Cultivos Tropicales, 2019, vol. 40, no. 3, e05
ISSN impreso: 0258-5936
ISSN digital: 1819-4087

julio-septiembre
Ministerio de Educación Superior. Cuba
Instituto Nacional de Ciencias Agrícolas

http://ediciones.inca.edu.cu

Original article

# Two soil types characterization dedicated to forage plants production

Andy Bernal-Fundora[1*]

Alberto Hernández-Jiménez[1]

Pedro José González-Cañizares[1]

Adriano Cabrera-Rodríguez[1]

[1]Instituto Nacional de Ciencias Agrícolas (INCA), carretera San José-Tapaste, km 3½, Gaveta Postal 1, San José de las Lajas, Mayabeque, Cuba. CP 32700

[*]Author for correspondence. andy@inca.edu.cu

## ABSTRACT

The evaluation of soil properties allows to know the level of degradation of indicators related to fertility and to have a better understanding of the responses of crops to fertilizer applications, in order to obtain acceptable yields. The present work was carried out with the objective of characterizing the current state of two types of soils dedicated to the production of forage plants for cattle feed. In both soils, their contours were delimited, their profiles were morphologically described and later they were classified. In the agrochemical sampling, elementary plots were delimited by soil type, in which a sample was formed for each one, to which were determined the pH, the assimilable phosphorus, the interchangeable cations, the content and the carbon reserve and They took several samples to determine their mechanical composition, clay dispersion coefficient, natural and hygroscopic moisture, soil density and solid phase density, total porosity and stability of the aggregates. The soils studied were classified as Gley Nodular Ferruginous and Red Brown Fersialitic. In addition, both soil types showed signs of degradation in the upper horizon, reflected by a low carbon content, high dispersion coefficient of clay, low moisture retention, low percentages of porosity, high values in the density of the soil and the density of the solid phase, together with a structure characterized by the presence of medium-sized prismatic blocks.

**Key word**: soil density, soil structure, clay, gleysol

# INTRODUCTION

One of the most important resources to guarantee human and animal food is the soil, which behaves as a natural formation composed of mineral and organic elements, resulting from various weathering processes where chemical, physical and biological changes occur continuously from the training material, reaching a morphology and particular characteristics depending on the ecosystem in which it develops (1,2).

The study of the morphological characteristics, as well as of the chemical and physical properties of the soils is fundamental, since it allows to know the level of degradation and affectation of indicators that are related to fertility and to have a more defined understanding of the responses of the crops to the application of fertilizers to obtain the highest yields.

The poorly cultivated soils when placed under continuous cultivation, change their properties, causing degradation problems, such as destruction of the structure and compaction, erosion and loss of fertility in general (3–5), which worsens when no measures are taken for the conservation and improvement of soils, leading to reducing the chances of obtaining high agricultural yields (6).

In Cuba, numerous characterization works have objectively addressed and quantified the problem of soil degradation. Among these works is the study on secondary salinization (7), acidification with high exchangeable aluminum content due to climate change (8), and more recently work has been carried out where erosion processes are characterized (9) and described the mechanism of degradation, based on changes in the properties that are degraded and some results on for improvement (10).

In the area where the studied soils are located, characterization works were carried out in the 80s, when they were part of the sugarcane areas of the Manuel Martínez Prieto Agroindustrial Complex, with which it is demonstrated how the monoculture of this grass influences negatively on some of its chemical and physical properties (11,12). Currently these soils belonging to the Directorate of Flora and Fauna of Boyeros municipality, have a vital importance for livestock production in the territory, since it is intended to establish the cultivation of protein plants for animal feed. Taking into account the above, the present work aims to describe the morphological characteristics of the profiles and characterize some of the chemical and physical properties of the soils under study.

# MATERIALS AND METHODS

The origin of this work is based on studies in livestock areas, belonging to the Directorate of Flora and Fauna of Boyeros municipality. Two types of soils were selected, in which field trips were made taking points with augers, to have a preliminary classification. Once the contours were specified by soil types, their profiles were morphologically characterized and described according to the Manual for the mapping and description of soil profiles (13) and subsequently classified according to the criteria of the Classification of Soils of Cuba (14) and the world reference base of the soil resource (15).

## Agrochemical sampling of Soils

In the agrochemical sampling elementary plots were delimited by soil types, for the Gley the plot had an area of 16 ha, while for the Fersialitic it was 13 ha, where 20 subsamples were taken with the help of a Dutch type auger in each plot at a depth of 0-20 cm along the diagonal of the zigzag field, to form a sample composed of soil, as described for pasture cultivation (13).

The samples were analyzed in the Laboratory of Chemical Soil Analysis of the Department of Biofertilizers and Plant Nutrition of the National Institute of Agricultural Sciences (INCA) and the following determinations were made (16):

- • pH: potentiometry, soil ratio: water 1: 2.5
- • Assimilable phosphorus: extraction with $H_2SO_4$ 0.1 N with soil solution ratio equal to 1:25 m: v and colorimetric determination by developing the blue color of the phosphoric molybdenum complex.
- • interchangeable cations: extraction with 1 mol $L^{-1}$ ammonium acetate at pH 7 and determination by complexometry (Ca and Mg) and flame photometry (K and Na)
- • carbon percentage: Walkley and Black
- • Carbon stocks (Mg $ha^{-1}$) was determined by the formula:
- Carbon reserve = Carbon (%) * Bulk density (kg $dm^{-3}$) * Depth (cm)

## Physical analysis of Soils

For the analysis of the physical properties of the soils, five random samples were taken at a depth of 0-20 cm in each of the elementary plots, and they were determined natural and hygroscopic humidity, soil density, the density of the soil solid phase and the stability of the aggregates and for the determinations of mechanical analysis and granulometric analysis of the microaggregates three samples were used.

The samples were analyzed in the Soil Physics Laboratory of the Department of Biofertilizers and Plant Nutrition of the INCA following the following determinations [17]:

For the analysis of the physical properties of the soils, five random samples were taken at a depth of 0-20 cm in each of the elementary plots, and they were determined natural and hygroscopic humidity, soil density, the density of the soil solid phase and the stability of the aggregates and for the determinations of mechanical analysis and granulometric analysis of the microaggregates three samples were used.

The samples were analyzed in the Soil Physics Laboratory of the Department of Biofertilizers and Plant Nutrition of the INCA following the following determinations [17]:

• Mechanical analysis, by the Bouyoucos method with sodium pyrophosphate and sodium hexametaphosphate

• Granulometric analysis of soil microaggregates by the Bouyoucos method and the dispersion coefficient, by dividing the percentage of microaggregated clay by the percentage of clay from the mechanical analysis multiplied by one hundred

• Determination of natural humidity and hygroscopic soil moisture, using the gravimetric method

• Determination of the apparent density, by the method of cutting cylinders of 100 cm3

• Determination of the real density, by the pycnometer method in water

• Determination of total porosity according to the formula:

Total porosity = (1 - Apparent density/Real density) * 100

• Analysis of soil aggregates, by the method of N. I. Savvinov

- análisis mecánico, por el método de Bouyoucos con pirofosfato de sodio y hexametafosfato de sodio

### Statistical processing

The coefficient of variation and the confidence interval of the mean of the analyzed variables were determined. The Statgraphics Centurion XV Version 15.2.14 program was used.

## RESULTS AND DISCUSSION

Taking into account the morphological description of the profiles, two types of soils were classified, one as Ferruginous Nodular Gley (GNF) and the other as Reddish Brown Fersialitic (FrsPR), which represent 38.28 and 25.59 % respectively, of a studied area of approximately 900 ha (18).

### Description of the Gley Nodular Ferruginous soil profile

The GNF soil is located in a depression area from Murgas to the town of El Rincón, located on the map of Bejucal, about 50 (m a.s.l.), at the flat coordinates: N: 349,250 m; E: 352,500 m Cuba Norte system of the Conform Lambert Conical projection. The topography of the land is flat, with a slope less than 2 %. This soil was cultivated with sugar cane and currently with grass, presenting a poor surface and internal drainage.

The formation process that manifests for this soil is gleyzation, with a diagnostic horizon A ocric and B nodular ferruginous, with the presence of glycemic properties from 16 cm deep. Due to its characteristics, they are classified as Agrogenic Ferruginous Nodular Gley (14) and Dystric Gleysol (15). This soil because its formation is from sediments enriched with iron and aluminum and due to the influence of hydromorphic conditions, the formation of ferruginous nodules occurs in almost the entire thickness of the profile (14).

### Description of the soil profile Fersialitic Brown Reddish

The FrsPR soil, this is located one km before reaching Murgas, coming from the Wajay, located on the map sheet of Bejucal, about 75 (m a.s.l.), at the flat coordinates: N: 352,800 m; E: 351,550 m Cuba Norte system of the Conform Lambert Conical projection. The topography of the terrain is undulating, with a slope less than 2 %. This soil was cultivated with sugarcane and currently with pastures and various crops, presenting a good internal and regular surface drainage.

The predominant formation process is Fersialitization, due to the presence of a fersialitic and normal ocric main diagnostic horizon, with diagnostic characteristics of red and carbonated color. Due to these characteristics, it is classified as Erogenic Reddish Brown Fersialitic (14) or chromic Cambisol (15).

## Chemical properties

### Ferruginous Nodular Gley Soil

When analyzing the chemical characterization of the GNF soil (Table 1), the results showed that it had an average content of assimilable phosphorus ($P_2O_5$) (13), neutral pH, average calcium content ($Ca^{2+}$), high magnesium ($Mg^{2+}$), very low sodium ($Na^+$), low exchangeable potassium ($K^+$), with a high base exchange capacity (CIB) (19) and a low percentage and carbon stock.

**Table1.** Chemical characterization of GNF soil

| Statisticians | pH ($H_2O$) | $P_2O_5$ (mg 100 g$^{-1}$) | $Ca^{++}$ | $Mg^{++}$ | $Na^+$ (cmol$_c$ kg$^{-1}$) | $K^+$ | BEC | C (%) | CR (Mg ha$^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|
| Mean | 6,9 | 1,83 | 22,5 | 16 | 0,17 | 0,21 | 38,87 | 1,23 | 36,65 |
| VC (%) | 4,35 | 4,92 | 3,56 | 5,0 | 3,46 | 2,79 | 4,13 | 4,88 | 6,82 |
| CI | ±0,75 | ±0,22 | ±1,99 | ±1,99 | ±0,01 | ±0,01 | ±3,99 | ±0,15 | ±6,22 |

BEC: Basis exchange capacity, C: Carbon, C.R: Carbon reserve; VC: Variation Coefficient; CI: Confidence Intervals

Some of the chemical characteristics of this soil do not coincide with those of its type, which generally have an organic matter content around 3-4% and the pH with a tendency to acidity (20). This pH value close to 7, together with its high capacity of exchange of bases, may be due to the influence of the relief forms, when receiving transported materials composed of a clayey layer of minerals of type 2: 1, which have these characteristics (11).

In studies carried out on Gley Nodular Ferruginous soils distributed in different areas of the country and under the cultivation of rice and different forage species (21–24), similar organic matter and phosphorus contents were found similar to those observed in the soil under study; However, these authors found pH values that ranged from slightly acidic to acidic, which could be given by the gleyzation process itself, since the reduction of iron and the gradual release of aluminum favor the acidity of these soils (18) .

## Reddish Brown Fersialitic Soil

With respect to the chemical characteristics of the FrsPR soil (Table 2), it is evidenced that it has a high assimilable phosphorus content ($P_2O_5$) (13), an alkaline pH, high calcium content ($Ca^{2+}$) and magnesium ($Mg^{2+}$), very low in sodium ($Na^+$), low potassium ($K^+$), with a high base exchange capacity (CIB) [19] and low carbon content and reserve.

**Table 2.** Chemical characterization of the soil FrsPR

| Statisticians | pH | $P_2O_5$ | $Ca^{++}$ | $Mg^{++}$ | $Na^+$ | $K^+$ | BEC | C | CR |
|---|---|---|---|---|---|---|---|---|---|
| | ($H_2O$) | (mg 100 $g^{-1}$) | (cmol$_c$ kg$^{-1}$) | | | | | (%) | (Mg ha$^{-1}$) |
| Mean | 8,3 | 5,05 | 45,03 | 10,03 | 0,17 | 0,15 | 55,38 | 1,44 | 40,03 |
| VC (%) | 7,23 | 4,76 | 6,11 | 19,44 | 3,46 | 3,94 | 1,44 | 13,19 | 12,74 |
| CI | ±1,49 | ±0,6 | ±6,83 | ±4,84 | ±0,01 | ±0,01 | ±1,98 | ±0,47 | ±12,65 |

BEC: Basis exchange capacity, C: Carbon, C.R: Carbon reserve; VC: Variation Coefficient; CI: Confidence Intervals

Many of these characteristics conform to soils of their type, which have a predominance of calcium among the interchangeable cations, a slightly alkaline pH, except in the content of organic matter in which they are around 3-5 % [20]. The chemical properties of this soil resemble those observed in characterization work carried out on soils of this same type, with slightly alkaline reaction, these values could be due to the high content of changeable bases, since we are in the presence of a soil that has a predominance of clay minerals of type 2: 1 from the group of Smectites [25,26].

Regarding the low content of organic matter, percentages and carbon stock in both studied soils, it can be attributed to the fact that for many years they were under the continued cultivation of sugarcane as part of the supply areas to the Manuel Martínez Agroindustrial Complex Tight In this sense, in an experiment carried out over several years [27], it was demonstrated how the sugarcane monoculture promotes soil degradation by decreasing the organic carbon content.

In addition, the values of these variables in these soils behave very similar to those achieved in studies conducted on Red Ferralitic Soils Lixiviated under conditions degraded by continued cultivation [10].

## Characterization of some physical properties

### Mechanical Composition

According to the results of the mechanical composition in the GNF and FrsPR soils (Figure 1), a predominance of clay fraction greater than 40 % was observed for both soils, so they are diagnosed as clayey (17).

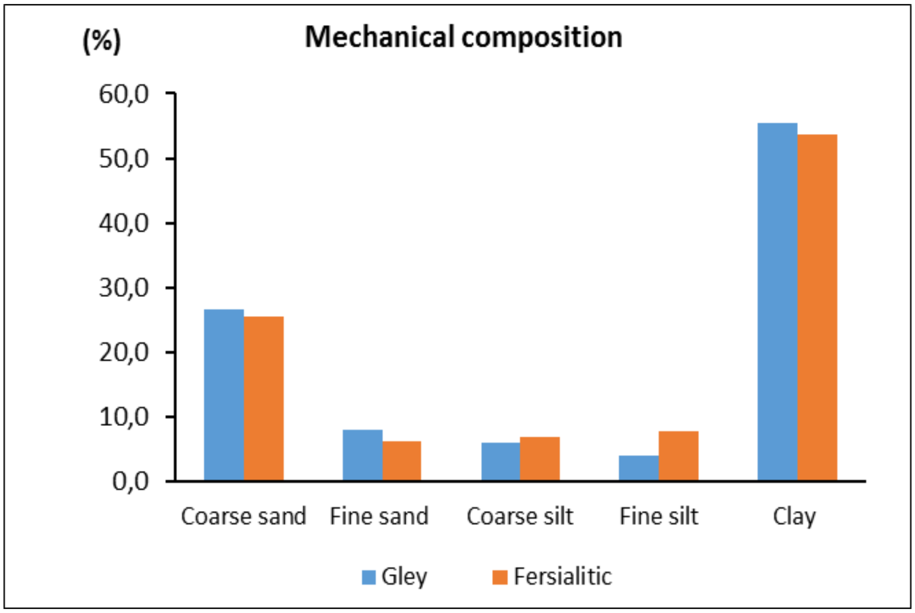
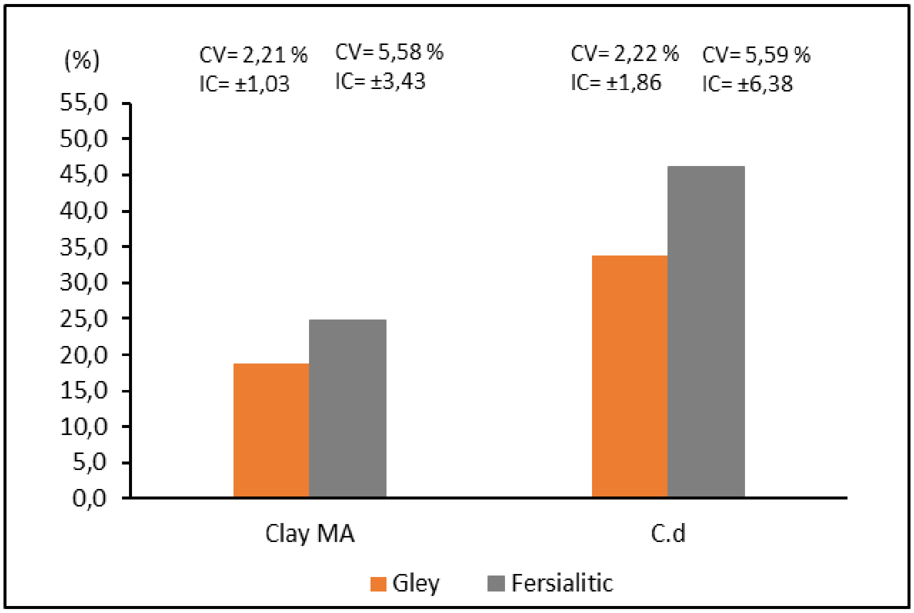



**Figure 1.** Mechanical composition, according to the percentages of the fractions

### Dispersion coefficient

The dispersion coefficient values are reflected in Figure 2, which is relatively high for any type of soil. This may be due to the agricultural activity in which they were subjected, in addition to the GNF soil during the hydromorphy process, with alternating periods of humidity causes a poorly defined structure and for the FrsPR soil, this behavior may be due to the predominance of clay minerals of type 2: 1, which have a high dispersion (28).




CV: coefficient of variation; IC: confidence intervals; Clay MA: clay in microaggregates; C.d: clay dispersion coefficient

**Figure 2.** Percentages of microaggregates clay and dispersion coefficient

Table 3 shows the results of some physical properties of the GNF soil. In relation to the percentages of natural and hygroscopic humidity, values below 20 % were observed, which is surely close to or below the Lower Limit of Productive Humidity (LIHP) (29), evidencing the lack of moisture in the soil, even for proper grassland development. The results of the soil density and density of the solid phase, for this soil it is evaluated as high and the percentage of total porosity is evaluated as average (30), not satisfactory for the arable layer (17). In contrast, the aggregate stability index is high.

**Table 3.** Analysis of some physical properties of GNF soil

| Statisticians | Natural humidity | Hygroscopic humidity | Apparent density | Real density | Total porosity | Stability index |
|---|---|---|---|---|---|---|
| | (%) | | (Mg m$^3$) | | (%) | |
| Mean | 16,3 | 13,43 | 1,49 | 2,73 | 45 | 0,79 |
| VC (%) | 2,45 | 4,02 | 3,03 | 2,38 | 6,67 | 3,80 |
| CI | ±0,99 | ±1,34 | ±0,11 | ±0,16 | ±7,45 | ±0,07 |

VC: Variation Coefficient; CI: Confidence Intervals

In relation to the physical properties of the FrsPR soil (Table 4), a humidity percentage greater than 20 % and a hygroscopic humidity percentage less than 10 % were observed.

With values of soil density and solid phase density, which are considered as average [30], these density levels observed in both soils can be given by the tillage to which they were subjected. Several authors demonstrated how mechanized agricultural work in the cultivation of sugarcane negatively influences a series of physical properties in soils, including compaction [31–33].

The total porosity for the FrsPR soil behaves on average, equally unsatisfactory for the arable layer.

With a high aggregate stability index, which could be due to the action of grass roots, a crop that was established after sugarcane that positively influenced the formation of aggregates in soils, mainly in the horizons surface, despite presenting a structure of medium subangular blocks in the GNF soil and in the FrsPR a small prismatic structure, which show signs of degradation, since at this depth when the soils present a good state of preservation a granular structure or small subangular blocks.

**Table 4. Analysis of some physical properties of the soil FrsPR**

| Statisticians | Natural humidity | Hygroscopic humidity | Apparent density | Real density | Total porosity | Stability index |
|---|---|---|---|---|---|---|
| | (%) | | (Mg m$^3$) | | (%) | |
| **Mean** | 24,9 | 9,85 | 1,39 | 2,59 | 47 | 0,85 |
| VC (%) | 1,81 | 0,56 | 3,25 | 1,36 | 6,38 | 6,51 |
| CI | ±1,12 | ±0,14 | ±0,11 | ±0,09 | ±7,45 | ±0,14 |

VC: Variation Coefficient; CI: Confidence Intervals

# CONCLUSIONS

- When describing the morphological characteristics of the profiles, a soil with glycemic properties was observed less than 50 cm deep and the presence of ferruginous nodules in all its horizons, which was classified as Ferruginous Nodular Gley and another soil with a Fersialitic horizon very clear, with red and yellowish colors, which was classified as Fersialitic Reddish Brown.
- The characterization of the chemical properties, show that the surface layer of these soils is affected by anthropogenesis, mainly reflected by the low content of organic carbon, together with the shortage of some nutrients.
- • The state of the physical properties studied shows that both soils show a certain degree of degradation, mainly reflected by high levels of compaction and an unsuitable structure.

# BIBLIOGRAPHY

1. Gardi C, Angelini M, Barceló S, Comerma J, Cruz C, Encina A, et al. Atlas de suelos de America Latina y el Caribe. Luxembourg: Luxembourg: Comisión Europea, Oficina de Publicaciones de la Unión Europea, 2014.; 2014. 176 p.

2. Alcalde S. Impulso y difusión de la Ciencia del Suelo en el 2015. Año Internacional de los Suelos (AIS2015). Enseñanza de las Ciencias de la Tierra. 2017;23:330-42.

3. Willians J, Reyes R. Procesos de compactación en un suelo vertisol bajo cuatro condiciones de manejo en la llanura de Coro, estado Falcón, Venezuela. Bioagro [Internet]. 2014;26(1):39–48. Disponible en: http://www.scielo.org.ve/scielo.php?pid=S1316-33612014000100005&script=sci_arttext

4. Duval ME, Galantini JA, Martínez JM, López FM, Wall LG. Evaluación de la calidad física de los suelos de la región pampeana: efecto de las prácticas de manejo. Ciencias Agronómicas [Internet]. 2015;15:33-43. Disponible en: https://ri.conicet.gov.ar/bitstream/handle/11336/11587/CONICET_Digital_Nro.15033.pdf?sequence=1

5. Zurrita AA, Badii MH, Guillen A, Serrato OL, Garnica JA. Factores Causantes de Degradación Ambiental. Daena: International Journal of Good Conscience [Internet]. 2015;10(3):1–9. Disponible en: http://www.spentamexico.org/v10-n3/A1.10(3)1-9.pdf

6. Mogollón J, Martínez A, Rivas W. Degradación química de suelos agrícolas en la Península de Paraguaná, Venezuela. Suelos Ecuatoriales. 2014;44(1):22–28.

7. Ortega F. Las causas de la salinidad de los suelos de Cuba. Ciencias de la Agriculutra [Internet]. 1986 [citado 20 de septiembre de 2017];(27):126-37. Disponible en: http://www.sidalc.net/cgi-bin/wxis.exe/?IsisScript=CENIDA.xis&method=post&formato=2&cantidad=1&expresion=mfn=058802

8. Martínez Y. Estudio sobre las transformaciones de las propiedades de los suelos en tres cuencas, situadas en las Alturas de Pizarra, del Occideente de Cuba [Tesis de Maestría en Ciencias del Suelo]. [Mayabeque, Cuba]: Universidad Agraria de la Habana; 2006. 113 p.

9. Febles J., Vega M. Buenos suelos en extinción: la degradación de los suelos ferralíticos rojos en el Occidente de Cuba. Anales de la Academia de Ciencias de Cuba [Internet].

2016;12. Disponible en: http://www.revistaccuba.sld.cu/index.php/revacc/article/viewFile/233/233

10. Hernández A, Morales M, Borges Y, Vargas D, Cabrera JA, Ascanio MO, et al. Degradación de las propiedades de los suelos Ferralíticos Rojos lixiviados de la" Llanura Roja de La Habana", por el cultivo continuado. Algunos resultados sobre su mejoramiento. Ediciones INCA. 2014;156.

11. Hernández A, Obregón A, Vantour A. Seudopodzolización y suelos Seudopodzolicos en Cuba. Academia de Ciencias de Cuba; 1986.

12. Hernández A, Morales M, Ascanio M, Morel F. Manual para la aplicación de la nueva versión de clasificación genética de los suelos de Cuba. La Habana, Cuba: Ediciones INCA; 2006. 193 p.

13. Vera L, Hernández A, Mesías F, Guzman A, Cedeño Á. Manual para la cartografía de suelos y la descripción de perfiles de suelos. 1.ª ed. Manabí, Ecuador: Ediciones Abya-Yala; 2017. 75 p.

14. Hernández A, Pérez J, Bosch D, Castro N. Clasificación de los suelos de Cuba 2015. Mayabeque, Cuba: Ediciones INCA; 2015. 93 p.

15. IUSS Working Group WRB,. Base referencial mundial del recurso suelo 2014 Actualización 2015. Sistema internacional de clasificación de suelos para la nomenclatura de suelos y la creación de leyendas de mapas de suelos. Roma: Informes sobre recursos mundiales de suelos 106. FAO; 2015. 218 p.

16. Paneque VM, Calaña JM, Calderón M, Borges Y, Hernández TC, Caruncho M. Manual de técnicas analíticas para análisis de suelo, foliar, abonos orgánicos y fertilizantes químicos. La Habana, Cuba: Ediciones INCA; 2010. 160 p.

17. Luis J. Métodos para el análisis físico de los suelos. La Habana: Ediciones INCA; 2007. 54 p.

18. Bernal A, Hernández A, Mesa M, Rodríguez O, González PJ, Reyes R. Características de los suelos y sus factores limitantes de la región de murgas, provincia La Habana. Cultivos Tropicales [Internet]. 2015 [citado 7 de abril de 2017];36(2):30-40. Disponible en: http://scielo.sld.cu/scielo.php?script=sci_abstract&pid=S0258-59362015000200005&lng=es&nrm=iso&tlng=pt

19. Paneque VM, Calaña JM. La fertilización de los cultivos. Aspectos teórico-prácticos para su recomendación. 2001.

20. Instituto de Suelos. Clasificación genética de los suelos de Cuba. La Habana, Cuba; 1979. 28 p.

21. Crespo G, Ramírez JF, González PJ, Hernández I. Coinoculación de cepas de rizobios y del hongo micorrízico arbuscular en Stylosanthes guianensis vc. CIAT-184. Revista Cubana de Ciencia Agrícola [Internet]. 2014 [citado 21 de septiembre de 2017];48(3):297-300. Disponible en: http://www.redalyc.org/html/1930/193032133016/

22. Ramírez JF, Fernandez Y, González PJ, Salazar X, Iglesias JM, Olivera Y. Influencia de la fertilización en las propiedades físico-químicas de un suelo dedicado a la producción de semilla de Megathyrsus maximus. Pastos y Forrajes [Internet]. 2015 [citado 21 de septiembre de 2017];38(4):393–402. Disponible en: http://scielo.sld.cu/scielo.php?pid=S0864-03942015000400002&script=sci_arttext&tlng=pt

23. Pérez León N de J, González Cepero MC, Castro Menduiña RI, Aguilar Portero M. Evaluación de cultivares de arroz en diferentes zonas de producción arrocera de Los Palacios, Pinar del Río, para su utilización en programas de mejoramiento. Cultivos Tropicales [Internet]. 2016 [citado 21 de septiembre de 2017];37(1):116–123. Disponible en: http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S0258-59362016000100016

24. Ruiz M, Muñoz-Hernández Y, Dell Amico-Rodríguez JM, Simó-González J, Cabrera-Rodríguez JA. Evaluación de diferentes cepas de micorrizas arbusculares en el desarrollo de plantas de arroz (Oryza sativa L.) en condiciones inundadas del suelo. Cultivos Tropicales [Internet]. 2016 [citado 21 de septiembre de 2017];37(4):67–75. doi:http://dx.doi.org/10.13140/RG.2.2.31096.85761

25. Romero A, Ruz R, González M. Evaluación de siete cultivares de soya (Glycine max) en las condiciones edafoclimáticas del municipio Majibacoa, Las Tunas. Pastos y Forrajes. 2013;36(4):459–463.

26. Serrano-Montero DO, González-Paneque OS, de la Rosa-Andino AA, Aguilera-Corrales Y, Ramírez-Chávez RE. Estrategia de manejo y conservación del suelo en áreas de producción agrícola. Revista Ingeniería Agrícola. 2017;7(1):41–48. doi:http://dx.doi.org/

27. Cabrera JA, Zuaznábar R. Impacto sobre el ambiente del monocultivo de la caña de azúcar con el uso de la quema para la cosecha y la fertilización nitrogenada. I. Balance del Carbono. Cultivos Tropicales [Internet]. 2010 [citado 21 de septiembre de 2017];31(1):5-13.

Disponible en: http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S0258-59362010000100001

28. Hernández A, Borges Y, Martínez M, Rodríguez J, Lorena F, Amaya M. Presencia de propiedades vérticas en los suelos fersialíticos de la antigua provincia La Habana. Cultivos Tropicales [Internet]. 2011 [citado 11 de julio de 2017];32(1):63–74. Disponible en: http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S0258-59362011000100006

29. Hernández A, Ascanio M, Morales M, Bojórquez I, García N, García D. El suelo: Fundamentos sobre su formación, los cambios globales y su manejo [Internet]. Primera edición. Nayarit: Univ. Autónoma de Nayarit; 2006 [citado 13 de marzo de 2017]. 255 p. Disponible en: http://books.google.es/books?hl=es&lr=&id=LdIARhjVZN4C&oi=fnd&pg=PA11&dq=El+suelo:+Fundamentos+sobre+su+formaci%C3%B3n,+los+cambios+globales+y+su+manejo&ots=mTX64rUWIx&sig=3GOLNL3-ouGLjbgc0bzDDjCiWd4

30. Mesa A, Naranjo M, Cancio R, Martín A, Clemente B, Suárez O, et al. Manual de interpretación de los índices físico-químicos y morfológicos de los suelos cubanos. La Habana, Cuba: Editorial Científico-Técnica; 1984. 136 p.

31. Soares G, Menezes Z, Barboza R, Sobreira R, Silva F. Effects of traffic control on the soil physical quality and the cultivation of sugarcane. Revista Brasileira de Ciência do Solo. 2014;38(1):135–146. doi:http://dx.doi.org/10.1590/S0100-06832014000100013

32. Cherubin MR, Karlen DL, Franco AL, Tormena CA, Cerri CE, Davies CA, et al. Soil physical quality response to sugarcane expansion in Brazil. Geoderma. 2016;267:156–168. doi:10.1016/j.geoderma.2016.01.004

33. Morejón Y, González R, García de la Figal AE, Vega E, Pérez JL. Influencia de la cosecha mecanizada de la caña de azúcar en la compactación del suelo. Revista Ingeniería Agrícola [Internet]. 2016;6(1):33–38. Disponible en: http://rcta.unah.edu.cu/index.php/IAgric/article/download/727/728