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Original article

Changes in physical properties of a fluvic cambic Feozem for agriculture use

Cambios en las propiedades físicas de un suelo Feozem flúvico cámbico por el uso agrícola

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ABSTRACT: In this paper are studied two soil profiles from the soil map in scale 1:25 000 of the fluvial plain region Carrizal-Chone, in Manabi province, Ecuador. One of profiles is a soil fluvic Feozem by tree vegetation and the other is a fluvic eutric Cambisol by long time cultivated condition. It is studied the changes of the physical soil properties by the anthropogenic conditions, with changes in the soil structure, volume density, and the increasing of the dispersion factor. In this paper is demonstrated the change from a Feozem soil to a Cambisol soil because the long time cultivated action

Key words: World Reference Base, soil degradation, organic carbon.

RESUMEN: En este trabajo se estudian dos perfiles de suelo seleccionados del mapa de suelos 1:25 000 del ecosistema de llanura fluvial de la región Carrizal-Chone, provincia de Manabí, Ecuador. Uno de los perfiles es un suelo Feozem flúvico y cámbico, conservado bajo condiciones de arboleda y el otro es un Cambisol flúvico, bajo cultivo de muchos años. Se estudia el cambio de las propiedades físicas del suelo conservado, con relación al del cultivo continuado, con impactos en la estructura del suelo, la densidad de volumen y el aumento del factor de dispersión. En el trabajo se demuestra el cambio de un suelo Feozem a Cambisol en esta región, por el cultivo continuado.

Palabras clave: World Reference Base, degradación del suelo, compactación.

INTRODUCTION

Soil degradation has increased considerably due to intensive cultivation with the application of techniques such as chemicalization, mechanization and irrigation. In 1990 it was shown that soil degradation in the world increased from 6 % in the period 1900-1945 to 17 % in 1945-1990, as a result of industrialization and the Scientific and Technical Revolution in Agriculture (1).

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One of the most important problems in soil degradation is the continuous cultivation with application of irrigation, fertilizers and mechanization, which leads to losses of soil organic carbon (COS), change of its physical properties such as destruction of micro-aggregates and the original soil structure, increase of the spreading factor and soil compaction (2-4). In tropical regions, soil degradation occurs more intensively, due to climatic conditions of precipitation and temperature (5).

In Manabi province, Ecuador, no remarkable results have been reported so far, especially in different provinces. For example, results have recently been presented on the change of soil properties according to its use, in the Membrillo parish, Manabí province (6).

Other results obtained in recent years include the study of the characteristics, properties and distribution of soils in the Carrizal Chone system, in Manabí province, which covers an area of 7233.7 ha (7). This plain, located in the northern part of the province, has naturally formed Feozem soils (covering an area of 2107 ha) and Fluvisols (with an area of 3787 ha), in natural or preserved conditions, most of which have been cultivated for years, resulting in soils that have deteriorated due to anthropogenesis, with changes in their properties, especially in the organic matter content of the soil (8).

The aim of this work is to obtain results on the change in the physical properties of Feozem fluvic and cambic soils due to continued cultivation.

MATERIALS AND METHODS

Taking into account the dokuchavian comparative genetic principle of comparing soils as natural or conserved as possible, with cultivated soils, by ecosystems, in order to diagnose the changes in their properties due to anthropogenic influence (9); the characteristics of two soil profiles are studied. One of them, Feozem fluvic and cambic (profile 1), which represents the natural formation of the soil, under an association of guaba machete (*Inga feuilleei*) and coffee (*Coffea arabiga*) trees; the other (profile 2), was the same soil, but under intensive cultivation for 18 years. The descriptions of both profiles are made by the Manual for soil mapping and description of soil profiles (10).

The analyses were performed at the Soil Analysis Laboratory of the Agricultural Faculty of ESPAM. These are: mechanical composition by the pipette method, applying sodium pyrophosphate to eliminate organic matter and break up soil microaggregates and sodium hydroxide as a dispersant, texture by the Soil Taxonomy textural triangle (11). The composition of microaggregates by the pipette method, but without destroying the microaggregates. Taking into account the mechanical particle composition with and without organic matter removal, the soil dispersion coefficient is calculated. The bulk density is carried out in the field by the cylinder method, using cylinders of 10 cc volume and moisture, taking samples with filter weighing and heating in an oven at 105 ºC, until constant weight.

The soil classification used in this work is the World Reference Base (12). In the descriptions of profiles, the following sub-indicators are used for the horizons (10): m: mellow; p: disturbed; camb: cambic; s: sandy, meaning that the Cs horizon is sandy.

RESULTS AND DISCUSSION

The study starts with the descriptions of two selected profiles, one close to the other under different coverages. The description of the soil profile is one of the most important steps that the soil scientist has to face. On the one hand, it is the first contact he has with the soils that may exist in the study region and, on the other hand, the soil profile manifests itself through its morphology, which presents a series of properties that are the result of soil formation (genesis) and anthropogenic influence, if any (13-15).

Description of the soil profiles studied

Profile No.: 1
Date: August 2, 2018
Described by: Alberto Hernández, Dilmo J. García, Geoconda López, Leonardo Vera and Freddy Mesías
Soil Classification:

Soil Taxonomy (Soil Survey Staff, 2010): Fluventic Haplustoll

WRB (IUSS Working Group World Reference Base, 2014): Fluvic and Cambic Feozem.

Location: Taken on the ESPAM Campus, on conserved soil under a grove of Guaba machete (*Inga feuilleei*) with coffee (*Coffea arabiga*).

Height (m a.s.l): 25

Parish Calceta

Canton: Bolívar

Province: Manabí

Country: Ecuador

Formation factors

Physiographic position of the site: Plain

Topography of the surrounding terrain: Plain with alluvial terrace formation

Microrelief: Not observed

Slope where the profile was taken: 2 %.

Vegetation or land use: Guaba machete grove (*Inga feuilleei*) with coffee *Coffea arabiga*)

Climate: Tropical sub-humid

Annual rainfall: 1200 mm; Average annual temperature: 25 ºC

Source material: Alluvial sediments

Time: Recent Quaternary

Drainage: Well drained

Profile description:

Horizon	Depth (cm)	Description
Am	0-22	Colour 10YR2/1, black, clayey loam, subangular block structure crumbling into granular and nuciform, friable consistency, fresh, highly porous, good amount of roots, no reaction to HCl, somewhat noticeable transition.
B camb.	22-41	Colour 10YR3/2, very dark greyish-brown, sandy clay loam texture, small subangular block structure, friable, slightly moist, slightly less porous, with good amount of roots, no reaction to HCl, remarkable transition
Cs	> 41	Colour 10YR4/3, brown, texture sandy to sandy loam, very unstable angular block structure, friable to loose, slightly moist, very porous, with few roots, no reaction to HCl.

The soil is covered with a layer of leaf litter. On the surface there is a thin layer of 2-3 mm of decomposing organic matter. Both the structure and the dark color of the surface make the A horizon a folic horizon and the B horizon a cambic horizon; it also has fluvial properties, due to the textural change in the profile. On the basis of these diagnoses, the soil is classified as Feozem fluvic and Cambic, according to 12.

Profile No.: 2
Date: August 2, 2018
Described by: Alberto Hernández, Dilmo J. García, Geoconda López, Leonardo Vera and Freddy Mesías
Soil Classification:

Soil Taxonomy (Soil Survey Staff, 2010): Aquic Haplustept
WRB (IUSS Working Group World Reference Base, 2014): Fluvic Cambisol
Location: In the Conventional Area of the ESPAM Campus.
Height (m a.s.l): 25
Calceta Parish
Canton: Bolívar
Province: Manabí
Country: Ecuador
Formation factors
Physiographic position of the site: Plain
Topography of the surrounding terrain: Plain with alluvial terrace formation.
Microrelief: Somewhat irregular due to ploughing, with medium and large clods on the surface
Slope where profile was taken: Less than 1 %.
Vegetation or land use: Continuous cultivation, land prepared for sowing
Climate: Tropical sub-humid
Annual rainfall: 1200 mm; Mean annual temperature: 25 ºC
Source material: Alluvial sediments
Time: Recent Quaternary
Drainage: Moderately drained

Profile description:

Horizon	Depth (cm)	Descriptionn
$IA_{11}p$	0-14	Colour 10YR7/1, light grey on the outside of the block and 10YR2/2, very dark brown, on the inside, clay loam texture, structure 5-10 cm prismatic blocks, stable, consistency compacted, fresh, moderately porous, with some coarse pores, few fine roots, no reaction to HCl, noticeable transition.
IA_{12}	14-22	Color 10YR7/1, light gray on the outside of the block and 10YR2/2, very dark brown, on the inside, clay loam texture, structure prismatic blocks of 5-10 cm, stable, compact consistency, fresh, moderately porous, with some coarse pores, few fine roots, no reaction to HCl, noticeable transition.
IBcamb	22-43	Colour 10YR3/2, very dark greyish brown, loamy texture, small polyhedral structure 3-5 cm long, crumbling into nuciform, friable consistency, moderately moist, highly porous, with coarse and medium pores, with sparse medium roots, no reaction to HCl, noticeable transition.
$IICs_1$	43-67	Colour 10YR4/3, brownish, texture sandy loam, structure 5-7 cm angular blocks very unstable, loose consistency, moist, porous, with very few roots, no reaction to HCl, little noticeable transition.
$IICs_2$	67-91	Colour same as previous horizon, 10YR4/3, brownish sandy loamy texture, structure larger angular blocks very unstable, loose consistency, slightly more humid, porous, with some roots, no reaction to HCl, noticeable transition.
IIIC	91-120	Colour 10YR4/1, dark grey, clay loam to clay loam, 5 cm subangular block structure, not very stable, friable consistency, very wet, porous, not rooted, no reaction to HCl.

This soil has the following diagnoses: The A horizon lost its good folic properties and cannot be classified as Feozem; it also has a Cambic B horizon and textural change from 43 cm onwards which confers the diagnosis of fluvic properties. Therefore, the Referential Soil Group (RSG) is Cambisol

Changes in some physical properties of the soil

Soil structure and consistency in the A-horizon

Soil structure is one of the most important characteristics in soil diagnosis. A good structure is a symptom of a good organic matter content and biological activity of the soil (16). In profile 1, under tree vegetation and coffee plantation, with an annual contribution of leaf litter to the soil, the structure of the A horizon is of the granular and nuciform type; however, in profile 2, in this same horizon it is of prismatic blocks. This indicates that profile 2, under intensive cultivation for 18 years, has lost its original structure (4). The change in the natural soil structure due to continued cultivation could be classified as anthropogenic, as some authors have suggested (4,17).

The consistency of this horizon, as determined in the field, is consistent with this characteristic (10). While in profile 1, preserved, the consistency is friable, in profile 2, anthropogenic, it is compacted, i.e. the consistency of the soil worsens in profile 2, under continuous cultivation.

Mechanical and micro-aggregate composition and dispersion factor

Table 1 shows the data on the mechanical composition of both profiles, in which it can be seen that there is a relatively high content of silty fractions, but in profile 1 from 41 cm depth there is a very marked textural change, with a predominance of sandy fractions. This textural change in profile 2 occurs at 43 cm depth. In both cases this textural change demonstrates the fluvial character in both profiles, according to the soil classification (12).

These results show that the soil texture does not change in a relatively short period of time due to continued cultivation (18), unless the soil is subject to erosive processes.

Table 2 shows the results of the mechanical composition in the micro-aggregate analysis, thus obtaining the amount of dispersed clay that is not found in the micro-aggregates. With the relationship between the clay content in the mechanical and micro-aggregate analysis, the soil dispersion factor is obtained, since when there is a higher dispersed clay content in the micro-aggregate analysis, this factor is higher and shows that there is not a good soil structure, as occurs in Ferrallitic soils in Cuba (2).

Table 3 shows the dispersion factor values for both profiles. Firstly, a much higher value is found in profile 2, for the depth of 0-18 cm, which corresponds to the field diagnosis that this part of the soil is degraded by continuous cultivation. In this profile 2, at the depth of 14-22 cm, the dispersion factor decreases, corresponding to the residual part of the former humic horizon that has not yet been degraded.

Table 1. Mechanical particle composition (in %) and soil texture

Soil profile	Horizon	Depth (cm)	Clay	Loam	Sand	Texture
1	IAm	0-22	24.8	29.6	45.6	Loam
	IB camb.	22-41	26.4	50.4	23.2	Silty loam
	IICs	> 41	5.6	8.8	85.6	Loamy sand
2	$IA_{11}p$	0-14	33.6	56.0	10.4	Silty clay loam
	IA_{12}	14-22	32.0	49.6	18.4	Silty clay loam
	IBcamb	22-43	34.4	47.2	18.4	Silty clay loam
	IIC_1s	43-67	8.0	24.0	68.0	Sandy loam
	IIC_2s	67-91	8.0	30.4	60.8	Sandy loam
	IIICg	91-120	17.6	57.6	24.8	Silty loam

Table 2. Composition of soil micro-aggregates

No. profile	Horizon	Depth (cm)	Clay %	Loam %	Sand %
1	IAm	0-22	12.0	40.0	48.0
	IB camb.	22-41	11.2	58.4	30.4
	IICs	> 41	2.4	9.6	88.0
2	$IA_{11}p$	0-14	23.2	48.0	28.8
	IA_{12}	14-22	19.2	53.1	27.7
	IBcamb	22-43	27.2	55.2	17.6
	IIC_1s	43-67	6.4	17.6	76.0
	IIC_2s	67-91	8.8	21.6	69.6
	IIICg	91-120	9.6	68.0	22.4

Table 3. Calculation of the dispersion factor of the two profiles

No. Profile	Horizon	Depth (cm)	% Clay in microaggregates	% Clay in mechanical composition	Dispersion factor (k)
1	IAm	0-22	12.0	24.8	48.3
	IB camb.	22-41	11.2	26.4	42.4
	IICs	> 41	4.4	5.6	78.5
2	$IA_{11}p$	0-14	23.2	33.6	69.0
	IA_{12}	14-22	15.8	32.0	49.4
	IBcambic	22-43	19.2	34.4	55.8
	IIC_1s	43-67	6.4	8.0	80.0
	IIC_2s	67-91	6.8	8.0	85.0
	IIICg	91-120	9.6	17.6	54.5

In the sandy horizons in both profiles the clay content is very low, almost all of it is dispersed, with high dispersion values in both profiles. The problem is that the sandy fraction does not capture carbon (19); therefore, there is no good structure formation in these horizons, so the low clay content in them is almost all dispersed.

Moisture content and bulk density

Table 4 shows the field moisture data for these two profiles and the bulk density values.

In profile 1, it is remarkable the moisture content, very low, of the 0-14 cm thickness of the heavily cultivated soil profile, corresponding to a higher volume density of 1.44 Mg m-3, due to the prismatic blocks formed on the surface by anthropogenesis, with a compacted consistency.

The formation of these blocks is related to the increase of dispersed clay, due to the destruction of micro-aggregates by the loss of organic carbon in the soil, with the continued cultivation; which in Cuba is called "agrogenic evolution of the soil" and is applied in the Cuban Soil Classification (20). In summary, the continuous cultivation of the soil with the application of fertilizers and irrigation leads to the deterioration of its physical properties, as has been demonstrated in soils of other tropical ecosystems, such as in Cuba (21,22), the Brazilian Amazon (23) and Campeche, Mexico (24).

CONCLUSIONS

In the Feozem fluvic and Cambic soil of the ecosystem of the Carrizal-Chone plain, Manabí province, Ecuador, the physical properties of the soil are deteriorated by continued cultivation, mainly in the upper humic cumulative horizon, in which the humic horizon condition is lost. Due to anthropogenic influence, the original Feozem luvic and cambic soil becomes Cambisol fluvic.

RECOMMENDATIONS

It is necessary to produce food in this ecosystem, so it is necessary to conduct research for the application of bio-inputs that maintain or improve the properties of these soils, when they are under cultivation.

It is recommended to use compost or worm humus for amendments with bio-inputs for degraded soil or soil under production.

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Table 4. Moisture and volume density data for these two profiles

No. Profile	Horizon	Depth (cm)	W (%)	Dv (Mg m^{-3})
1	$IA_{11}p$	0-14	13.0	1.44
	IA_{12}	14-22	34.1	1.10
	IBcamb	22-43	38.0	1.11
	IIC_1s	43-67	32.0	1.06
	IIC_2s	67-91	30.0	1.08
	IIICg	91-120	46.0	0.95
2	IAm	0-22	21.0	1.22
	IB camb.	22-41	25.0	1.18
	IICs	> 41	22.0	1.15

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