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Evolutionary State of Soil Properties Due to Land Use Change

Estado evolutivo de las propiedades del suelo por el cambio de uso de la tierra

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ABSTRACT: A study was carried out on the effect on chemical properties of soil with the cultivation of sugar cane (Saccharum officinals L.) as a monoculture for over 30 years and subsequently the establishment of various crops in soils of the Ferrálíco and Gleysol Groups, in the municipality of Nueva Paz, Mayabeque province, whose results were compared with standard profiles of these Groups, which have never been cultivated. Álvaro Reynoso cited by Humbert (1965) reported that in the last century, in the fertilization of sugar cane, ammonium nitrate was used as a mineral fertilizer, which has acidic characteristics, which led to the acidification of these soils and the washing of the bases. With the establishment of various crops (vegetables, grains, tubers) by farmers, where they have applied organic fertilizers, filter cake and rotation with livestock, the soils have suffered a resilience, both in pH, base content and in the organic carbon content of the soil, which resembles the properties of the standard profiles, where there has been no anthropic activity. In the soils of the Gleysol Groupings, poor drainage begins at 40 cm depth, however, the use of organic amendments has led to an improvement in the properties of soils from 0 - 40 cm and therefore a better crop yield.
Keywords: Resilience, Reference Profiles, Esmectita Clay, Gleyzation.

RESUMEN: Se realizó un estudio, del efecto en las propiedades químicas del suelo, con el cultivo de la caña de azúcar (*Saccharum oficinales* L), como monocultivo, durante más de 30 años y posteriormente el establecimiento de cultivos varios en suelos de los Agrupamientos Ferrálíco y Gleysol, del municipio de Nueva Paz, provincia Mayabeque, cuyos resultados se compararon con perfiles patrones de estos Agrupamientos, que nunca han sido cultivados. Álvaro Reynoso citado por Humbert (1965), reportó que en el siglo pasado, en la fertilización de la caña de azúcar, se utilizó como fertilizante mineral, nitrato de amonio, que posee características ácidas, lo que conllevó a la acidificación de estos suelos y al lavado de las bases. Con el establecimiento de los cultivos varios (hortalizas, granos, tubérculos) por los campesinos, donde han aplicado abonos orgánicos, cachaza y rotación con ganado, los suelos han sufrido una resiliencia, tanto en el pH, el contenido de bases y en el contenido de carbono orgánico del suelo lo que se asemeja a las propiedades de los perfiles patrones, donde no ha existido actividad antrópica. En los suelos del Agrupamientos Gleysol, el mal drenaje comienza a partir de los 40 cm de profundidad, sin embargo, la utilización de enmiendas orgánicas ha propiciado una mejoría en las propiedades de lo suelos de 0 - 40 cm y con ello un mejor rendimiento de los cultivos.
Palabras clave: resiliencia, perfiles de referencia, arcilla esmectita, gleyzación.

INTRODUCTION

The soils belonging to the Red Ferralitic and Red Ferral Groupings occupy approximately 700 000 ha in the plains of Cuba, distributed in the provinces of Artemisa, Mayabeque, Matanzas and Ciego de Ávila (Hernández *et al.*, 2020). This author proposes that they are of the best soils in Cuba, on which grains, meats and vegetables, besides fruits, are grown; being unfit for the cultivation of rice. They are distributed in the ecosystem of the karst plains with subhumid tropical climate, natural vegetation of semi-deciduous forests and emergent palms (Hernández, 2018).

In recent years' research has been carried out on the change in the properties of these soils due to continued cultivation (Amores, 2020). Thus it has been possible to determine that they retain a relatively high organic carbon content when they are for many years, under groves, pastures and the cultivation of sugarcane (Saccharum officinarum L.), which decreases when subjected to intensive management (Martín *et al.* 2022). Even the losses of organic carbon reserves by years have been determined when soils are exploited continuously. (Carnero *et al.*, 2019).

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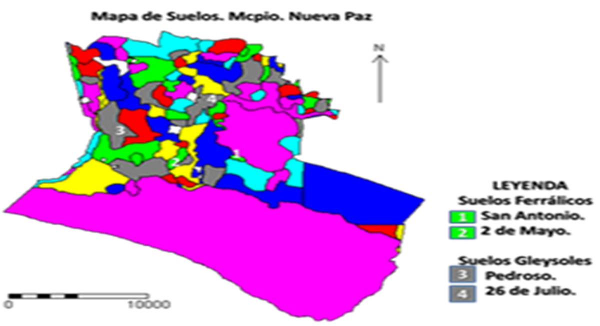
In addition, it has been possible to determine the change of other properties such as the value of volume density and scattering factor, in relation to the losses of organic matter, which occurs in these soils due to anthropogenesis (Martín *et al.*, 2018).

These soils constitute one of the main ecosystems for food production in the province of Mayabeque, divided into two regions and occupy a territory of 17 734 ha (Hernández, 2018).

Keeping the above in mind, a study was carried out, with the objective of knowing the evolutionary status of soil properties due to land use change. The soils were classified as Red Ferralitic, Red Ferralic and Gleysol Vertical, in the Nueva Paz region Paneque (1990) and Hernández *et al.* (2015), which are located in the southern part of this ecosystem, limiting to the south, with a cumulative plain possessing soils of the Vertisols, Gleysols and Fluvisols groupings. (Hernández *et al.*, 2023).

MATERIALS AND METHODS

Soil sampling was conducted on four farms, taking samples from the top of the profile (0-10, 10-20, 20-30 cm) homogenized to ensure a representative sampling as shown on the map where location and name are reflected of the farms, and the soil type according to the analysis performed.



Source: Nueva Paz Agriculture
Delegation Territorial CITMA Group.

FIGURE 1. Soil map of the municipality of Nueva Paz Province Mayabeque

For sampling, a zigzag round was done in the selected areas and the method utilized was a compound sample, that is, a soil sample obtained from various extractions or simple samples, united in a recipient coded for depth, if it is the case, and later well mixed where a kg of soil was taken out. This is the most used sampling to plan fertilization. Between 6 and 12 subsamples per sampling unit is recommended (Mendoza & Espinoza, 2017).

These farms were for more than 30 years cultivated with sugarcane (*Saccharum officinarum* L.), with manual cutting and leaving the straw in the field, during that period, mineral fertilizers with acidic characteristics were applied, as well as the application of sugarcane filter cake a las areas sown with sugarcane. Subsequently, after the resizing of the sugarcane crop, several crops, mainly grains and meats, were established. The analyzed samples were compared with reference profiles that have not been cultured.

The soil samples were analyzed in the INCA and ICA chemical analysis laboratory performing the following determinations.

Organic Matter by the method of Walkley and Black, pH by potentiometry at the soil / water ratio 1:2. Calcium and magnesium exchangeable by the ammonium acetate extraction method and valorization with EDTA. The Ca/Mg ratio was calculated and assimilable Phosphorus and Potassium were determined by Oniani's method.

A producer survey was conducted, in which the history of the fields shown below was synthesized:

History of the fields sampled:

Municipality: Nueva Paz.

Estate Farm: "San Antonio"

CCS "Santa Elena.

Total field area: 40.26 ha.

Coordinates: N: 324,790 and E: 423,8

Mean annual temperature: 24.60C.

Annual mean precipitation: 442.41mm.

Soil type: Red Ferralic hydrated, moderately humid, slightly eroded, clayey, of plain relief on hard limestone, shallow, moderately desaturated.

Sown with sugar cane. (*Saccharum officinarum* L.) from 1940 to 1989 In the year 1990, it is devoted to Miscellaneous Crops (meat, vegetables and grains).

Crop rotation being established in the sampled area: Boniato (Ipomoea batatas) - maize (*Zea mays* L.) - cassava (*Manihot esculenta* Crantz) - bean (*Phaseolus vulgaris*) - tomato (*Solanum lycopersicum* L.) - Malanga (*Colocasia esculenta* L.)

Management: Intensive Cultivation.

Applications of chemical products for the control of pests and arvense plants.

Mineral fertilizers applied: N-P-K (9-13-17). Urea: $CO(NH_2)_2$, Ammonium Nitrate (NH_4NO_3) in crop dependence.

Hunting was applied, as organic fertilizer.

Agricultural yields generally are high.

Soil preparation system: The conventional model is applied.

Plowing depth: 25 cm.

Duration of preparation: It is in dependence of the crop and the season of sowing.

Cultivation labours: They are carried out by animal traction.

Sprinkler irrigation.

Estate "2 de mayo"

CCS "Santa Elena".

Total area of the farm: 21 ha.

Coordinates: N: 323,310 and E: 423,6

Mean annual temperature: 24.60C.

Annual mean precipitation: 442.41mm.

Soil type: Red ferralic hydrated, saturated, moderately humid, slightly eroded, clayey, little loss of horizon A, plain relief, moderately deep.

The total area of the farm was sown with sugar cane, from 1954 to 1989, subsequently several crops were sown.

Crop rotation being established in the sampled area:

Malanga (*Xanthosoma sagittifolium* (L.)), banana (*Musa x paradisíaca* L.), cassava (Manihot esculenta Crantz) -Boniato (*Ipomoea batatas*) and bean (*Phaseolus vulgaris* L.).

Soil preparation: Conventional System.

Agricultural implements: Disc ploughs: AD-3.

Stairs of discs.

Multiploughing.

Labors: Crossing, Recrossing, Grade Pass, Furrowing and Sowing.

Mineral Fertilization: Complete Formula: N-P-K (9-13-17), Urea: $CO(NH_2)_2$, Ammonium Nitrate: (NH_4NO_3).

Organic fertilizers: sugarcane filter cake was applied.

Surface irrigation: Furrow irrigation.

For pest control: Chemical products are fundamentally used.

Farm: Pedroso

CCS "Niceto Pérez"

Total Farm Area: 26 ha.

Coordinates: N: 324.967 and E: 419.947.

Mean annual temperature: 24.60C.

Annual mean precipitation: 442.41 mm.

Area sampled: 4 ha.

Soil type: Gleysol Vertical chromic nodular ferruginous over limestone.

Sugarcane cultivation during from 1950 to 1990, after 1991, this area was rotated with minor crops, such as tomato (*Solanum lycopersicum* L.), maize (*Zea mays* L.), bean (*Phaseolus vulgaris*), cassava (*Manihot esculenta* Crantz), this crop rotation is done every 5 years.

System Type: Conventional System.

Mineral fertilization: Complete formula: N-P-K (9-13-17) and Urea: CO $(NH_2)_2$.

Never applied organic fertilizer.

Herbicides were used for arvense plant control.

Surface irrigation. Technique applied furrow irrigation.

CPA "26 de Julio"

Total cultivated: area: 44 ha.

Coordinates: N: 329,390 and E: 324,6

Mean annual temperature: 24.580C.

Annual mean precipitation: 6529.91mm.

Area sampled: 3 ha.

Its social object, is livestock.

Soil type: Gleysol Vertical chromic nodular ferruginous over hard limestone, moderately humified, almost plain, with little loss of horizon A. This area was seeded with sugarcane (*Saccharum officinarum* L.), 1965 - 2003, in the year 2004, it was broken and King grass was sown keeping this crop for 5 years, starting in 2008, several crops were sown and a crop rotation was established as follows: Cassava (*Manihot esculenta* Crantz), pumpkin (*Curcurbita pepo* Duchesne), bean (Phaseolus vulgaris), boniato (Ipomoea batatas) and maize (*Zea mays* L.). In 2020, 1.5 ha of sugarcane (*Saccharum officinarum* L.) and 1.5 ha of King grass (*Pennisetum purpureum*) were sown, with the aim of producing fodder for livestock.

Soil preparation was done in conventional way but cultivation works are done with animal traction.

Mineral fertilization: Complete formula (9-13-17).

Organic matter was applied to this field.

RESULTS AND DISCUSSION

The results of the studies carried out in the farms "San Antonio", "2 de Mayo" and in the reference profile, are shown in Table 1. By the data shown, the Ferralic soils of the two farms have slightly acidic pH values, while the reference profile, is valued as neutral (MINAGRI,1984). It can be due to that, when sugarcane was sown as a monocrop, before 1959, mineral fertilizers were used, with acidic characteristics, which was reported by Humbert (1965), Subsequently, crop rotation was applied; it involved vegetables, grains and tubers, and organic fertilizers were applied, as evidenced by the history of field. The soils underwent a resilience in their characteristics. This soil grouping possesses a cation exchange capacity higher than 20 cmolc kg-1 in the clay fraction, due to the fact that smectite clay predominates from about 10 to about 42% (Hernández *et al.*, 2015).

Similar results were obtained by Saidy (2012, 2013), where they report that the content of active iron (oxide and oxyhdroxides of iron) , control the estabilization of organic carbon in kaolin soils. As well as Elberling *et al.* (2013) manifiest that iron nodules have trapped and inmobilized at about 21% of organic carbon reserves of the soil in the 1m-deep layer.

TABLE 1. Chemical characteristics of the Ferralic Soil Group existing in the Nueva Paz Municipality.

Farm and Grouping of Soil	Depth of field (cm)	OM %	pH		Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	CCB	Ca/Mg	Carbon Reserves
			H_2O	KCl	$cmol_c\ kg^{-1}$						$Mg.m^{-3}$
San Antonio Grouping Ferralic	0 - 10	3.5	6,3	5,1	18,5	9,0	0.04	0.04	28,02	2,1	20,30
	10 -20	3.0	6,1	5,7	17,5	3,5	0.06	0.06	21,40	5,0	17,4'0
	20 - 30	2,6	6,4	5,5	14,0	4,5	0.06	0.06	18,95	3,1	18,25
2 de Mayo Ferralic Grouping	0 - 10	3,4	6.4	5,5	19.5	6.0	0.04	0.01	25.5	3.3	19,72
	10 -20	3.4	6.4	5,3	15.5	5.0	0.06	0.02	20.58	3.1	19,72
	20 - 30	3,3	6.7	5,7	15.5	13.0	0.06	0.01	28.57	1.2	19,14
Reference Profile (100 years without cultivation) Ferralic Grouping. Taken from Frómeta (1980) cited by (Martín *et al.* 2022)	0-10	5,35	6,9	6,0	21,94	8,3	0,05	0,55	30,85	2,64	16.37
	10-20	2,90	6,8	6,0	18,84	8,5	0,07	0,28	27,39	2,22	13.65
	20-40	1,82	6,7	6,0	16,68	7,5	0,11	0,21	24,53	2,21	12,64
	40-70	0,40	6,8	6,1	12,64	7,4	0,12	0,15	20,31	1,79	11,09
	70-100	0,21	6,9	6,3	13,82	9,8	0,11	0,08	23,81	1,41	10,31

Source: Own elaboration from the results obtained in the laboratories.

The content of Ca^{2+} (15,5-18,5) and Mg^{2+}(3,5-9,0) is valued as high, according to Paneque (1990) and the relation Ca/Mg (2-6) is considered adequate (Mesa, 1992). The content of these two elements, existing in soils, can be due to the material from which they were formed, to the origin of the material they were formed and to the filling of the mineral fertilizers that have been applied to crops through the time. Values are consulted in the interpretation table to confirm what previously cited authors referred (Molina & Meléndez, 2002).

If this ratio is not ideal, formation of chlorophyll molecule may affected and crop yields may decrease (Mesías, 2018).

The organic carbon reserve at each depth is valued as very ow (Mesias, 2018), which can be due to the mineralization of organic matter because of agricultural labors and soil aeration.

In this table, data of a reference profile of a soil that has not been cultivated in more than 100 years are offered. It is preserved that the content of calcium on the soil surface es lightly higher (21,94 $cmol_c\ kg^{-1}$). It is due to that, during many years, plants have extracted the calcium contributed by dolomite rock which originated this kind of soil. That coincides with the criteria of the WordReference Base WRB (2007). The magnesium is high, making the relationship Ca/Mg is adequate, according to (Mesa, 1992).

When assessing the organic carbon reserves at the depth of 0 to 20 cm, they were cataloged as low Mesías (2018). This could be due to the plowing done for the establishment of the crops, which propels the oxidation of the organic matter. In addition, the formation process that gives rise to these soils, the ferralitization, generates a good structure and, therefore, there is good aeration, which oxidizes organic matter.

The chemical characteristics presented by the Gleysol Vertic soils in "Pedroso" and "26 de Julio" Farms are exposed in Table 2 and they are compared with the results of a reference profile that were not cultivated for more than 50 years. In this profile, it was detected that gleyzation process that gave rise to this type of soil, was from the 40 cm depth, which limited the internal soil drainage, and a change in organic matter content, a decrease of calcium, potassium and the ability to exchange bases occurred. The organic carbon reserves on the two farms were valued as low (0-30 cm) and in the reference profile as middle (0-20 cm depth) (Mesa, 1992).

To know the quality of soils, it is very important to identify its content in organic matter (Table 3), which, in general for the 0-20 cm layer is between 3 and 4%, what is classified as medium. Even at "Pedroso" Farm, at the depth of 0-10 cm, it was higher than 4.1%, but for the average 0-20 cm, it was 3.78%, so it could not be classified as humified, according to Hernández *et al.* (2015).

It is notable that, in spite of these soils were under continuous cultivation with irrigation and fertilizers, they had that relatively high content of organic matter, which could be due to the fact that they were under the cultivation of sugarcane (*Saccharum officinarum* L.), during many years, with manual cutting and organic fertilizer fundamentally, sugarcane fiber cake. It should be emphasized that Ferralitic Red and Ferralic Red soils have a great capacity for resilience, especially to soil organic carbon capture. This is due to the relatively high iron content that controls carbon stabilization in kaolinitic soils Vershinin (1959). This particularity is outstanding for Red Ferralitic and Red Ferralic soils of the karst plains of Cuba Hernández *et al.* (2014) and Morales (2015).

It should be noted also that in these soils, despite of having been subjected for a long time to continued cultivation, it is very difficult to find low values in the content of organic matter (Table 3), since that, when little carbon content remains in them, clay with iron manage to chelate it and protect it from oxidation Saidy (2013), cited by Hernández *et al.* (2020).

TABLE 2. Chemical characteristics of Gleysol Soil Grouping Vertic Chromic, Nodular and Ferruginous in Nueva Paz Municipality

Farm and Soil Grouping	Depth of field (cm)	M O.	pH		Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	CCB	Ca/Mg	Carbon Reserves
		%	H_2O	KCl			$cmol_c\ kg^{-1}$				Mg m^3
"Pedroso" Gleysol Grouping	0 - 10	3.5	6,7	5.9	26,0	14,0	0,12	0,24	40,4	1,9	23,78
	10 - 20	3.0	6,4	5.3	31,5	28,0	0,06	0,27	59,8	1,1	19,72
	20 - 30	2,6	6,4	5.2	14,5	13,0	0,09	0,19	27,8	1,1	17,98
"26 de Julio" Gleysol Grouping	0 - 10	3,4	7,0	6,2	25,0	11,9	0,21	0,23	36,44	2,19	19,08
	10 - 20	3.4	7,3	6,5	27,5	9,0	0,07	0,29	36,86	3,05	18,90
	20 - 30	3,3	7,3	6,4	25,0	11,5	0,06	0,04	36,6	2,17	16,76
Reference Profile Gleysol Grouping. Taken from Ascanio (1980) cited by Mesías (2018).	0 - 20	3,8	7,7	6,8	36,8	6,8	0,2	0,29	44,09	5,41	44,020
	20 - 40	2,0	7,8	6,7	39,8	4,9	0,1	0,20	45,08	8,12	23,20
	40 - 50	0,8	8,0	6,9	25,0	4,2	0,2	0,06	29,46	5,95	9,29
	50- 70	0,4	8,1	7,0	21,8	3,9	-		25,7	-	_
	70 - 85	0,3	8,1	7,0	-	-	-		-		-_

Source: Own elaboration from the results obtained in the laboratories.

TABLE 3. Average values of organic matter for the depth of 0-20 cm

Farm	Depth of field (cm)	OM (%)	Average Organic Matter de 0-20 (cm), in (%)
San Antonio	0 - 10	3,46	3,23
	10 - 20	2,99	
2 de Mayo	0 - 10	3,47	3,41
	10 - 20	3,37	
Pedroso	0 - 10	4,14	3,78
	10 - 20	3,41	
26 de Julio	0 - 10	3,29	3,28
	10 - 20	3,26	
Reference Profile Ferralic Grouping	0 - 10	5,35	4,13
	10 -20	2,90	
Reference Profile Gleysol Grouping	0 - 10	3,8	3,35
	10 - 20	2,9	

Source: Own elaboration from the results obtained in the laboratories.

In this soils, there is the possibility of carbon sequestration. COS plays an important role in climate change mitigation, due to the soil capacity for carbon sequestration during centuries. That is a reference on how antropic action, by using lands, can intervene into COS, either to increase or to reduce its quantity in agrarian ecosystems, according to the soil management by mens of the different agricultural practices.

In addition, carbón content of soils is important since it notably influences in soil properties (Post y Kwon, 2000**).** Podmanicky *et al.* (2011) express that "knowledge of the stocks of organic carbon state in the soils, is fundamental to approach any strategy to increase its content and mitigate climate change through atmospheric carbon sequestration. To be conscious of the factors that influrnce its concentration, as well as knowing the evolution of the quantity storaged though the years, is relevant to undestand the dynamcs of COS".

In Table 4, the existing fertility on the different farms sampled in Nueva Paz Municipality, are presented. It is appreciated that there is a medium nitrogen content for most of the several crops, due to the tenors of organic matter present in the soils, which contribute this element. In addition, elevated phosphorus and potassium content was detected, this may be due to fertilizer applications that farmers performed through time. Smectite clay is present in these Ferralic soils, which have retained these nutrients, in addition to influencing a capacity of cation exchange above 20 cmolc kg-1.

CONCLUSIONS

- The Ferralic Red soils of Nueva Paz Municipality, Mayabeque Province, cultivated for many years with sugarcane (*Saccharum officinarum* L) and subsequently used for various crops, maintain the medium tenors of organic matter, (3.23-3.78) which provides the soil with good physical properties and chemicals.
- The Ferralic soils of Nueva Paz possess a high fertility potential due to the organic carbon reserves of the soil.
- The Gleysol soils of Nueva Paz present the process of gleyzation at 40 cm depth, making that the poor drainage conditions, diminish the contents of organic matter, calcium, potassium and the organic carbon reserves of the soil.

Table 4. Fertility of the soils sampled in the different farms of Nueva Paz Municipality

Farm	Depth of field (cm)	N	P_2O_5	K_2O
			kg ha^{-1}	
San Antonio	0 - 10	103,8	658,77	273,7
	10 -20	89,7	481,19	172,04
	20 - 30	78,0	563,68	211,14
2 de Mayo	0 - 10	103,2	481,19	329,69
	10 -20	101,1	902,75	207,23
	20 - 30	97,8	600,34	254,33
Pedroso	0 - 10	124,2	132,35	187,68
	10 -20	102,3	80,15	211,14
	20 -30	92,7	81,02	148,58
26 de Julio	0 - 10	98,7	419,82	223,56
	10 -20	97,8	303,25	252,72
	20 -30	86,7	903,84	238,88
Reference Profile Ferralic Grouping	0 - 10	160,5	150,0	430,0
	10 -20	87,0	150,0	203,84
	20 -30	54,6	112,0	152,88
Reference Profile Gleysol Grouping	0 - 10	114,0	4,54	156,4
	10 -20	60,0	3,44	148,2
	20 -30	24,0	1,22	123,4

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