustalf World Reference Base [10] : Nitisol rhodic, lyxic, eutrophic

Localization

Coordinates (according to Lambert): N: 329.500 E: 406.500
Height (m a.s.l.): 25
Municipality: San Nicolás de Bari
Province: Mayabeque
Country: Cuba

Formation factors

Physiographic position of the site: Denudation plain.
Topography of the surrounding terrain: Plain
Microrelief: In furrows
Slope where profile was taken: < 2 %
Vegetación o Vegetation or land use: Crops for 5-6 years, but the profile was taken in pasture.
Climate: Tropical sub-humid
Annual rainfall (in mm): 1300 Average annual temperature (in °C): 23.8 ºC
Source material: Transported materials and Miocene hard limestone
Time: Ancient Quaternary
Drainage: Surface: Good; Internal: Fair
Soil surface condition: Small furrows

Profile description

Horizon	Depth (cm)	Description
A_{11}	0 - 15	Color 5YR3/3, dark reddish brown, clayey, structure of subangular blocks of 5-10 cm, which crumble easily, compacted, dry, with medium amount of fine pores, with roots up to 25 cm deep, presence of small dark gravels, no reaction to HCl, somewhat noticeable transition.
A_{12}	15 - 25	Color 2.5YR3/4, dark reddish brown, a little more clayey, subangular block structure 3-5 cm deep, compacted, fresh, with medium amount of fine pores, rooted, with small dark gravels, no reaction to HCl, noticeable transition.
B_1t	25 - 46	Color 10R4/4, weak red, more clayey, 3 cm angular block structure and granular, friable, slightly moist, with many fine pores, no roots, no small dark gravels, with cutans, no reaction to HCl, noticeable transition.
B_2t	46 - 90	Color 10R3/6, dark red, with many shiny faces, a little more clayey, 3-5 cm angular block structure, friable and somewhat plastic, a little more humid, with many fine pores, with an abundance of cutans, many of them look like pressure, no roots, no reaction to HCl, noticeable transition.
B_3R	90 - 100 to more	Soil mixed with hard limestone rock outcrops

It is remarkable the amount of cutans of the B2t horizon in this profile. Possible to include as a cutanic diagnosis in the next version of the Cuban Soil Classification

Figure 1. Soil profile studied at farm "Roma"

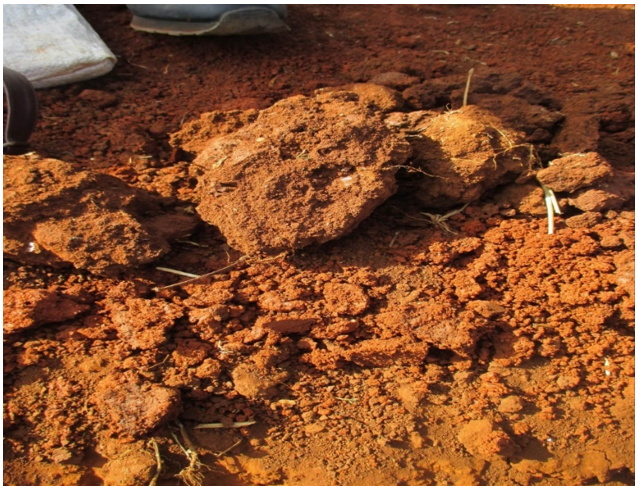

Figure 2. Structure of prismatic blocks without sliding faces, of the A horizon of the Ferrallic soil at farm La Roma

Figure 3. Horizontal angular block structure of the studied profile

Figure 4. Polyhedral structure with cutans typical of leached red Ferrallitic soils

Table 2. Mechanical composition and texture of the Cary 1 profile

Horizon	Depth (cm)	(%)			Texture
		Sand	Silt	Clay	
A_{11}	0 - 15	25.37	10.28	64.35	Clayey
A_{12}	15 - 25	21.53	7.28	71.19	Clayey
B_1t	25 - 46	17.53	2.28	80.19	Clayey
B_2t	46 - 90	17.53	3.28	79.19	Clayey

Some chemical characteristics

Soil reaction (pH) is slightly above neutral, decreasing slightly at depth (7.4). The organic matter content is medium, although it reaches up to 3.1 % up to 25 cm depth, which indicates that the producer may be applying organic fertilizers, which is a beneficial measure for the soil (Table 3).

The calcium and magnesium content of the soil is very important, the sum of which reaches 22.5 to 26.0 cmol+ kg^{-1}, increased in depth. According to the Cuban soil classification, this quantity of calcium and magnesium cations does not correspond to ferralitization, since in the depth of 25-46 cm, it has a sum of 25.0 cmol+ kg^{-1}, with a clay content of 80.19 %, if it is taken to 100 % it would be 31.17 cmol+ kg^{-1}, much higher than the ferralitization limit, which is 20 centimoles in clay (11).

Everything seems to indicate that we are dealing with a ferralitic soil profile, since there is not really a complete ferralitization process (1). As these soils are in the limit between Ferrallitic soils and those previously classified as Dark Plastic, according to the soil map 1:25 000 (4), with a diagnosis that is not typical of Ferrallitic soils, this profile is classified as Ferrallic Red Leached, which is not in the last version of soil classification of Cuba (6). It could be proposed as a haplic subtype, but with the amount of leaching cutans or clay cutans (they are clay coatings, which are observed as shiny surfaces that are formed on the face of the aggregates in the form of a lacquered or varnish, but in relatively small size) that it has, it is proposed as cutanic, with the eutric genus, formed of limestone rock and transported materials, deep species, clay variety.

Results of soil sampling at the Nueva Paz farms

The chemical characteristics of the soils of these two farms are shown in Table 3. The pH of the soils of the farms is adequate, with values between 6 and 7, the organic matter content is valued as medium, between 3 and 4, according to the Manual for the description of soil profiles (6).

These pH and organic matter values are characteristic of a Ferrallitic soil. However, the values of the sum of exchangeable cations are higher, greater than 20 cmol+ kg^{-1} in all cases, which indicates that the soil is not Ferrallitic, but Ferrallic.

The above results show that the soils mapped and classified as Red Ferrallitic in this region are not Red Ferrallitic, but rather Ferrallitic, with a leaching process, which is evidenced by the presence of cutans, as well as by the presence of an argillic horizon, demonstrated by

Table 3. Chemical characteristics of Cary profile 1

Depth cm	pH H_2O	OM %	Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	Sume
			cmol+ kg^{-1}				
0 - 15	7.4	3.3	19.5	3.0	Nd	Nd	22.5
15 - 25	7.1	3.1	21.5	2.8	Nd	Nd	24.3
25 - 46	7.2	2.1	21.5	3.5	Nd	Nd	25.0
46 - 90	6.9	1.1	2325	3.7	Nd	Nd	26.2

Nd: not determined

the mechanical composition of the soil. This leads to the hypothesis that in the ecosystem of the denudative plain of Mayabeque with Red Ferrallitic soils, in contact with the ecosystem of the denudative plain with Vertisols, Gleysols and Fluvisols, there are Ferrallitic soils, apparently formed from Miocene limestone and materials transported with clay of the 2:1 type, which results in a slightly higher content in exchangeable bases than in Ferrallitic soils and the presence of a structure not typical of these soils.

Changes in soil properties due to continued cultivation in the case of leached red Ferrallitic soils have been studied in recent years. It has been possible to determine organic carbon gains and losses in these soils under different forms of use (12, 13). In addition, how the properties of these soils change by continued cultivation (14-18); which is applied in the classification of soils of Cuba 2015, with the classification of subtypes of agrogenic soils (2).

It is important to note that the attributes for the classification of soils affected by anthropogenic influence are not contemplated in world classifications, such as the Soil Taxonomy (7) and the World Reference Base (8). This was pointed out at the International Soil Classification Conference held in 2022 in Querétaro, Mexico. During this conference, papers were presented that demonstrated the impossibility of applying these classifications to soils whose properties have been transformed by human action, according to studies carried out on soils from Poland (19, 20) and Mexico (21). This problem does not occur with the current version of the Cuban Soil Classification (2).

For the properties that are diagnosed, in this work, the soil classified as Ferrallic, does not seem to have a degradation process as occurs with many areas of Ferrallitic Red Leached soils in the region of San José de las Lajas, since there is no plowing floor or a sharp decrease in the organic matter content.

CONCLUSION

It is shown that the soils studied are not Ferrallitic but Ferrallitic, being classified as Ferrallitic Red Leached genetic type. The distribution area of this soil is located in the ecosystem of the denudative plain with Ferrallitic soils in the southern limit with the accumulative plain with Vertisols, Gleysols and Fluvisols soils of the south of Mayabeque province. In addition, there is the presence of an argillic horizon with numerous cutans, a characteristic not previously described in Cuban soils.

RECOMMENDATIONS

- It is necessary to continue conducting soil characterization studies of those classified as Ferrallitic in this region to determine whether they truly belong to that grouping.
- The Soil and Fertilizer Service of Mayabeque Province should carry out soil mapping and classification studies to reorganize the soil map of that region.
- It is proposed to include the attributes "leached" and "pedocutanic" in the next version of Cuba's soil classification system for this soil subtype.
- Agricultural production results (yields and management technologies) should be investigated in the region, as Ferrallic soils are expected to be more fertile than Ferrallitic ones.

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Table 4. Chemical characteristics of the soils sampled at the Nueva Paz Farms

Farm	Depth cm	OM %	pH		Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	CEC	Ca/Mg
			H_2O	KCl	$cmol^{+}\ kg^{-1}$					
San Antonio	0 - 10	3.46	6.3	5.1	18.5	9.0	0.04	0.04	28.02	2.1
	10 -20	2.99	6.1	5.7	17.5	3.5	0.06	0.06	21.40	5.0
	20 - 30	2.60	6.4	5.5	14.0	4.5	0.06	0.06	18.95	3.1
2 de Mayo	0 - 10	3.44	6.4	5.5	19.5	6.0	0.04	0.01	25.50	3.3
	10 -20	3.37	6.4	5.3	15.5	5.0	0.06	0.02	20.58	3.1
	20 - 30	3.26	6.7	5.7	15.5	13.0	0.06	0.01	28.57	1.2

OM: organic matter; CEC: cationic exchange capacity

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