Effects of land-use change on Nitisols properties in a tropical climate

Efectos del cambio de uso de la tierra en las propiedades de los Nitisoles en un clima tropical

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ABSTRACT

Keywords:
Degradation
Physical properties
Soil management
Tillage

Land use change, especially conversion of native forests to cultivated land, exerts an impact on the physical, chemical and hydrophysical soils properties. To quantify and better understand responses, this study was aimed at evaluating the influence of different tropical soil management systems reflected in some physic, chemical and hydro-physical properties. Nine Nitisol profiles were evaluated and grouped in three categories: (I) native forest (Benchmark > 30 years); (II) soils formerly cultivated then turned to pasture (Conservation > 10 years); and (III) soils under continuous cultivation (Agrogenic > 50 years). The analyzed variables were organic matter, bulk density, soil particle density, porosity, field capacity, texture and structural index. Results determine that the action of traditional farming techniques in tropical environments produces excessive soil degradation. Organic matter content and the structural index showed a linear relationship with high degree of dependence (R^2=0.99). Bulk density average for (I) and (II) profile were lower (P<0.05) than the bulk density values for (III). In the regression analyses the bulk density increased, the field capacity decreased, and the tendency for profile (I) and (II) were of a linear type. While the profile for (III) was of a polynomial type with (R^2=0.83), being able to be influenced by the higher values of bulk density, greater soil compaction, lower structural index, organic matter and porosity in correspondence with the other profiles.

RESUMEN

Palabras clave:
Degradación
Propiedades físicas
Manejo del suelo
Labranza

El cambio en el uso de la tierra, especialmente la conversión de bosques nativos en tierras cultivadas ejerce un impacto sobre las propiedades físicas, químicas e hidrofísicas de los suelos. El objetivo de este estudio fue evaluar la influencia de diferentes sistemas de manejo de un suelo tropical reflejado en algunas de sus propiedades físicas, químicas e hidrofísicas. Se evaluaron nueve perfiles de un suelo Nitisol agrupado en tres categorías: (I) bosque nativo (Referencia > 30 años); (II) suelos anteriormente cultivados y luego convertidos en pastizales (Conservados > 10 años); y (III) suelos bajo cultivo continuado (Agrogénicos > 50 años). Las variables analizadas fueron materia orgánica, densidad aparente, densidad real, porosidad, capacidad de campo, textura e índice estructural. Los resultados determinaron que la acción de las técnicas agrícolas tradicionales en ambientes tropicales produce una excesiva degradación de las propiedades del suelo. El contenido de materia orgánica e índice estructural muestran una relación lineal con un alto grado de dependencia (R^2=0,99). La densidad aparente promedio para los perfiles (I) y (II) fue menor (P<0,05) que los valores de densidad aparente del perfil (III). En los análisis de regresión a medida que aumenta la densidad aparente disminuye la capacidad de campo y la tendencia observada para (I) y (II) es lineal, mientras que para (III) es polinómica con (R^2=0,83), pudiendo estar influenciado por los valores más altos de la densidad aparente, mayor compactación, menor índice estructural, materia orgánica y porosidad en correspondencia con los otros perfiles.

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Since the beginning of agricultural development, during Neolithic era, humans influenced the properties of virgin lands. This land use is one of the main drivers of many processes of environmental change, as it had influenced basic resources within the landscape. Without a doubt, the anthropogenic factor has played its role as a force that affects both soils and climate, having increased exponentially during the last 300 years, to such an extent that this phenomenon is now considered a new era in the evolution of the Earth: "The Anthropocene" (Crutzen and Steffen, 2003). During the last millennium, nearly all soils have undergone some modifications through human action, directly or indirectly. Thus, at present, the genesis of many soils has been determined more from human effects than from natural forming factors. Such is the magnitude of this transformation that some authors speak of an agrogenic evolution of soils (Lebedeva *et al.*, 2008).

Tropical regions are characterized by having high rainfall intensities resulting in severe erosional rates if inappropriate land management practices are applied. In Cuba, there are extensively weathered tropical soils (Ferralsols, Nitisols, Oxisols, Lixisols, Acrisols, and Alisols)". It is a country with soils subjected to anthropogenesis, constituting one example for tropical regions. I Cuba being a long-narrow island presents diverse soil groupings, dominated by the Nitisols, especially in the western and center of the country, which because of its good characteristics, has been the main source of food production for the inhabitants of this region. (Hernández *et al.*, 2017). In the last 10 years some Cuban researchers has been working on the diagnosis for soil degradation, in order to achieve their sustainability through medium and long-term research on the basis of the so-called reference sectors (Hernández *et al.*, 2006). Some of these results were presented by Hernández *et al.* (2009, 2013) and by Olivera (2017), about the change of Red Lixiviated Ferralitic soils properties (Nitisols) by continued cultivation. These authors show indicators and mechanism of soil degradation as well as agroproductive responses to improvement.

Changes in soil functionality are indicators of their performance and handling to which they are subjected. However, it should be noted that if a better understanding is to be achieved then studies of each soil type must be conducted., It is also noted that among soil samples with similarities in their relationships and some dependency, which makes it possible for the interpretation of one, to infer the behavior of another (Fultz *et al.*, 2013; Duval *et al.*, 2016). According to information from the Soil Institute of Cuba (2006), 69.6% of soils have low organic matter (OM) and 43.3% have strong erosion, limiting their productivity. In this sense the pursuit of quality of soil and timely identifying their limitations is one of the main objectives of research in soil physics, as demonstrated by (Zhu *et al.*, 2015; Deng *et al.*, 2016). Although significant knowledge about soil and landscape change in agriculture has been gained, much remains unknown and uncertain. Major reasons are the relative scarcity of soil studies, methodological shortcomings, the complexity of agricultural systems and soils, and imprints of multiple land use and environmental change. With this purpose, the aim of this study was to evaluate the influence of different tropical soil management systems reflected in their physical, chemical and hydro-physical properties.

MATERIALS AND METHODS

The study was carried out in Banao community in the Sancti Spiritus Province, which is located to the south in the central region of Cuba, between X: 216 000 - 218 000 and Y: 539 000 - 550 000 according to the rectangular plane coordinate system of Northern Cuba, cartographic sheet 4 281-II-b (Figure 1). This experimental area ("Hermanos Alonsos") has suffered anthropic action for more than 30 years, despite the high income generated by the production of onions (*Allium cepa* L.). The production levels obtained in the last years have compromised the ecosystem's stability and as a vulnerable factor increased soil erosion (Figure 2).

We analyzed nine Nitisol profiles where three conditions were considered as treatments (three repetitions for each land use) grouped as: (I) native forest (Benchmark > 30 years); (II) soils formerly cultivated then turned to pasture (Conservation > 10 years); and (III) soils under continuous cultivation (Agrogenic > 50 years). The profile description was according to the manual for detailed cartography and integral evaluation of soils (Hernández *et al.*, 1995). Soils were identified by the World Reference Base for Soil Resources (WRB) classification (International Union of Soil Sciences (IUSS), Working Group, 2014).
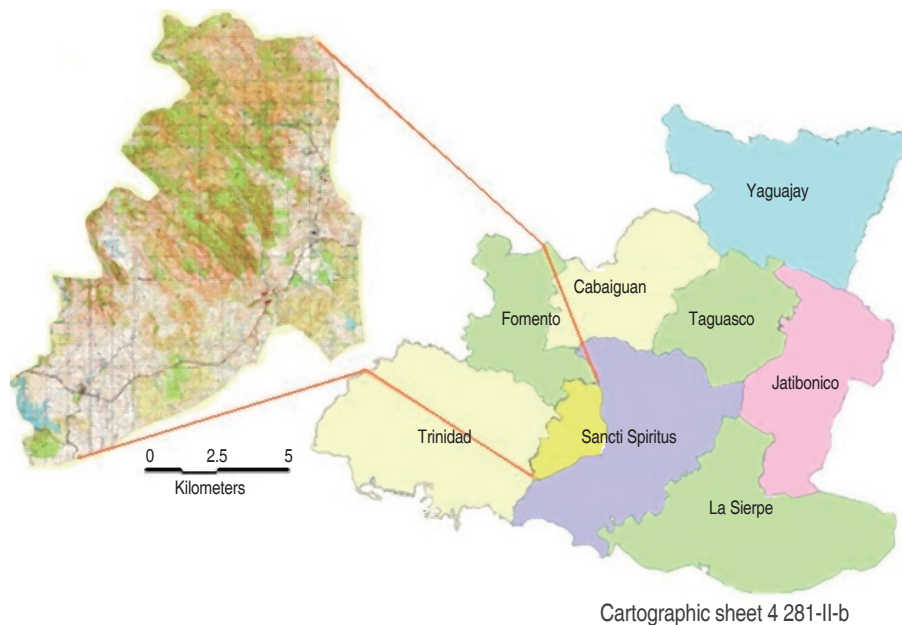
Cartographic sheet 4 281-II-b

Figure 1. Cartographic sheet generated from the Map Info Professional 9.0 software (2010) (Banao comunity).
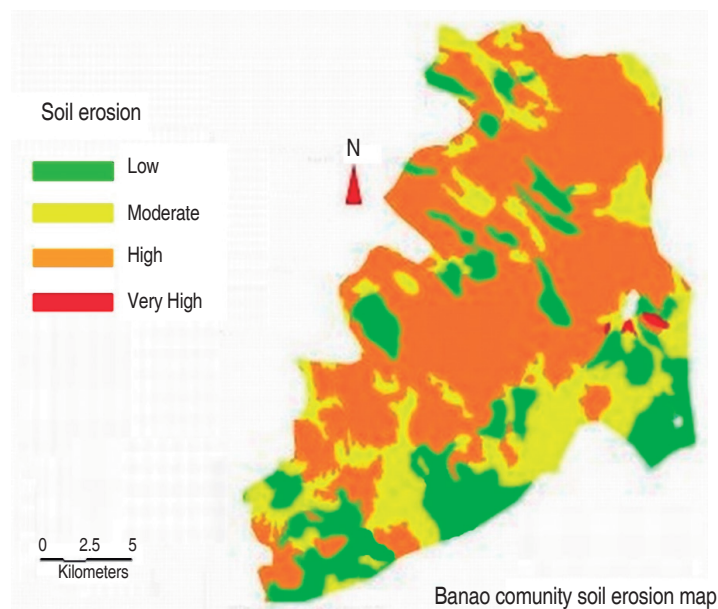

Banao comunity soil erosion map

Figure 2. Soil erosion using the 1:25 000 map generated from the MapInfo Professional 9.0 software (2010).

Soil samples were taken every 10 cm up to 50 cm deep for every profile. All soil samples were analyzed at the Territorial Station of Investigations of the Sugar Cane (ETICA), Villa Clara, Cuba, in accordance with the following analytical methods: organic matter (OM) according to (Walkley and Black, 1934); color profile (Figure 3) by (Munsell Soil Color Charts, 2000), bulk density (Db) was determined for a humidity close to the field capacity considering that some soils contain dilatable clays in which the humidity level exerts a big influence on their values. (Db) was measured using 100 cm^3 cylinders (Grossman and Reinsch, 2002) and soil

particle density (Dp) was determined according to the pycnometer method. Field capacity was obtained from periodical measurements of soil water content (Simeon, 1979). Soil texture Hydrometer Method (Bouyoucos, 1951) and structural index was determined according to Pieri (1995). The total porosity (P) was calculated using the mathematical model represented below [1].

$$\%P = \left(1 - \frac{Db}{Dp}\right)100 \qquad [1]$$

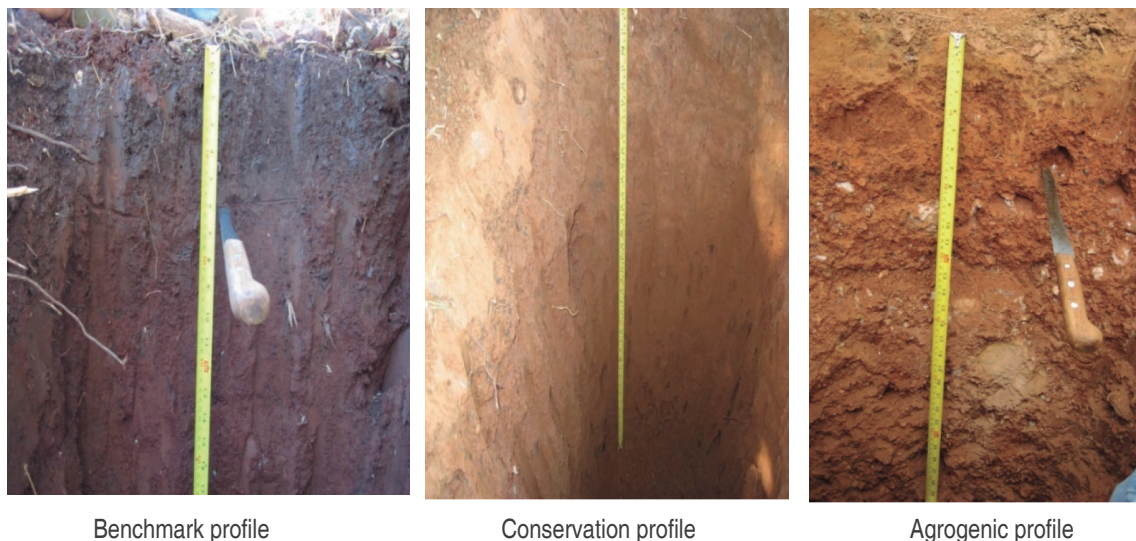| Benchmark profile | Conservation profile | Agrogenic profile |

Figure 3. Nitisol profile under different management systems.

Variance analysis (ANOVA) tests were carried out on the results considering a completely random design in which the profiles of each category were considered repetitions and each of the three conditions were considered treatments. Physical soil measurements were compared by the Tukey test, at 5% probability. Relationships between bulk density, field capacity, organic matter and structural index were investigated by regression models. All statistical analyses were performed using the statistical software Agroestat (Barbosa and Maldonado, 2011).

RESULTS AND DISCUSSION
The results demonstrated that the soils in this study presented differences in their physical properties due to its land utilization (Table 1). According to (Hernández *et al.*, 2010), soil degradation processes increase where the management practices are selected without regard for the edaphological conditions, which are specific to every particular region. Benchmark topsoil (0 – 10 cm) had a mean (± standard deviation) bulk density of (0.90 ± 0.09 g cm^{-3}), which was similar to that of topsoils taken from conservation profile (0.94 ± 0.06 g cm^{-3}). The mean bulk density for Benchmark and Conservation profile were lower ($P<0.05$) than the bulk density values for agrogenic profile (1.21 ± 0.04 g cm^{-3}). Bulk density values both for Benchmark and Conservation profile are considered normal, whereas for the agrogenic profile the soils are considered compacted according to Martin and Duran (2011). A tendency towards a lower bulk density for soils taken from Benchmark and the conservation profile system compared to those from agricultural land uses (agrogenic) could also be detected for the 10-50 cm (Table 1). Compaction, measured by increased bulk density, often accompanies structural degradation as soil porosity and pore size are reduced through physical compression and decreased organic matter. According to Homburg and Sandor (2011) in the Mimbres study, bulk density increased about 9% relative to uncultivated soils and may not have been a major problem, but that degree of compaction has been shown in experiments to inhibit maize seedling development and root elongation, especially in fine-grained soils.

Soil particle density (Pd) follows a similar behavior in all profiles without revealed significant differences. This could be explained because the soil macro particles can

Table 1. Land use systems effect on soil physical properties.

Depth (cm)	Db (g cm^{-3})	Dp (g cm^{-3})	Porosity (%)
Profile I (Benchmark)			
0-10	0.90 ± 0.09[b]	2.61 ± 0.2025[a]	65.5 ± 1.8036[a]
10-20	0.98 ± 0.11[b]	2.64 ± 0.2042[a]	62.9 ± 3.1262[a]
20-30	1.03 ± 0.07[b]	2.72 ± 0.1778[a]	62.1 ± 4.1356[a]
30-40	1.04 ± 0.08[b]	2.76 ± 0.2402[a]	62.3 ± 2.8219[a]
40-50	1.05 ± 0.10[b]	2.77 ± 0.1670[a]	62.1 ± 2.5696[a]
Profile II (Conservation)			
0-10	0.94 ± 0.06[b]	2.63 ±0.22[a]	64.3 ± 5.14[a]
10-20	1.02 ± 0.05[b]	2.68 ± 0.15[a]	61.9 ± 1.81[a]
20-30	1.05 ± 0.07[b]	2.76 ± 0.27[a]	61,9 ± 2.81[a]
30-40	1.05 ± 0.07[b]	2.72 ± 0.18[a]	61.4 ± 4.35[a]
40-50	1.10 ± 0.06[b]	2.74 ± 0.16[a]	59.9 ± 2.70[a]
Profile III (Agrogenic)			
0-10	1.21 ± 0.04[a]	2.80 ± 0.24[a]	56.8 ± 1.00[b]
10-20	1.26 ± 0.05[a]	2.79 ± 0.15[a]	54.8 ± 1.64[b]
20-30	1.31 ± 0.07[a]	2.79 ± 0.19[a]	53.1 ± 1.95[b]
30-40	1.39 ± 0.12[a]	2.76 ± 0.15[a]	49.6 ± 5.77[b]
40-50	1.38 ± 0.07[a]	2.78 ± 0.19[a]	50.4 ± 2.25[b]

Average ± standard deviation. Different letter in the same column vary for (P<0.05).

change in a short time with the management practices, but it does not happen in the same way with microparticles and soil texture. On the other hand, soil porosity did not present significant differences between the benchmark and conservation profile, but with the agrogenic profile. Higher bulk densities are usually attributed to compaction, structural damage and destruction of macropores of topsoil by overgrazing and use of machinery (Kelishadi *et al.*, 2014; Lal, 1986; Price *et al.*, 2010) or by intensive agricultural practices (Emadi *et al.*, 2008). Our results are thus consistent with previous studies that reported higher bulk densities for pastures or croplands compared to native or forest plantations in Argentina, the north-eastern USA (Zhou *et al.*, 2008), Costa Rica (Reiners *et al.*, 1994), Iraq (Emadi *et al.*, 2008) and Ethiopia (Selassie and Ayanna, 2013).

According to the regression analyses, as the bulk density increases, the field capacity decreases and the observed tendency is linear for Benchmark and Conservation soils (R^2=0.94) and (R^2=0.93) respectively (Figure 4A, B). That is, the field capacity decreases 42.6% for Benchmark profile and 49.1 % for Conservate profile for each unit of soil bulk density variation. It a polynomial regression can be observed For the Agrogenic profile (R^2=0.83) (Figure 4C). This non-linear behavior corresponding to the Agrogenic profile could be influenced by higher values of bulk density, presenting a greater soil compaction, lower structural index, organic matter content and porosity coinciding with a compacted soil according Martin and Duran (2011) as was previously described.

The texture of all land types and depths were predominantly clayey, with the clay content increasing with depth (Table 2). The Soils of all depths sampled were classified as (Nitisol Rodico Eutrico) based on (IUSS, 2014). On average, soils from the lower depths (25–50 cm) contained slightly less sand and slightly higher clay content (Table 2). According to Homburg and Sandor (2011) structure degradation is signaled by loss of granular structure, weaker structure

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grade, tendency toward larger aggregates (peds) and massive condition. These differences appear to be due to intensive anthropogenesis experienced by the soils which was not sub soiled in the last years. It is therefore reasonable to infer that the soil compaction is conditioned by the history of land use and management. According to
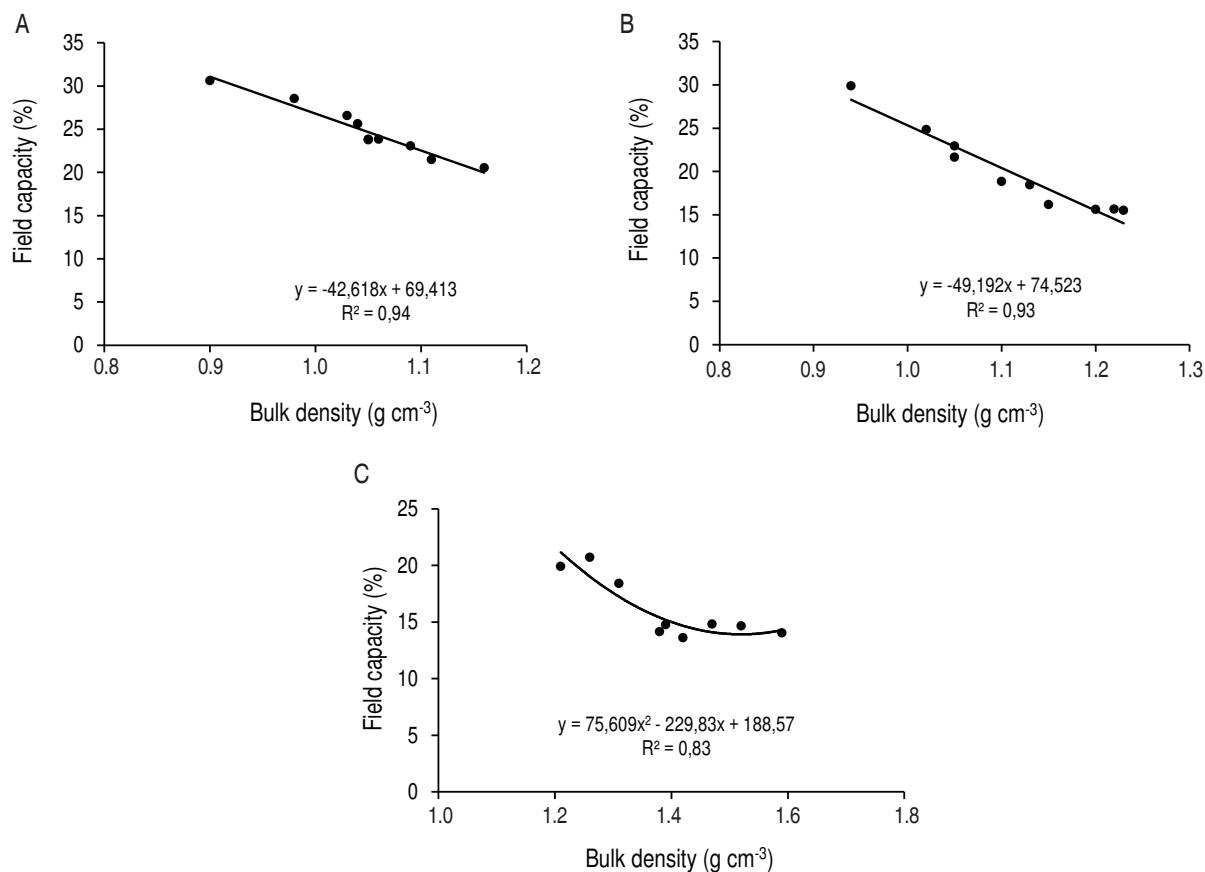
A

$y = -42,618x + 69,413$
$R^2 = 0,94$

B

$y = -49,192x + 74,523$
$R^2 = 0,93$

C

$y = 75,609x^2 - 229,83x + 188,57$
$R^2 = 0,83$

Figure 4. Relationship between field capacity and bulk density: A. Benchmark profile, B. Conservation profile, C. Agrogenic profile.

Table 2. Average soil particle size distribution across three land use types and three depths.

Land use	Depth (cm)	Sand	Silt	Clay	Structural index	OM
		(%)				
Benchmark	0–15	20.43	5.52	62.23	9.30	6.3
	15–25	17.06	3.61	63.82	5.78	3.9
	25–50	15.78	3.87	64.76	4.52	3.1
Conservation	0–15	19.76	3.74	58.38	5.15	3.2
	15–25	17.26	4.51	61.18	5.33	3.5
	25–50	12.79	4.74	66.97	2.09	1.5
Agrogenic	0–15	18.66	8.41	62.45	2.54	1.8
	15–25	16.85	8.53	64.63	1.37	1.0
	25–50	15.21	6.41	65.57	0.83	0.6

Olivera (2017), as soil compaction increases under heavy farm machinery, the soil physical structure deteriorates, bulk density increases and total porosity decreases.

The organic matter content and the structural index shows a linear relationship with high degree of dependence (R^2=0.99). Therefore, with increasing organic matter the structural index increases and vice versa (Figure 5). This relation may be more dependent for this type of soil dominated by oxides and 1: 1 mineral compared to soils dominated by 2: 1 mineral (Six *et al.*, 2000). It should be noted that predictions made by using the regression line fitting (R^2=0.99) obtained in this figure produced practically the same results as the regression on individual soil management.
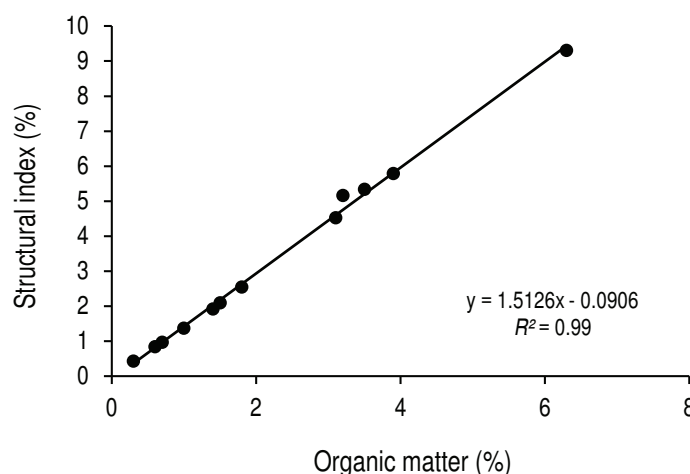

Figure showing:
$$y = 1.5126x - 0.0906$$
$$R^2 = 0.99$$

Figure 5. Relationship between organic matter and structural index.

CONCLUSIONS

Our study shows that all soil properties were markedly different between native forest (Benchmark) and the continuous cultivation (Agrogenic). The other land types increased bulk density, decreased field capacity, organic matter, porosity and structural index. Continuous cultivation caused the degradation of the topsoil eventually reaching a 50 cm depth which leads to a greater compaction, porosity limiting and humidity reserve. Benchmark profile did not present significant differences with the conserve profile which we attribute the No-till policy and adequate rest time. Establishing pastures could help reduce bulk density and improve the soil physical properties.

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REFERENCES

Barbosa JC, Maldonado Júnior W. 2011. AgroEstat: sistema para análises estatísticas de ensaios agronômicos. FCAV/UNESP, Jaboticabal, version 1, No. 0.694.

Bouyoucos GJ. 1951. A Recalibration of the Hydrometer Method for Making Mechanical Analysis of Soils 1. Agronomy Journal 43(9): 434-438.

Color Munsell (Org). 2000. Munsell soil color charts: year 2000 revised washable edition. GretagMacbeth, New Windsor. 50 p.

Crutzen PJ and Steffen W. 2003. How long have we been in the Anthropocene era? Climatic Change. 61(3): 251-257. doi: 10.1023/B:CLIM.0000004708.74871.62

Deng YS, Dong XIA, Cai CF and Ding SW. 2016. Effects of land uses on soil physic-chemical properties and erodibility in collapsing-gully alluvial fan of Anxi County. China. Journal of Integrative Agriculture. 15: 1863-1873. doi: 10.1016/S2095-3119(15)61223-0

Duval ME, Galantini JÁ, Martínez JM, López FM and Wall LG. 2016. Sensitivity of different soil quality indicators to assess sustainable land management: Influence of site features and seasonality. Soil and Tillage Research 15: 9-22. doi: 10.1016/j.still.2016.01.004

Emadi M, Baghernejad M, Fathi H and Saffari M. 2008. Effect of land use change on selected soil physical and chemical properties in North Highlands of Iran. Journal of Applied Sciences 8(3): 496–502.

Fultz LM, Moore-Kucera J, Zobeck TM, Acosta-Martínez V, Wester DB and Allen VG. 2013. Organic carbon dynamics and soil

stability in five semiarid agroecosystems. Agriculture Ecosystems and Environment. 181: 231-240. doi: 10.1016/j.agee.2013.10.004.

Grossman RB and Reinsch TG. 2002. Bulk density and linear extensibility. pp. 201-228. In: Dane, J.M., and G.C. Topp (eds.) Methods of soil analysis. Part 4. Physical methods. Soil Science Society of America, Madison, Wisconsin, USA.

Hernández A, Vargas D, Bojórquez JI, García JD, Madueño A and Morales M. 2017. Carbon losses and soil property changes in ferralic Nitisols from Cuba under different coverages. Scientia Agricola. 74(4): 311-316. doi: 10.1590/1678-992x-2016-0117

Hernández JA, Cabrera RA, Borges BY, Vargas BD, Bernal FA, Morales DM and Ascanio MO. 2013. Degradación de los suelos Ferralíticos Rojos Lixiviados y sus indicadores de la Llanura Roja de La Habana. Cultivos Tropicales 34(3): 45-51.

Hernández A, Serrano JB, Planes FM, Rodríguez AC, García MO, Paredes JDG and González ON. 2010. Fundamentos de la estructura de suelos tropicales. Publicado en formato digital por la Universidad Autónoma de Nayarit, México.

Hernández A, Morales M, Morell F, Borges Y, Bojórquez JI, Ascanio MO, García JD, Ontiveros H, and Murray R. 2009. Changes in soil properties by agriculutral activity in tropical ecosystems. Abstracts International conference «Soil Geography: New horizons». Huatulco, Mexico, p. 57.

Hernández A, Ascanio O, Morales M, Bojórquez JI, García N and García JD. 2006. El suelo: fundamentos de su formación, cambios globales y su manejo. Editorial Universidad de Nayarit, México. 255 p. ISBN: 968-833-072.

Hernández A, Paneque J, Pérez JM, Mesa A, Bosch D and Fuentes E. 1995. Metodología para la cartografía detallada y evaluación integral de los suelos. Instituto de Suelos, La Habana. 52 p.

Homburg JA and Sandor JA. 2011. Anthropogenic effects on soil quality of ancient agricultural systems of the American Southwest. Catena. 85(2): 144-154. doi: 10.1016/j.catena.2010.08.005

Instituto de Suelos de Cuba. 2006. La degradación de los suelos en Cuba. En Resúmenes del Taller "La Metodología LADA y la Evaluación de las Tierras de Cuba". La Habana, p. 25.

International Union of Soil Sciences [IUSS]. 2014. World Reference Base for Soil Resources 2014: International Soil Classification System for naming soils and creating legends for soil maps. FAO. Rome. Italy. (World Soil Resources Reports. 106).

Kelishadi H, Mosaddeghi MR, Hajabbasi MA and Ayoubi S. 2014. Near-saturated soil hydraulic properties as influenced by land use management systems in Koohrang region of central Zagros. Iran. Geoderma 213: 426-434. doi: 10.1016/j.geoderma.2013.08.008

Lal R. 1986. Conversion of tropical rainforest: agronomic potential and ecological consequences. Advances in Agronomy 39: 173-264. Academic Press. doi: 10.1016/S0065-2113(08)60468-X

Lebedeva II, Tonkonogov VD and Gerasimova MI. 2008. A new classification system of soils of Russia: Preliminary results of discussion. Eurasian Soil Science 41(1): 93-99. doi: 10.1134/S1064229308010110.

Martin N and Duran JL. 2011. Soil and fertility. Ed. Felix Varela, La Habana. pp. 1-347.

Olivera D. 2017. Degradação de propriedades físicas de latossolos vermelhos pela ação antrópica. En: XXXVI Congresso Brasileiro de Ciência do Solo. 2017. Belen. Para- Brasil. Amazônia e seus solos: peculiaridades e potencialidade. 2017. https://doi.org/10.13140/rg.2.2.32841.03681

Pieri C. (1995). Long term management experiments in semiarid Francophone Africa. In: Lal R, Stewart BA (eds.). Soil management: experimental basis for sustainability and environmental quality. CRC Press, Boca Raton, pp 225–266.

Price K, Jackson CR, Parker AJ. 2010. Variation of surficial soil hydraulic properties across land uses in the southern Blue Ridge Mountains. North Carolina. USA. Journal of Hydrology. 383(3-4): 256–268. doi: 10.1016/j.jhydrol.2009.12.041

Reiners WA, Bouwman AF, Parsons WF and Keller M. 1994. Tropical rain forest conversion to pasture: changes in vegetation and soil properties. Ecological Applications 4(2): 363-377. doi: 10.2307/1941940

Selassie GY, Ayanna G. 2013. Effects of different land use systems on selected physico-chemical properties of soils in northwestern Ethiopia. The Journal of Agricultural Science 5(4): 112–120. doi: 10.5539/jas.v5n4p112

Simeon P. 1979. Propiedades físicas de los principales suelos de Cuba. Voluntad Hidráulica 5: 10-19.

Six J, Elliott ET and Paustian K. 2000. Soil structure and soil organic matter II. A normalized stability index and the effect of mineralogy. Soil Science Society of America Journal 64(3): 1042-1049. doi: 10.2136/sssaj2000.6431042x

Walkley A and Black IA. 1934. An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. Soil Science: 37(1): 29-38.

Zhou X, Lin HS and White EA. 2008. Surface soil hydraulic properties in four soil series under different land uses and their temporal changes. Catena 73(2): 180–188. doi: 10.1016/j.catena.2007.09.009

Zhu Q, Schmidt JP, Bryant RB. 2015. Maize (*Zea mays* L.) yield response to nitrogen as influenced by spatio-temporal variations of soil–water-topography dynamics. Soil and Tillage Research 146: 174-183. doi: 10.1016/j.still.2014.10.006.