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CHARACTERISTICS AND CLASSIFICATION OF FERRUGINOUS NODULAR GLEY SOILS UNDER INTENSIVE RICE CROP PRODUCTION FROM LOS PALACIOS

Características y clasificación de suelos Gley Nodular Ferruginoso bajo cultivo intensivo de arroz en Los Palacios

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ABSTRACT. Soils under intensive rice crop production, for more than 50 years were studied to describe problems in physical properties and morphological characteristics and to classify the soils by the New Version of Cuban Genetic Soil Classification, American Soil Taxonomy and the Word Reference Base, taking into account the showed evidences. The results indicated soils affected by gleyzation process, observed at soil depth equal or higher than 50 cm, where iron and manganese nodules where abundant. There were evidences of not good conditions of soil physic properties, characterized by an increase of bulk density and a reduction of total porosity. In addition, it was observed poor soil fertility, in both profiles, characterized by low levels of nutrients. However, such behaviors there were not enough to define anthropic effects by the existence of an Anthraquic or Hydragric horizon, due to the absences of a low pan and other diagnostic characteristics.

Key world: morphological characteristics of soil, soil fertility, physics-chemical properties of soil

RESUMEN. Suelos bajo cultivo intensivo de arroz, por más de 50 años, fueron estudiados con el propósito de describir afectaciones en propiedades físicas y características morfológicas, y clasificarlos teniendo en cuenta las evidencias de dichas afectaciones, según la Nueva Versión de Clasificación Genética de los Suelos de Cuba, la Soil Taxonomy y la World Reference Base. Los resultados obtenidos mostraron que los suelos estaban afectados por el proceso de gleyzación a profundidades iguales o mayores a 50 cm, donde es abundante la presencia de nódulos de hierro y manganeso. Se evidenció afectaciones en propiedades físicas del suelo en ambos perfiles, caracterizada por aumento de la densidad aparente y disminución de la porosidad total. Se observó además, deterioro de la fertilidad del suelo en ambos perfiles, expresados en bajos niveles nutricionales. Sin embargo, tales manifestaciones no fueron suficientes para diagnosticar efectos antrópicos por la presencia de un horizonte Antrácuico o Hidrágrico, dada la ausencia de piso de aradura y otras características de diagnóstico.

Palabras clave: características morfológicas del suelo, fertilidad del suelo, propiedades físico-químicas del suelo

INTRODUCTION

The intensive cultivation of rice is one of those that cause the greatest degradation in soil properties, mainly due to the flood conditions to which they are subjected, to the intensive use of machinery and to tillage in unsuitable physical conditions (1, 2).

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Likewise, monoculture practices have unfavorable effects on the properties of rice soils (3,4). However, the manual for rice cultivation does not address the issue of the change in soil properties due to the aforementioned, this being one of the current problems that merit being served in the cultivated areas of the cereal (5).

In the genetic classification of the soils of Cuba (6), the transformations of the soils due to intensive rice cultivation are not treated with the required depth.

However, soil classifications of international importance, based on the properties of soils through horizons and diagnostic features related to genesis, if included in their latest versions, qualifiers to distinguish the influence of man by continued cultivation and be rice or another crop. For example, in the new version of China soil classification (7), there are several diagnostic horizons such as the Anthrostacnico epipedon and the sub-surface Hydragric horizon and in the World Reference Base (8), the qualification of Anthraquic and Hydragric horizon, which is similar to the one, used by the classification of the Chinese. The classification of Cuban soils 2015 includes these qualifiers taken from the World Reference Base (9).

The objective of the work was to characterize and classify Gley Nodular Ferruginous soils under intensive rice cultivation and describe affectations in physical properties.

MATERIALS AND METHODS

The study was carried out in areas of the Sierra Maestra rice farm, belonging to the Los Palacios agroindustrial grains company, Los Palacios municipality, Pinar del Río province, southwest of the Cuban capital. The altitude above the mean sea level is between 5 and 15 meters, and may be lower in some areas.

The selected fields, 7 and 8A, under intensive exploitation for more than 50 years, have an area of 120 ha in total, 67 ha in field 7 and 53 ha in 8A. Field 7 is located in the coordinates 291,1 N and 272,5 E and 8A in the coordinates 290,5 N and 272,5 E.

The representative profiles of each field were selected making observations with auger at a distance of approximately 100 meters, and were described according to methodologies (10,11). The geo-referencing of the profiles was done with Gps mark:'Garmin' model'Gps Map'. The soil color was determined by the color table (12). For soil classification, the New Version of Genetic Classification of Soils of Cuba (6), the World Reference Base (8) and Soil Taxonomy (13) were used. From both profiles representative samples were taken for physical and chemical analysis by horizons.

The possible affectations in physical properties of both profiles were evaluated from the ranges of values of volumetric density (apparent density) and total porosity that the undisturbed soils should have according to the textural class (10).

The mechanical composition of the soil was determined by the hydrometer method, described (14). The volumetric density was determined in undisturbed samples, taken in cylinders of 98 cm^3, following the Cuban norm (15). The specific gravity was determined following the Cuban norm (16).

For each horizon three replications were taken for both determinations. The total porosity was estimated from the volumetric density and specific gravity, according to the Cuban norm (17). The natural humidity of the soil was determined by the gravimetric method, according to Cuban norm (18). The interchangeable bases and cation exchange capacity was determined by the ammonium acetate method at pH 7, described in branch rule (19). The pH of the soil was determined in water in a ratio of 1: 2.5: using the potentiometric method (14). The organic matter was determined by the colorimetric method, described in Cuban standard (20). Phosphorus and assimilable potassium were determined by the Oniani method, described in Cuban norm (21). For the taking of samples of the chemical analyzes the Dutch type auger of the firm Eijkelkamp was used.

RESULTS AND DISCUSSION

Morphological characteristics

In Tables I and II, the morphological descriptions of the profiles studied are presented.

The profiles show variation of colors and their tonalities with the increase in depth, due to differences in deposited sediments and their transformation, to the increase of humidity and to the manifestation of gleyic properties. There are also differences in the texture of the subsoil of both profiles, profile 1 to 55 cm and profile 2 to 30 cm, observing an abrupt textural change, which has been interpreted as a lithological discontinuity. These conditions favor the manifestation of gleyic properties and a greater presence of iron and manganese nodules with variable hardness, which are more abundant in profile 1 than in 2.

The texture of both profiles in the superficial horizons is frank and clayey in the deepest, there being a transition in the intermediate horizons. The structure is in small sub-angular blocks in the superficial horizons and in angular blocks in the deeper ones.

Given the characteristics described and in spite of the differences between the two profiles, the manifestation of gleyic properties, the presence of abundant ferruginous nodules at depths of less than one meter and an angular block structure, with greater or lesser development, are common and evident in the whole profile. These characteristics are due, in both profiles, to hydromorphic conditions of natural and artificial origin, with a temporary character, which cause alternating oxidation-reduction conditions. There is no evidence of formation of an Anthraquic or Hydragric horizon in both profiles, as well as the presence of a plowing floor.

Table I. Morphological description of profile 1, field 7

Horizonte	Profundidad (cm)	Descripción
Ap	0 – 14	Color (10YR5/4) pardo amarillento en seco y (10YR3/3) pardo oscuro en húmedo; textura franca, ligeramente plástico, con estructura en bloques sub angulares pequeños. Posee buen desarrollo de raíces, el límite es plano y no reacciona al HCl.
B_1	14 – 40	Color (10YR6/4) pardo amarillento claro en seco y (10YR4/4) pardo amarillento oscuro en húmedo; textura franco arcillosa, ligeramente plástico y presenta estructura en bloques sub angulares pequeños. Posee poco desarrollo de raíces, el límite es plano y no reacciona al HCl.
B_2g	40 – 55	Color (10YR6/6) amarillo parduzco en seco y (10YR4/6) pardo amarillento oscuro en húmedo, con 40 % de moteados de color (5GY6/1) gris verdoso en seco y (5GY4/1) gris verdoso oscuro en húmedo; textura franco arcillosa, plástico, estructura en bloques angulares. Posee muy poco desarrollo de raíces; la transición es notable, el límite es plano y no reacciona al HCl.
2Cg	55 – 140	Color (5GY6/1) gris verdoso en seco y (5GY4/1) gris verdoso oscuro en húmedo, con moteados de color (7,5YR6/8) amarillo rojizo y (7,5YR25/1) negros, debido a la presencia de nódulos de hierro y manganeso, textura arcillosa, plástico. Presenta estructura en bloques angulares. Sin raíces y no reacciona al HCl.

Fecha: 10/10/2014
Coordenadas: N 291,1 E 272,5
Relieve: llano
Material de origen: materiales transportados
Vegetación: ausente debido al cultivo intensivo de arroz
Horizontes de diagnóstico: normal: Nodular Ferruginoso
Características de diagnóstico: propiedades gléyicas y cambio textural abrupto

Table II. Morphological description of profile 2, field 8 A

Horizonte	Profundidad (cm)	Descripción
Ap	0 – 10	Color (10YR6/3) pardo pálido en seco y (10YR5/3) pardo en húmedo, textura franca, ligeramente plástico, con estructura en bloques sub angulares pequeños. Posee buen desarrollo de raíces, el límite es plano y no reacciona al HCl.
B_1g	10 – 30	Color (10YR6/3) pardo pálido en seco y (10YR5/3) pardo en húmedo, con 30 % de moteados de color (2,5Y6/6) amarillo olivo en seco y (2,5Y6/4) pardo amarillento claro en húmedo, textura franca, ligeramente plástico y presenta estructura en bloques sub angulares pequeños. Posee poco desarrollo de raíces, el límite es plano y no reacciona al HCl.
2B_2 g	30 – 60	Color (2,5Y6/6) amarillo olivo en seco y (2,5Y5/6) pardo olivo claro en húmedo, con 30 % de moteados de color (2,5Y5/4) pardo olivo claro en seco, textura arcillosa, plástico, estructura en bloques angulares. Posee muy poco desarrollo de raíces; la transición es notable, el límite es plano y no reacciona al HCl.
2B_3g	60 – 78	Color (2,5Y6/6) amarillo olivo en seco y (2,5Y5/6) pardo olivo claro en húmedo, con 50 % de moteados de color (2,5Y5/4) pardo olivo claro, textura arcillosa, con nódulos de Fe y Mn, plástico, estructura en bloques angulares pequeños y medianos. Posee muy poco desarrollo de raíces; la transición es notable, el límite es plano y no reacciona al HCl.
2Cg	78 – 130	Color (2,5Y6/6) amarillo olivo en seco y (2,5Y5/6) pardo olivo claro en húmedo, con más de 50 % de moteados de color (2,5Y5/4) pardo olivo claro en seco y (2,5Y5/2) en húmedo, textura arcillosa, plástico y estructura en bloques angulares pequeños y medianos sin raíces; no reacciona al HCl.

Fecha: 10/10/2014
Coordenadas: N 290,5 E 272,5
Relieve: llano
Material de origen: materiales transportados
Vegetación: ausente debido al cultivo intensivo de arroz
Horizontes de diagnóstico: normal: Nodular Ferruginoso
Características de diagnóstico: propiedades gléyicas y cambio textural abrupto

General characteristics and soil formation

The formation of the soils of the area under study has been closely linked to the relief, since they were formed, in the greater percentage of cases, as a consequence of the dragging and redeposition of soil particles dissolved in the water that flowed from the highest places. The water rich in iron and manganese minerals, mainly, when arriving again and again at the lowest areas and depositing and infiltrating to certain depths, was increasing its contents in the profile. Alternating conditions of over-wetting and aeration, oxidation-reduction, conditioned the development of gleyzation processes and the formation of iron and manganese pellets, sometimes reaching the formation of petroferric and magnesian horizons or armour (22,23). The reductive properties are characterized by their white to greenish, bluish gray and gray color under conditions of permanent reduction, and reddish in periods of non-saturation, while the oxidative properties are characterized by a mixture of gray-red-yellowish, yellowish reddish brown and the formation of dark iron and manganese nodules (6). Due to the heterogeneity of the deposited materials and the magnitude in which the soil formation processes were developed, the morphology, texture and physical-chemical and mineralogical composition can be different.

Physical-chemical characteristics and nutrient content

In both profiles, a predominance of frank texture was observed in the superficial horizons, which changes to clay with depth, in addition to depths close to 30 cm in both profiles, there are a significant decrease in total porosity (PT) and an increase in the apparent density (Da) (Table III).

This behavior shows a possible degradation in physical properties of the soil and affects the movement of water and air in the soil. Such expression is associated with the influence of human activity on the soil, intensive rice cultivation, tillage under unsuitable soil conditions, the use of inappropriate cultivation practices and the use of mechanization; those that can cause damage directly to the structure of the soil and its compaction (24-27). According to studies (10) the maximum values of volume density per textural class for undisturbed cuban soils is 1,4 g cm^{-3} for open textures and 1,2 g cm^{-3} for clay textures, due to these reports we consider the possibility that there are affectations in the physical properties of the studied soils, since the obtained values were of 1,6 g cm^{-3} for the horizons of frank texture and 1,83 g cm^{-3} in those of clay texture.

Due to the edaphic demands of the rice and the cultivation systems used, it is difficult to achieve soil plowing in conditions of adequate humidity and crop rotation in the rainy season, which would reduce the effects on physical properties. However, there are numerous studies that demonstrate how the application of other cultivation systems favors soil conservation and productive increase (28-30).

The pH value in the superficial horizon, for both profiles, is higher than 5,5, which correlates with a base saturation higher than 69 % (Table IV). This characteristic is accentuated in the following horizon, where an increase in the saturation by bases was observed, being able to be the elevation cause of the pH values. The existence of a compact layer in these horizons, as already described, characterized by an increase in Da and decrease in PT, could condition the accumulation of bases and increase in the pH value.

Table III. Behavior of some physical properties of the profiles studied

Perfil	H	Profundidad (cm)	Grava	Arena	Limo	Arcilla	Da (g cm^{-3})	PT (%)	Textura
				%					
1	AP	0-14	0,3	30	43,8	25,9	1,23	54,3	Franca
	B_1	14 - 40	0,4	23,7	44,3	31,5	1,64	37,9	Franco Arcillosa
	B_2g	40 - 55	6,2	45,0	14,7	34,1	1,45	45,9	Franco Arcillosa
	2Cg	55 - 140	0,5	25,6	27,6	54,3	1,77	34,0	Arcillosa
2	AP	0 - 10	7,3	33,2	40,6	18,9	1,22	54,3	Franca
	B_1g	10 - 30	7,4	36,7	33,6	22,3	1,60	38,7	Franca
	$2B_2g$	30 - 60	0,7	34,0	22,0	43,3	1,83	33,0	Arcillosa
	$2B_3g$	60 - 78	14,0	22,6	20,9	42,5	1,76	36,5	Arcillosa
	2Cg	78 - 130	0,0	18,2	23,3	58,4	1,77	31,7	Arcillosa

Perfil 1: campo 7; Perfil 2: campo 8A; H: horizonte; Prof.: profundidad; Da: densidad aparente; PT: porosidad total

Table IV. Chemical characteristics by horizons of the profiles studied

Perfil	H	Profundidad	pH		$CE_{1:5}$	P_2O_5	K_2O	M.O	Ca	Mg	Na	K	S	CIC	V
		cm	H_2O	KCl	dS cm^{-1}	Mg kg^{-1}		%			$cmol_c$ kg^{-1}				%
1	AP	0-14	5,5	4,7	0,16	6,89	16,39	2,5	13,4	0,8	0,2	0,4	14,8	20,9	70,9
	B_1	14-40	6,5	5,4	0,13	1,56	7,21	1,4	13,4	1,3	0,8	0,2	15,6	20,1	77,6
	B_2g	40-55	5,0	3,6	0,19	0,65	5,46	1,0	7,0	0,8	1,4	0,1	9,4	19,4	48,6
	2Cg	55-140	4,7	3,3	0,23	0,17	5,73	-	6,1	0,8	1,9	0,1	9,0	19,8	45,2
2	AP	0-10	6,0	4,7	0,08	2,99	4,25	2,7	7,1	0,5	0,2	0,1	7,9	11,4	69,0
	B_1g	10-30	7,3	5,9	0,09	0,52	3,09	1,8	9,2	0,6	0,4	0,1	10,3	11,4	90,1
	$2B_2g$	30-60	6,5	5,2	0,16	0,65	3,49	1,2	13,4	3,7	1,1	0,1	18,3	20,9	87,5
	$2B_3g$	60-78	6,1	4,8	0,20	1,30	3,22	-	16,8	1,4	1,8	0,1	20,1	22,4	89,7
	2Cg	78-130	6,0	4,9	0,32	1,69	3,36	-	12,1	3,2	2,6	0,1	17,9	22,4	79,8

Perfil 1: campo 7; Perfil 2: campo 8A; H: horizonte; Prof.: profundidad; CE: conductividad eléctrica; M.O: materia orgánica; S: bases intercambiables; CIC: capacidad de intercambio catiónico; V: Saturación por bases

In profile 1 it was also observed that at higher depths there is an accentuated decrease in the pH value, associated with the decrease in base saturation and possibly with the presence of exchangeable aluminum, similar behavior was observed in profile 2, although less accentuated

El en perfil 1 se observó, además, que a mayores profundidades ocurre una disminución acentuada del valor del pH, asociada con la disminución en la saturación por bases y posiblemente con la presencia de aluminio intercambiable, similar comportamiento se observó en el perfil 2, aunque menos acentuado.

In none of the horizons described was concentration of salts greater than the limits lower allowable (10), represented by the variable CE, although increases were observed with depth. This result shows that in the soil there are no conditions for its salinization, at least to depths less than 130 cm.

The contents of phosphorus and potassium in the superficial horizons of both profiles are very low, except potassium in the superficial horizon of profile 1 where it has a mean value. The differences in the contents of the elements may be associated with deficits in the application doses of these nutrients as fertilizers. It was also observed that these elements decreased with depth, there being a marked difference in the horizon

The contents of organic matter are suitable in both profiles according to the clay content (10), with a tendency to decrease with the increase in depth, which represents a normal behavior of the distribution of organic matter in soils. However, proper management of fertility and cropping systems in rice areas should favor carbon sequestration and increased soil fertility to a greater degree (31).

The Ca contents in the soil are adequate in the first two horizons of profile 1 and deficient in the last two. In profile 2 it was observed that the contents of Ca are adequate throughout the profile, except in the latter, where it is slightly deficient. The magnesium contents in profile 1 are deficient in all the horizons, while in profile 2 they are deficient in the first, second and fourth horizons, being adequate in the third and fifth. The Ca / Mg ratio is unbalanced in all horizons of profile 1, mainly due to magnesium deficiencies. In profile 2 the Ca / Mg ratio is unbalanced in the first, second and fourth horizon and adequate in the third and fifth. The interchangeable potassium contents in both profiles are deficient. The contents of Na are low in the superficial horizons of both profiles and although they increase with depth, the values do not represent severe affectations to the soil. The CIC is average in the first two horizons of profile 1, being low in the rest, while in profile 2, the rest of the profile is low in the first two horizons and a half, the CIC in the superficial horizon and the subsurface. Such behavior of profile 1 oscillates over 20 cmol kg^{-1}, while demonstrating the few reserves of both nutrients in the soil, conditioning its productivity to the application of mineral fertilizers and amendments.

In profile 2 it is lower than 12, this behavior is associated with a lower clay content, since the contents of organic matter are similar in both profiles. Given this behavior, the soil of profile 1 has greater capacity to retain and exchange nutrients in the superficial horizon than that of profile 2. The value of the CIC also reflects the predominance, in the clay fraction, of minerals of a 1: 1 ratio. 2: 1, behavior associated with a high degree of transformation in this fraction.

Soil classification

According to the results shown, the effects on soil physical properties in both profiles are evident, expressed in the increase of volumetric density values and decrease in total porosity, as well as deterioration of soil fertility in both profiles, expressed at low levels nutritional; however, they are not sufficient to diagnose the presence of an Anthraquic or Hydragric horizon, given the absence of a plowing floor and other diagnostic characteristics.

In Table V the soils of both profiles are classified according to the New Version of Genetic Classification of the Soils of Cuba (6), the World Reference Base (8) and the Soil Taxonomy (13).

Table V. Classification of the soils studied according to the New Version of the Genetic Classification of Soils of Cuba (NVCGSC), the World Reference Base and the Soil Taxonomy

PERFIL 1 CAMPO 7		
NVCGSC (1999)	Soil Taxonomy (2014)	World Reference Base (2014)
Agrupamiento: Hidromórfico	Orden: Inceptisols	Grupo de suelo: Gleysol
Tipo: Gley Nodular Ferruginoso	Suborden: Aquept	Unidad de Suelo: Gleysol Férrico
Subtipo: Típico	Grande Grupo: Endoaquept	
Género: Dístrico	Subgrupo: Typic Endoaquept	
PERFIL 2 CAMPO 8A		
Genética cubana (1999)	Soil Taxonomy (2001)	World Reference Base (2014)
Agrupamiento: Hidromórfico	Orden: Inceptisols	Grupo de suelo: Gleysol
Tipo: Gley Nodular Ferruginoso	Suborden: Aquept	Unidad de Suelo: Gleysol Férrico
Subtipo: Típico	Grande Grupo: Endoaquept	
Género: Eútrico	Subgrupo: Typic Endoaquept	

CONCLUSIONS

- ♦ The presence of iron and manganese nodules is common in both profiles studied and determines the formation of the "Ferruginous Nodular" diagnostic horizon.
- ♦ The effects of human activity on the soil are evident, characterized by an increase in apparent density and a decrease in the total porosity of the soil.
- ♦ Soil fertility is low, which determines the need for application of mineral fertilizers and amendments.
- ♦ The magnitude of the evidences observed in the soil profiles described, are not sufficient to classify them as soils with an anthropogenic effect.
- ♦ Both soils are classified, according to the Cuban classification, within the Hydromorphic grouping, Gley Nodular ferruginous type and Typical subtype; according to the Soil taxonomy, in the order Inceptisols and in the WRB, in the Gleysol group.

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