ASSESSMENT OF THE EROSION PROCESSES IN CEJA DEL RÍO LOCATION, LA PALMA MUNICIPALITY

VALORACIÓN DE LOS PROCESOS EROSIVOS EN LA LOCALIDAD CEJA DEL RÍO, MUNICIPIO LA PALMA

AVALIAÇÃO DOS PROCESSOS DE EROSÃO NA LOCALIZAÇÃO DE CEJA DEL RÍO, MUNICÍPIO DE LA PALMA

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Abstract

Actually, the diagnostic methods and indices used to evaluate the erodibility of soils in these territories (hillsides) do not take into account the present phase of morphogenesis, which has led to their degradation. Research carried out in the town of Ceja del Rio in San Andrés region, province of Pinar del Río, revealed the manifestations of the water erosion and erosive-gravitational processes that take place in the Leached Red Ferralitic soils; a situation that is relevant not only in the municipality of La Palma but also in the province since they are distributed in the regions with the highest agricultural production. Given this methodological insufficiency, it became necessary to develop the method: geographical - comparative, morphopedaphological and genetic, allowing for a comprehensive evaluation under a new approach, of soil erosion that precisely defines the natural and socioeconomic factors that limit productive capacity and fertility. of the soils in these regions.

Keywords: soils, erodibility, degradation, erosion, red ferralitic.

Resumen

Hasta el presente, los métodos e índices diagnósticos empleados para evaluar la erodabilidad de los suelos en estos territorios (laderas), no tienen en cuenta la fase de la morfogénesis presente, lo cual ha propiciado su degradación. Investigaciones desarrolladas en la localidad de Ceja del Rio de la región de San Andrés, provincia de Pinar del Río, revelo las manifestaciones de los procesos de erosión hídrica y erosivo - gravitacionales que tienen lugar en los suelos Ferralíticos Rojos Lixiviados; situación que alcanza relevancia no solo en el municipio de La Palma sino también en la provincial por cuanto los mismos se distribuyen en las regiones de mayor producción agrícola. .Ante esta insuficiencia metodológica, se hizo necesario desarrollar de forma integrada. Los métodos: geográfico – comparativo, morfoedafológico y genético, permitió evaluar integralmente bajo un nuevo enfoque, la erosión de los suelos que define con precisión los factores naturales y socioeconómicos que limitan la capacidad productiva y fertilidad de los suelos en estas regiones.

Palabras clave: *suelos, erodabilidad, degradación, erosión, ferralítico rojo.*

Resumo

Até à data, os métodos de diagnóstico e os índices utilizados para avaliar a erodibilidade dos solos destes territórios (encostas) não têm em conta a presente fase de morfogénese, que tem levado à sua degradação. Pesquisas realizadas na cidade de Ceja del Rio, na região de San Andrés, província de Pinar del Río, revelaram as manifestações da erosão hídrica e dos processos erosivo-gravitacionais que ocorrem nos solos Ferralíticos Vermelhos Lixiviados; situação que é relevante não só no município de La Palma, mas também na província, uma vez que se distribuem nas regiões de maior produção agrícola. Dada esta insuficiência metodológica, tornou-se necessário desenvolver o método:

geográfico – comparativo, morfopedafológico e genético, permitindo uma avaliação abrangente sob uma nova abordagem, da erosão do solo que defina com precisão os factores naturais e socioeconómicos que limitam a capacidade produtiva e a fertilidade dos solos. os solos destas regiões.

Palavras-chave: solos, erodibilidade, degradação, erosão, ferralítico vermelho.

INTRODUCTION

The influence of anthropic action on nature has been a growing object of research, with a view to managing its occupation and even evaluating the state of conservation of the territory. For this, it is necessary that they support the proper planning and management of natural resources in a sustainable manner, especially when the discussion focuses on the fragility of these environments in the face of soil degradation and their losses due to erosive processes (dos Santos da Silva et. al, 2022).

With respect to soil degradation, the report called Status of the World's Soil Resources, prepared in 2015 by the Food and Agriculture Organization of the United Nations (FAO), indicates that approximately 33% of the soils in the world has some degree of degradation, whether due to processes of erosion, salinization, sealing, compaction, acidification and pollution, causing innumerable environmental, social and economic losses (FAO, 2015).

In a study by the FAO, 2021, it indicates that each year there is a loss of soil due to erosion on arable lands of between 20,000 and 30,000 million tons due to the effect of water, 5,000 million due to tillage, and 2,000 million by the action of the wind on arable land.

In Cuba it reaches 40% and can reach up to 56% depending on their susceptibility. This process causes the main physical, chemical and biological properties of the soil to be altered, which in turn affect the productivity of the agroecosystems (Riverol & Aguilar, 2015).

In the Cuban archipelago, Red Ferralitic soils represent 23.56% of the agricultural land pool nationwide and are mainly distributed in the Southern Coastal Plain of Havana - Matanzas (45,600 km2), as well as in the Calcareous Plain of Western Camagüey (1 800 km2) and isolate in the eastern provinces and in Pinar del Río (Febles, 2020).

The Leached Red Ferralitic soils belonging to San Andrés Valley in the municipality of La Palma, province of Pinar del Río, specifically in the town of Ceja del Río, are marked by their hillside conditions which favors the degradation of these soils due to erosion. Therefore, it becomes of relevant importance to know the behavior of erosion in these soils. Therefore, the objective of the research is to assess the current state of erosive processes in leached red ferralitic soils from the locality "Ceja del Rio" in the municipality of La Palma, Pinar del Río, Cuba.

MATERIALS AND METHODS

Morphoedafological Unit (UME). (MEU). "Ceja del Río"

It extends over more than 350 hectares, limited to the North by El Mirador, to the South by Ceja de Luna, to the East by the town of San Andrés and to the West by Yayal.

Additionally, at a local scale, two morphopedaphological units (MEU) were included, which according to their spatial distribution, genesis and agricultural use are representative of the geologist-geomorphological environments in which the soil erosion phenomena present in this subregion of the province (Table 1).

Table 1. Geographic location of the Morphoedafological Units (MEU). (Source: self-made)

Tabla 1. Localización geográfica de las unidades morfoedafológicas. (Fuente: elaboración propia)

MORPHOEDAFOLOGICAL UNIT II "CEJA DEL RÍO" -	
Section I	(X = 236137; Y = 316672)
Section II	(X = 236973; Y = 316763)

Figure 1. Satellite shot of the study area (Source: Google Maps)
Figura 1. Toma satelital del área de estudio (Fuente: Google Maps)

Main methods used

The methodological sequence used to evaluate erosion with a genetic approach (Febles et. al., 2008) is summarized below:

Geographic method – comparative

It allowed us to characterize the geological environment of formation in which the pedogenesis – morphogenesis processes take place both in the current and historical context and in a broader sense the dynamics of soil properties under different conditions of use and management.

Description of profiles and soil sampling:

a. Selection of main profiles and control points in the upper, middle and lower thirds in the microrelief flexures.

b. Morphologist – genetic description of soil horizons.

c. Taking samples by depth every 10 cm. starting from the surface to the depth of the erosive diagnostic horizons A + B0-50cm. From that level onwards, every 20 cm. to depths never less than one meter.

d. Selection in the transept or toposequence of profiles with complete horizons (without apparent erosion), as reference profiles or patterns.

e. Use of the new version of the Genetic Classification of Soils of Cuba (Hernández et al., 2019).

Morphopedaphological method

It was oriented to reflect the spatial distribution that leached Red Ferralitic soils objectively present (Schad, 2023), defining on the basis of historical - comparative and evolutionary analysis, the current stage of morphogenesis and in a broader sense the dynamics of the properties of soils (Vega & Febles 2005, Febles et. al., 2020).

Other methods applied

Analytical methods

The methods used for the physical, physical-chemical and chemical characterization of soils are set out in Table 2.

Table 2. Analytical methods used to evaluate soil properties. (Source: self-made)
Tabla 2. Métodos analíticos utilizados para evaluar las propiedades del suelo. (Fuente: elaboración propia)

Determination	**Method**
Chemistry	
pH (H_2O) y pH (KCl)	Potentiometric (1: 2.5)
Organic material	Walkley y Black
Phosphorus and Potassium	Machiguin
Calcium and Magnesium	For its value with EDTA salt
Base change capacity (S) and Cation exchange capacity	Schatschabell
Physics	
Soil density	Cutting cylinders
Solid phase density	Pignometric (in water)
Total porosity	By calculation
Mechanical composition	Kachinski's acid-alkali

RESULTS AND DISCUSSION

"Ceja del Río" morphopedaphological unit. Section I - I

In the erosive diagnosis phase, was found that the intensive and continued use of soils with almost permanent predominance of tobacco cultivation and other seasonal crops, favors the detachment and areal migration of the finest fractions at a rate directly related to the energy velocities of water droplets, causing a sequential descent of the solum towards the concave flexures of the microrelief which act as local base levels for the erosion products generated on neighboring automorphic surfaces. (Figure 2)

Figure 2. Effects of erosion in UME "Ceja del Río". Section I -I. (Source: self-made)
Figura 2. Efectos de la erosión en la UME "Ceja del Río". Sección I-I. (Fuente: elaboración propia)

Influence of erosion on the behavior of physical properties

In the morphogenetic recognition, phenomena that develop as a consequence of erosion were differentiated. In this sense, even when the edaphoclimatic conditions are very similar to the rest of the territory, the development and maintenance of the slopes show a different dynamic, according to the classification of slope elements proposed by Troeh (1965) (See Section I – I. MEU "Ceja del Río").

In fact, profiles C10 and C11 (Moderately eroded) inscribed in one of the convex flexures of the upper third of the macroslope and with lower microgeomorphological stability, denote a differentiated behavior in the results of the mechanical analysis (Table 3).

Table 3. Behavior of the physical properties of soils due to erosion Morphopedaphological Unit II "Ceja Río". Section I – I (Source: Pinar del Río Provincial Soil Institute, 2021)
Tabla 3. Comportamiento de las propiedades físicas de los suelos por erosión Unidad Morfopedafológica II "Ceja Río". Tramo I – I (Fuente: Instituto Provincial de Suelos de Pinar del Río, 2021)

Depth (cm.)	**% of fractions**				**Mg.m^{-3}**	**%**
	Coarse C. 2 – 0,2	**Fine C. 0,2 – 0,02**	**Silt 0,02 - 0,002**	**Clay < 0.002**	**Soil density**	**Total porosity**
Profile C_{10} (Moderately eroded)						
- TYPICAL LEACHED RED FERRALITIC -						
0 - 10	2,40	23.58	28,47	45,55	1,25	47
10 - 20	2,09	18,93	30.48	48,50	1.29	37
20 - 30	1.10	14,85	29.61	54,44	1.30	37
30 - 40	1,07	12,37	29,87	56,69	1.30	37
40 - 50	1,02	10,92	30,03	58,03		
50 - 70	0,96	8,07	31,13	59,84		
70 - 90	0,77	6,12	32,14	60,97		
Profile C_{11} (Moderately eroded)						
- TYPICAL LEACHED RED FERRALITIC -						
0 - 10	0,97	25,83	26,03	47,17	1.25	46
10 - 20	0,89	24,02	27,03	48,06	1.25	42
20 - 30	0,95	19,55	27,00	54,41	1.31	36
30 - 40	0,93	13,19	30,56	55,32	1.33	33
40 - 50	0,83	10,79	31,16	57,22		
50 - 70	0,90	8,32	31,79	58,99		

70 - 90	0,79	6,86	31,29	61,06		
Profile C_{12} (No apparent erosion)						
- TYPICAL LEACHED RED FERRALITIC -						
0 - 10	1.02	25,07	24,31	49,60	1.23	50
10 - 20	1,00	21,11	27,80	50,09	1.25	49
20 - 30	0,90	11,21	27,88	60,01	1.31	48
30 - 40	0,89	9,02	29,05	61,04	1.30	44
40 - 50	0,71	7,01	31,14	61,14		
50 - 70	0,69	6,60	31,15	61,56		
70 - 90	0,66	6,00	31,29	62,05		

Thus, profiles C10 and C11 (Moderately eroded) at a depth of 30 cm. shows an average of the finest fractions (<0.002 mm), of 49.49% and 49.88% respectively, the lowest for the entire transept.

However; the extent that this slope evolves towards forms of greater morphogenetic stability, where the deep alteration and diffuse removal of particles begins to descend, a progressive increase in these same fractions (illumination) is noted, which is expressed in the Profile C12 (No apparent erosion), not only on the surface but also in depth, which is representative for this sector of the unit; similar conclusions were reached (Acosta & Perdomo 2021) in other coverages.

Influence of erosion on the behavior of physical - chemical and chemical properties.

In the analysis of the behavior of the main properties due to erosion effects (Table 4), is possible to see certain differences. Indeed, in the sector of the slope represented by the C10 profile (Moderately eroded), potassium remains low in all the profiles with values between 0.08 and 0.02 Cmol (+).Kg-1 at the level of the solum.

On the other hand, it is striking that in the sector of the slope represented by profile C12 (No apparent erosion), the calcium and magnesium contents are similar to those of profiles C11 (Moderately eroded) and higher in relation to the segment of the slope. microslope represented by profile C10 (Moderately eroded), which could be attributed to the low application of calcium amendments, the intensive use to which this unit has historically been subjected (tobacco - corn succession) and the characteristic mobility of these elements.

The general behavior of the physical - chemical and chemical properties fundamentally in the middle - lower third, where progressively the dynamics of the erosive processes is lower, as there is an environment of greater geomorphological stability, a result that coincides with those reported by Izquierdo et al. . to the. (1990), in hillside environments.

Table 4. Behavior of some of the physical-chemical and chemical properties of soils due to the effect of erosion Morphopedaphological Unit "Ceja del Río". Section I – I (Source: Pinar del Río Provincial Soil Institute, 2021)
Tabla 4. Comportamiento de algunas de las propiedades físico-químicas y químicas de los suelos por efecto de la erosión Unidad Morfopedafológica "Ceja del Río". Tramo I – I (Fuente: Instituto Provincial de Suelos de Pinar del Río, 2021)

Profile C_{10} (Moderately eroded)										
- TYPICAL LEACHED RED FERRALITIC -										
DEPTH	**pH**		**Cmol (+).Kg^{-1}**						**%**	
(cm)	**H_2O**	**KCL**	**Ca^{2+}**	**Mg^{2+}**	**K^{+}**	**Na^{+}**	**S**	**T**	**V**	**M. O.**
0 - 10	4.0	5.0	2.80	0.26	0.08	0.02	3.28	8.80	37.20	1,63

10 - 20	4.0	5.0	3.60	0.61	0.04	0.02	3.89	8.80	44.20	1,35
20 - 30	4.0	5.0	3.20	0.63	0.04	0.02	3.89	10.72	36.20	0,66
30 - 40	5.0	6.0	2.40	1.00	0.04	0.02	3.46	8.42	41.00	
40 - 50	5.5	6.5	2.00	1.06	0.04	0.02	3.17	8.80	36.0	
50 - 70	5.5	6.5	2.40	0.68	0,02	0.02	3.18	8.42	37.70	
70 - 90	5.5	6.5	1.60	0.31	0.02	0.02	1.95	8.04	24.20	
Profile C_{11} (Moderately eroded)										
- TYPICAL LEACHED RED FERRALITIC -										
0 - 10	5.0	6.0	6.40	1.26	0.06	0.05	7.77	16.23	45.0	2,03
10 - 20	5.0	6.0	5.00	0.54	0.42	0.07	6.18	22.98	28.8	1,02
20 - 30	5.0	6.0	4.10	1.74	0.17	0.07	5.96	36.38	18.3	0,85
30 - 40	5.5	6.5	4.00	0.59	0.13	0.05	4.77	17.61	27.0	
40 - 50	5.5	6.5	1.65	0.31	0.15	0.07	2.13	10.72	19.8	
50 - 70	5.5	6.5	1.60	0.35	0.13	0.12	2.16	19.91	10.82	
70 - 90	5.5	6.5	1.60	0.30	0.23	0.05	2.13	10.46	20.36	
Profile C_{12} (No apparent erosion)										
- TYPICAL LEACHED RED FERRALITIC -										
0 - 10	5.0	6.0	6.60	0.99	0.17	0.05	8.06	11.93	42.41	2,15
10 - 20	5.0	6.0	4.80	0.73	0.13	0.07	5.77	11.55	15.32	1,85
20 - 30	5.0	6.0	4.86	0.73	0.13	0.07	5.73	9.1	9.05	1,40
30 - 40	5.5	6.5	4.45	0.65	0.17	0.12	5.31	10.08	32.83	
40 - 50	5.5	6.5	1.25	0.66	0.17	0.05	2.08	7.66	27.1	
50 - 70	5.5	6.5	1.20	3.24	0.32	0.1	4.71	12.81	36.76	
70 - 90	5.5	6.5	2.45	3.01	0.35	0.07	5.80	15.2	37.8	

"Ceja del Río" morphopedaphological unit Section II –II

During the exploratory tours it was found that despite the morphogenetic features that the landscape generally has, the historical succession of tobacco - corn and other temporary crops, have induced the products of erosion which, by virtue of their size, weight and shape have been redistributed by the agroecosystem, by the joint and simultaneous action of two main processes: water erosion and mass removal with defined, but interrelated functions, especially in those sectors with predominantly convex slopes

Figure 3. Effects of erosion in morphopedaphological Unit "Ceja del Río" Section II –II (Source: Own elaboration)
Figura 3. Efectos de la erosión en la Unidad Morfopedafológica "Ceja del Río" Tramo II –II (Fuente: Elaboración propia)

Influence of erosion on the behavior of physical properties

In the analysis of the behavior of the mechanical composition (Table 5), a certain stability is observed in the morphogenesis – pedogenesis balance by virtue of the sector of the macroslope considered, regardless of the relative position shown by the soils in the transept, which could be associated with greater attention by farmers to erosive problems (empirically), using soil conservation practices such as living barriers arranged transversely to the maximum slopes (Fig. 5), which have contributed to reducing runoff during each heavy rain.

Table 5. Behavior of the physical properties of soils due to erosion Morphopedaphological Unit "Ceja Río". Section II – II (Source: Pinar del Río Provincial Soil Institute, 2021)
Tabla 5. Comportamiento de las propiedades físicas de los suelos por erosión Unidad Morfopedafológica "Ceja Río". Tramo II – II (Fuente: Instituto Provincial de Suelos de Pinar del Río, 2021)

DEPTH (cm.)	**% of fractions**				**$Mg.m^{-3}$**	**%**
	Coarse C. 2 - 0.2	**Fine C. 0.2 - 0.02**	**Silt 0,02 - 0,002**	**Clay < 0.002**	**Soil density**	**Total porosity**
Profile C_{13} (Moderately eroded)						
- TYPICAL LEACHED RED FERRALITIC -						
0 - 10	3.62	21,93	22.40	52.85	1,27	49
10 - 20	2,27	19,18	21,87	56,89	1,28	47
20 - 30	2,15	14,28	23,63	59,94	1,33	44
30 - 40	1,01	11,01	25,62	62,36	1.32	42
40 - 50	1,02	8,26	27,09	63,72		
50 - 70	0,98	5,65	2756	65.81		
70 - 90	0,87	4,24	28,96	65,93		
Profile C_{14} (No apparent erosion)						
- TYPICAL LEACHED RED FERRALITIC -						
0 - 10	0,97	17,49	26,09	55,45	1,25	50
10 - 20	0.78	15,13	27,09	57,00	1,26	49
20 - 30	0,70	11,27	28,00	60,03	1,30	45
30 - 40	0,67	7,57	28,57	63,19	1,30	45
40 - 50	0,65	6,89	28,45	64,01		
50 - 70	0,63	5,09	29,13	65,51		
70 - 90	0,59	3,35	30,00	66,06		
Profile C_{15} (No apparent erosion)						
- TYPICAL LEACHED RED FERRALITIC -						
0 - 10	0,82	14,94	26,73	57,51	1,24	52
10 - 20	0,75	11,94	27,12	60,19	1,25	50
20 - 30	0,73	8,87	27,31	63,09	1,28	49
30 - 40	0,70	6,40	27,90	65,00	1,30	45
40 - 50	0,68	4,25	28,04	67,03		
50 - 70	0,60	3,52	28,52	67,36		
70 - 90	0,53	2,15	29,92	68,40		

However, in the three profiles and in correspondence with the degrees of erosion, some illuviation of the fractions < 0.002 mm is evident, this process being relevant in profile C 13 (Moderately eroded), up to a depth of 40 cm. At greater depths, a similar proportion is observed in all the profiles and with a certain independence of the degrees of erosion in all the soils of the slope.

Likewise, the soil density values (Table 5) also denote little difference, especially in the sector represented by profile C 13 (Moderately eroded) due to more energetic erosion, where the intensity of mechanical manipulations, as well as the methods Traditionally used, according to the standards for the cultivation of different crops guided by the Ministry of Agriculture, they produce transformations in the structural state of the soils, causing what Henin et al. (1972) call cultural profile. In correspondence with this morphodynamics, the erosion categories obtained ratify the criteria of Crespo et al. (2006), that under conditions of intensive exploitation, all soils to one degree or another are affected by a physical degradation process.

CONCLUSIONS

- Compaction constitutes one of the most important degradation processes in the physical properties of soils, directly conditioned by the high values obtained in the apparent density and influenced by soil erosion.
- The behavior of the physical and chemical properties in the middle - lower third, the dynamics of the erosive processes is lower, as there is an environment of greater geomorphological stability. little application of calcium amendments, due to the characteristic mobility of these elements, the intensive use of these soils.
- Depth should not be considered a totally reliable index, since in the morphological units investigated, regardless of the degrees of erosion, the Leached Red Ferralitic soils continue to be deep, even when they are eroding.

ÉTICA Y CONFLICTO DE INTERESES

Los autores del manuscrito declaran que han cumplido totalmente con todos los requisitos éticos y legales pertinentes, tanto durante el estudio como en la producción del mismo; que no hay conflictos de intereses de ningún tipo; que todas las fuentes financieras que se mencionan completa y claramente en la sección de agradecimientos; y que están totalmente de acuerdo con la versión final editada del artículo.

REFERENCES

Acosta, ONR, & Perdomo, NAC (2021). Program of actions and improvement alternatives to mitigate erosion in the "Mártires de Barbados" Agricultural Production Cooperative. Scientific Journal Agroecosystems, 9(3), 49-56.

Crespo G., Otero L., Calero B. and Morales A. (2006): Effects of mechanical work on the rehabilitation of a guinea grassland (Panicum maximum Jacq) and on the physical, chemical and biological properties of the soil. Havana. Cuba. VI Congress of the Cuban Society of Soil Science (16:2006 March 8-10: Havana). Memories. CD ROM. Cuban Society of Soil Science, 2006. ISBN 959-7023-35-0

Dos Santos da Silva, ER, Fernandes Ribeiro de Oliveira, V., da Rocha Lima, CG, Salinas Chávez, E., Bacani, VM, & Vick, EP (2022). Geotechnologies applied to the analysis of environmental fragility to erosive processes. Geography Notebooks: Colombian Journal of Geography, 31(1), 222-240.

FAO (Food and Agriculture Organization of the United Nations). 2015. Status of the World's Soil Resources. Rome: FAO

FAO (2021) Soil erosion will lead to reduced food production. Retrieved from: https://www.agronewscastillayleon.com/segun-la-fao-la-erosion-del-suelo-provocara-una-reduccion-de-la-produccion-de-alimentos-del-10-en

Febles-González, José Manuel, Febles-Díaz, José Miguel, Amaral-Sobrinho, Nelson Moura, Zonta, Everaldo, & Maura-Santiago, Ana Victoria. (2020). Myths, realities and uncertainties about the degradation of Red Ferralitic soils in Cuba. Tropical Crops, 41(3), e10. Epub September 1, 2020. Retrieved on February 28, 2024, from http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S0258-59362020000300010&lng=es&tlng=pt

Febles-González, JM, Martínez-Robaina, AY, Amaral-Sobrinho, NMB, Febles-Díaz, JM, & Zonta, E. (2020). Geological environments in the accumulation of heavy metals in soils of Pinar del Río. Tropical Crops, 41(2).

Febles, JM, Vega, MB, & Febles, G. (2008). Integrating system of qualitative and quantitative methods to evaluate soil erosion in the karst regions for livestock use in Cuba. Cuban Journal of Agricultural Science, 42(3), 313-317.

Henin, S., R. Gras, and G. Mounier (1972): The cultural profile. Ediciones Mundi Prensa, Madrid, Spain, 235 pp.

Hernández-Jiménez, Alberto, Pérez-Jiménez, Juan Miguel, Bosch-Infante, Dalmacio, & Speck, Nelson Castro. (2019). The classification of soils in Cuba: emphasis in the 2015 version. Tropical Crops, 40(1), e15. Retrieved on February 28, 2024, from http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S0258593620190001000015&lng=es&tlng=es

Izquierdo, R.; Chirino, E.; Obregón, A.; Frometa, E.; Díaz, A. (1990): The absorption complex in a sequence of Red Ferralitic soils from the heights of Cacahual, Cuba. Rev. Tropical Crops. INCA 12(3): 9-13.

Riverol, M., & Aguilar, Y. (2015). Alternatives to reduce soil degradation in Cuba and confront climate change. Sowing in living soil. Manual of agroecology, Havana, Cuba, 117-132.

Schad, P. (2023). World Reference Base for Soil Resources—Its fourth edition and its history. Journal of plant nutrition and soil science, 186(2), 151-163.

Troeh, F. R. (1965). Landform equations fitted to contour maps. American Journal of Science, 263(7), 616-627.

Vega-Carreño, MB, & Febles-González, JM (2005). Investigation of eroded soils: diagnostic methods and indices. Mining and Geology, 21(2), 18-18.