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Original article

Ph changes in brown soils of Cuba when eroded

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ABSTRACT

In the last 15 years, it has been considering that in Cuba the process of soils degradation by acidification occurs with some intensity. It is about that 40 % of the whole Cuban territory the soils are affected by this process, with an increase or 2.9 % annually. Besides, that with erosion processes occur the acidification of soils. The objective of this paper is to demonstrate that this problem is no really. The increase of soil acidity by soil erosion take place only in Allitics Group of soils, which have a B horizon with a high content of exchangeable aluminum and pH value equal or less than 4,5, but these soils are few extensive in Cuba occupying 555 400 ha that is only 5 % of the territory. The main objective of this paper is to demonstrate that soils of Brown Siallitic Group (that are the most extensive in Cuba, occupying 2 355 800 ha, that is 21 % of the country), when are affected by erosion process increase the pH value because these soils with the depth the pH value is higher. These results show that the acidification process in Cuban soils isn´t so intensive, as is present in some papers.

Key words: Soil degradation. Soil reaction, acidity

INTRODUCTION

One of the great challenges facing agriculture today is to guarantee the food security of the population. For this, it is necessary to have soils that have appropriate conditions to maintain agricultural production in a sustainable way (1).

Soil acidification is one of the negative processes that limit its productivity. It can occur naturally and anthropogenic. It naturally occurs in tropical regions due to the evolution of the soil, due to the chemical-mineralogical transformations that occur due to weathering, in time and space, with the stages of formation sialitization, fersialitization, ferralitization and alitization, recognized by the Cuban Soil Classification (2).

In the alitization process, soils acquire a percentage greater than 50 % due to changeable aluminum. It has caused that in recent years they are classified independently at the first level in soil classifications; as Alitic soils as in the Cuban Soil Classification (1), Alisols as in the World Reference Base soil classification (3) or at the Large Group level as it is in the Brazilian Soil Classification (4).

These soils, in tropical regions, due to the presence of high amounts of exchangeable aluminum, lead to limitations in the adequate development of crops such as wheat (*Triticum aestivum*) and rice (*Oriza sativa*). There is a very high fixation of assimilable P_2O_5, limitations for the development of microorganisms, toxicity created by aluminum since it causes abnormal root development and pH conditions that limit the assimilation of nutrients (5,6) .

Another natural form of acidification of soils occurs in the rainier temperate countries. With the loss of bases in the exchange complex, hydrogen saturation occurs with the decrease in soil pH. This type of acidity is less harmful than in the case of alitization.

In Mexico, great attention is paid, to the problem of soil acidity and its negative influence on agriculture. It has been determined that 7 % of the country's surface (14 million ha) has soils with a pH equal to or less than 6.5 and that the area under cultivation with acidic soils is approximately 14 % of the total surface under cultivation (7). Most of these soils are located in tropical regions such as Veracruz, Tabasco, Oaxaca and Chiapas.

In addition, it must be taken into account that Mexico is a country where volcanism has a great influence on the formation of soils and that volcanic ash in a humid tropical environment evolves rapidly, giving rise to the accumulation of exchangeable aluminum in soils (8).

In Colombia, there are also studies in relation to the acidity of the soil in relation to exchangeable aluminum. For example, one of the most common limitations in Colombian soils is related to the phenomena caused by acidity, which is a consequence of the toxicity generated, mainly, by interchangeable aluminum [9,10]. Other results on the effect of aluminum in different crops at the experimental laboratory level are obtained, in the study of the growth and root morphology of tolerant plants such as wheat (*Triticum aestivum*) and sensitive to high concentrations of aluminum and low values pH (around 4.0) [5]. The development of the roots of the wheat plants (*Triticum aestivum*) was in greater quantity and size than the tolerant ones could be verified. Likewise, high amounts of Al were found in tropical regions changeable in a highly weathered Oxisol [11].

Also in this country, soil pH and nutrient availability are being for a very important crop studied, for the Amazon region such as cocoa (*Teobroma cacao*) [12]

Other studies are related to the improvement of acid soils using different materials that lead to a decrease in the acidity of the soil [9].

In summary, in tropical soils the acidity is by the much-accentuated weathering process caused, which results in the formation of high amounts of changeable aluminum, which leads to the soils being highly acidic (pH less than 4.5).

Despite the toxic nature of aluminum in soils, there are results that show positive aspects in this element, when applied with phosphoric rock in the cultivation of strawberry (*Fragaria vesca*), but in experimental conditions without soil. In this case, it is to aluminum attributed, a beneficial action by solubilizing phosphorus from phosphoric rock and raising its level as a nutrient available to the plant [13].

In Cuba, the high concentration of changeable aluminum and therefore acidity is found in soils classified as Alitic, for which one of the indicators of the classification of these soils is the presence of a pH equal to or less than 4.5, with a changeable aluminum content equal to or greater than 50 %. This process is called alitization [2] and it manifests itself mainly on horizon B and is generally located in the oldest soil formation regions of the Island such as the Alturas de Pizarras, Pinar del Río, Isla de la Juventud and in the stable regions of the Nipe - Sagua - Baracoa, Sierra Maestra and Escambray mountain ranges.

According to some authors, the formation of acidic soils by anthropogenic influence takes place [14] when:

- There is development of acid rains in countries with high industrialization
- Intensive application of residual acid fertilizers such as nitrates and sulfates
- Erosion in soils with acidic pH in the middle and lower part of the profile

In recent years, it is argued that the acidification of soils in Cuba occurs intensely with the erosive process. In our opinion manifests itself well in Alitic soils, but is exaggerated in relation to the extent of soils degraded by acidity (3.4 million ha; 40.3 % of the territory of Cuba) and with the estimated growth of soil acidification for the next 15 years of 2.9 % of the agricultural area (15). There are even authors who affirm the following: Among the factors that most influence the acidification of Cuban soils, erosion is considered, since large amounts of soil are lost and with it, significant base losses, among which calcium and magnesium due to its greater relative abundance with respect to total bases. This causes an increase in the concentration of H^+ ions, lowering the pH levels and increasing the acidification of the soil. According to data from the Soil Institute, 51 % of the total area of acidic soils is eroded, which is evidence of the incidence of the factor that is analyzed (16).

Taking into account the foregoing, this work aims to demonstrate that the soils of the Brown Sialitic Grouping, which are the most extensive in Cuba (3,355,800 ha; 21 % of the territory) (17) and highly susceptible to erosion, they are not acidified by the erosive process, but on the contrary, the pH increases with depth.

MATERIAL AND METHODS

Results of Brown soil characterization were from different publications taken (18-21).

From these results, data were taken from 71 profiles of Sialitic Brown soils, 52 of them from Brown soils and 19 from Grayish Brown soil (Table 1).

Table 1. Number of profiles studied according to the type of soil and source material

Grouping of soils	Genetic type	Source material	Nu. of profiles
SIALYTIC	BROWN	Intermediate rock	12
BROWN		Basic and ultrabasic rock	18
		Rock with little carbonate	17
		Rock with a lot of carbonates	5
	GRAYISH BROWN.	Acid rock	19
	Total of profiles		71

The analytical results shown were by the following analytical methods determined.

- pH by potentiometry with the ratio soil water 1:2
- Changeable acidity by the Sokolov method
- Bases changeable by extraction with ammonium acetate

- Base change ability by extraction with ammonium acetate and saturation with sodium acetate
- Base saturation degree by calculation method

RESULTS AND DISCUSSION

Natural acidification of soils is a process that occurs over time through the action of weathering, being more intense in tropical climates, especially humid tropical ones. In studies carried out in Colombia, it is stated that the nature of acidity in tropical soils is produced by weathering when the bases in clays are replaced by aluminum, this element being the cause of acidity in most soils tropical [(10)].

For the soils of the Amazon it is stated that: Acidic soils are known to be found above all in the tropical strip, Amazonian soils are acidic, generally poor in nutrients and have a low retention potential, especially calcium, potassium and phosphorus . Thus, the soils of the Vaca Diez province are characterized by their low fertility, good internal and external drainage, frank and loamy clay texture, good surface and internal drainage, effective depth greater than one meter, very acid pH (3.7) to moderately acidic (5.5) and a greater use capacity for forest production [(22)].

Despite the fact that aluminum acidity has been found to be toxic to soils, there are results of the application of aluminum accompanied by phosphoric rock, to dissolve phosphorus by acidity, in strawberry cultivation, although in hydroponic conditions [(12)].

At the present time in many texts it is stated that acidification of soils is related to erosion and that many soils when eroded are acidified. This can really happen in Alitic soils. As an example, the data from a non-eroded Alitic soil profile (Table 2) studied in San Juan and Martínez, Pinar del Río are presented below [(23)].

Table 2. Characteristics of an Alitic soil profile of Low clay activity in San Juan y Martínez, Pinar del Río province

Depth, cm	pH		Changeable acidity (cmol)			Changeable bases (cmol)				S cmol	T cmol	GS (%)
	H_2O	KCl	Al^{+3}	H^+	Total	Ca^{+2}	Mg^{+2}	Na^+	K+			
0-20	5.9	4.9	0.6	0.8	1.4	2.0	0.27	0.1	0.45	2.83	4.12	47.0
20-30	5.2	4.0	1.4	2.4	3.8	3.5	0.49	0.1	0.25	4.34	6.34	54.3
30-60	5.0	3.9	5.8	1.2	7.0	3.5	0.63	0.1	0.20	4.43	11.34	43.9
60-90	4.5	3.5	6.0	1.0	7.0	0.9	0.46	0.1	0.15	2.61	---	---

Another highly acidic soil profile in pre-mountainous regions of the Alturas de Pizarras in Pinar del Río, also shows the enrichment in acidity and changeable aluminum in the middle and lower part of the profile (Table 3) [18].

Table 3. Characteristics of an Alitic soil of low clay activity of Alturas de Pizarras, in Pinar del Río

Depth., cm	pH		Changeable acidity (cmol)			Changeable bases (cmol)				S cmol	T cmol	GS (%)
	H_2O	KCl	Al^{+3}	H^+	Total	Ca^{+2}	Mg^{+2}	Na^+	K+			
0-15	4.9	4.1	4.11	0.37	4.48	1.04	0.66	0.15	0.30	2.15	11.78	18.3
15-30	4.8	4.2	4.75	0.37	5.12	0.43	0.52	0.07	0.10	1.12	10.08	11.1
30-60	4.7	4.2	9.26	0.26	9.52	0.24	0.29	0.05	0.07	0.65	11.16	5.8
60-90	4.6	3.8	18.56	0.43	18.99	0.59	0.98	0.27	0.14	1.92	19.90	9.6
90-110	4.7	3.7	17.52	0.44	17.86	0.28	0.19	0.36	0.19	1.02	20.71	4.9

The same occurs with the Alitic soils that appear in stable and ancient parts of the mountainous regions, such as the PDG-5 profile, taken in the Sierra Maestra (Table 4) [24].

Table 4. Characteristics of an Alitic soil of Low clay Activity in the Sierra Maestra, Cuba

Depth., cm	pH		Changeable acidity (cmol)			Changeable bases (cmol)				S cmol	T cmol	GS (%)
	H_2O	KCl	Al^{+3}	H^+	Total	Ca^{+2}	Mg^{+2}	Na^+	K+			
Profile PDG-5												
0-22	4.30	4.10	---	---	---	2.50	1.87	9.35	0.53	5.25	---	---
22-50	4,10	4.00	---	---	---	1.25	0.62	0.22	0.15	2.24	---	---
50-80	4.00	3.90	---	---	---	1.25	1.25	0.22	0.06	2.78	---	---
80-110	4.15	4.20	---	---	---	---	---	---	---	---	---	---

As can be seen in these three soil profiles, they present a very acid reaction, especially in the middle part, with a lot of changeable aluminum. Its formation is natural due to the alitization process in time and space. If they erode, the acidity increases, they appear in the upper part of the profile, the clayier and more acidic horizon B, with a high content of changeable aluminum. That is, the Alitic soils are formed by a natural process of soil formation, called alitization [1] and are distributed both in Alturas de Pizarras, as well as in the part of San Juan and Martínez in Pinar del Río, as well as in the mountainous massifs of Cuba. For them, the accumulation of exchangeable aluminum in a percentage greater than or equal to 50 % is common, mainly in the middle and lower part of the profile; with very acidic reaction. They, by their nature and the relief conditions, are very vulnerable to erosion; thus, when they are eroded, the acidity increases, due to a relative acidification of the soil. Therefore, acidification of soils by erosion is valid for the Alitic soils of Cuba. However, not all soils that are eroded have this problem.

In order to know if this problem is extensive, it would be necessary to determine the area of eroded Alitic soils. In this case, in the first place, it would be necessary to see what surface these soils occupy in Cuba, since many mountainous soils are not cultivated and if they are the cultivation of coffee or cocoa, which are permanent plantations that tend to enrich the organic matter content of the soil. Furthermore, Alitic soils occupy relatively little extensive surfaces in Cuba.

However, this same problem does not occur in the Brown Sialitic soils, which are the most extensive in Cuba, in wavy-ridged, pre-mountainous and mountainous reliefs [(17)].

It must first considers the process of formation of these soils, which is sialitization called [(1)]. Due to this process, the decomposition of the primary minerals results in the formation of clay, with bases such as calcium, magnesium, potassium and sodium in the form of hydroxides, which initially leads to an alkaline pH, later with the weather and over time the soil is washed, partly with silica and with bases, the pH being less alkaline. The most important thing is the formation of clay of the smectite type, in conditions of pH between 6.5 and 7.5. In the deeper layers, with BC and C-horizon, the weathering is less intense, so the pH tends to be higher.

Taking into account the above, in this work 71-soil profiles of the Brown Sialitic Grouping are analyzed, which include the Brown and Greyish Brown types (Table 1). The degree of erosion and its correspondence with the pH values in each of the types of these soils were determined, also in relation to the type of source material. These results are set forth below in Table 5.

The data obtained shows that, in all cases, with depth the pH value increases or remains almost the same instead of decreasing. This shows that, if these soils are eroded, they increase in pH instead of decreasing, very different from what is proposed that with erosion the acidity of the soil increases [(16)].

Table 5. pH values in Brown Soils of Cuba, in relation to the degree of erosion

Type of soil	Type of origin of material	Degree of erosion	pH(H_2O)		
			Hor. A	Hor. B	Hor BC
Brown	Intermediate rock	No erosion	6.56	6.60	7.15
		Soft	6.20	6.20	6.10
		Median	6.90	6.78	6.88
		Strong	6.80	6.75	6.84
		Very strong	7.83	---	---
	Basic or ultrabasic rock	No erosion	6.26	6.53	6.68
		Soft	6.85	7.00	---
		Median	7.06	7.45	7.70
		Strong	6.53	7.03	7.40
		Very strong	No	No	No
	Rock with little to medium carbonate content	No erosion	7.29	7.56	7.88
		Soft	6.77	7.75	7.91
		Median	---	---	---
		Strong	---	---	---
		Very strong	Sin Hor A	Sin Hor B	7.89
	High carbonate rock	No erosion	8.10	8.19	8.40
		Soft	7.68	7.78	8.00
		Median	---	---	---
		Strong	---	---	---
		Very strong	Without Hor A	8.10	8.50

In the case of the genetic type of gray-brown soil, they are also formed by the sialitization process, but edaphogenesis occurs under conditions of a very particular type of rock that is made up of acidic rocks (in Cuba mainly granitoid rocks), rich in quartz, feldspars and some amphiboles and pyroxenes. In these conditions under a sub-humid tropical climate that takes place in most of the plains of Cuba, in relatively young reliefs, the soil is formed with accumulation of a lot of quartz, which remains residual in the form of sand, while feldspars and amphiboles and pyroxenes and weathering resulting in the formation of clay, and the corresponding hydroxides. Silica is not as abundant as in intermediate and basic rocks, 2:1 type clay is in combination with 1:1 formed, and the washing process tends to be faster due to the mineralogical composition and lighter texture than it acquires the soil compared to this same process on other types of soil-forming rocks.

However, at depth the soil has a higher pH than on the surface and does not become acidic, on the contrary, the pH becomes more alkaline. This is why, as with brown soils, if the soil erodes, it becomes more alkaline rather than more acidic. The data shown in Table 6, demonstrate the above described, for the different degrees of erosion that can occur in these soils.

Table 6. PH values in gray-brown soils of Cuba, according to the degree of erosion

Soil Type	Source Material Type	Erosion Degree	pH(H_2O)		
			Hor. A	Hor. B	Hor. BC
Greyish Brown	Acid rock	No erosion	6.32	6.46	6.50
		Soft	6.36	6.33	6.86
		Median	6.50	6.68	7.03
		Strong	6.01	6.52	6.82
		Very strong	6.32	6.46	6.50

Even now, it has been recognized that in the Ferralitic Red and Red Leachate soils of the so-called "Red Plain of Havana" the pH is increasing (25). For this, a hypothesis was, based on the degradation of the soil developed by continued cultivation and the increase in the average temperature in the plains of Cuba (26) it has increased 0.9 ºC in the last 60 years.

This problem of the increase in pH in Ferralitic Red and Ferralitic Red Leachate soils is affecting tobacco cultivation in the lands of the Tobacco Company Lázaro Peña in Artemisa, for which reason research is being to decrease the pH in these soils carried out by applying acidic peat with very good results (27, 28).

All this contradicts what is argued about the excessive acidification of the soils in Cuba and the tenor of acidification predicted for 15 years, as it was proposed in 2001 (15).

CONCLUSIONS

- Acidification of soils in Cuba occurs in Alitic soils naturally by the alitization process and anthropogenic when the erosion process occurs in them.
- The Brown Sialitic soils of Cuba are by the sialitization process formed, they do not acidify when they are eroded, but in most cases, the pH value increases, on the contrary, what with Alitic soils occurs.
- From the above, it is shown that acidification by erosion in Cuba is reduced only to Alitic soils that are not very extensive, reduced only to areas in the Alturas de Pizarra regions in Pinar del Río, in some parts of Isla de la Juventud and on the old stable surfaces of the mountainous regions of Cuba.

- The results of this work demonstrate that the data related to degradation by acidification in Cuban soils, its prognosis and the process that occurs due to soil acidification by erosion are not valid.

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