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Bibliographic review

Myths, realities and uncertainties on the degradation of red ferralitic soils in Cuba

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ABSTRACT

Currently there is a global debate on the degradation of soils, their magnitude and agro-environmental impact, on which, long-term experimentation provides qualitative and quantitative criteria regarding their capacity for restoration through rational use and management. In this context, research conducted over the past 30 years confirms that the existence of degradation processes in Red Ferralitic soils in Cuba has a multifactorial nature, dependent on geological - geomorphological conditions, extreme weather events and intensive anthropogenesis. Taking into account these aspects, the present work reviews 10 main visions, which have limited the full recognition of the specific modalities assumed by water erosion and erosive - karst in these regions, which reveal the need to adopt a policy so that its protection ceases to be a myth and becomes a National Security issue. Experience shows that the lack of harmonized methods of surveillance and information transfer is one of the causes that generates uncertainty about the state of its degradation.

Key words: Uncertainty, degradation, karst region, Red Ferralitic soil

INTRODUCTION

Uncertainty is the imperfection in knowledge about the state or processes of nature (1). For any scientific discipline it is good to look back and distinguish what has been achieved, how it was done and if something can be learned from the past. In relation to Soil Science, it is not only to look back, but forward, so that centific advances can take place.

Every day the number of pediatric research and publications increases in such a proportion that they have lost their ability to obtain objective conclusions from scientific reports on the effects of one or more factors under study, expressed with wide uncertainty due to the fact that the sizes The sample or working scale are insufficient (2), modulated by the anthropogenic factor in the last 300 years in such a way that a new geological era called Anthropocene has been proposed (3).

In Cuba a generation of soil scientists is retiring and there are few new positions created, so it is necessary to face this change and ensure knowledge with the available methods to better understand and manage our soils. Scientists have never had so many pedological problems to investigate as they do today. For this, it is necessary to emphasize the investigation in agro-environmental regimes of geographic surfaces, in order to determine the effects in a space-time dimension where the karst regions impose their singularity.

The study of the geological environments of formation of the Red Ferralitic soils began during the third decade of the last century (4), which marked a milestone in Cuban pedology and especially in its geography. Subsequently, numerous researchers (especially in the 1980s) supported their doctoral theses on topics related to their genesis and geography, which denotes the unquestionable edaphological-heritage value and uniqueness that these soils possess for Cuba (5).

Taking as reference the research and articles published for more than three decades that reveal the effects of karst morphogenesis associated with Red Ferralitic soils in the Southern Karst Plain Havana-Matanzas, this work performs an objective examination of the main results that have led to certain myths and uncertainties about these soils, which the Soil Institute (6) continues to classify as "not eroded", a situation on which it is imperative to reconsider in order to prevent the sequential degradation of the most productive soils of Cuba.

Some necessary background

The term karst is a word used to refer to the earth's surface when limestone or other soluble rocks are dominant (7). In these environments, the relief is characterized by the diversity of negative forms such as sinkholes and grape-like depressions, and positive forms such as karst heights or "mogote karst" with sizes ranging from millimeters such as lapiaz to large poljes (8,9). The basic conditions for the formation of karst according to (10), are three, the lithological, structural and climatic factors. Subsequently, two more factors were incorporated, the vegetation and the time of exposure of the rock to weathering.

There is currently a global debate on soil degradation, its magnitude and agro-environmental impact, which can only be resolved through systematic evaluation and long-term experimentation to obtain criteria on its specific functions and rational use (11). However, studies of soil erosion in the karst regions are very scarce, given their geomorphological, climatic and biogeographic singularity with phenomena that occur at different spatial and temporal scales that can cover thousands of hectares or hundreds of years (12), which influence erosion estimates and modeling.

Cuban karst has been developed on carbonate-type lithological units whose age varies from pre-Jurassic to Quaternary, both inclusive (13). It contains the most important underground water reserves, oil fields, important useful minerals and practically four fifths of the nation's population uses or takes advantage of its natural resources (14). In this context, the Red Ferralitic soils constitute an important category due to the wide extension they occupy and those of the Red Leached Ferralitic Type are predominant, which can be correlated with the eutric rhodic Nitisol (15), where the differences are given by the type of use. of the land and the distribution of the horizons.

Myth: Its geographical distribution only in plains regions

In the Cuban archipelago, the Red Ferralitic soils represent 23.56 % of the agricultural land fund at the national level and are distributed mainly in the Southern Coastal Plain Habana-Matanzas (45 600 km^2), as well as in the Calcarea Plain of the West of Camagüey (1 800 km^2) and isolated in the eastern provinces and in Pinar del Río (16). They are also present to a lesser extent in horst-like environments with flat tops (17) (Figure 1).

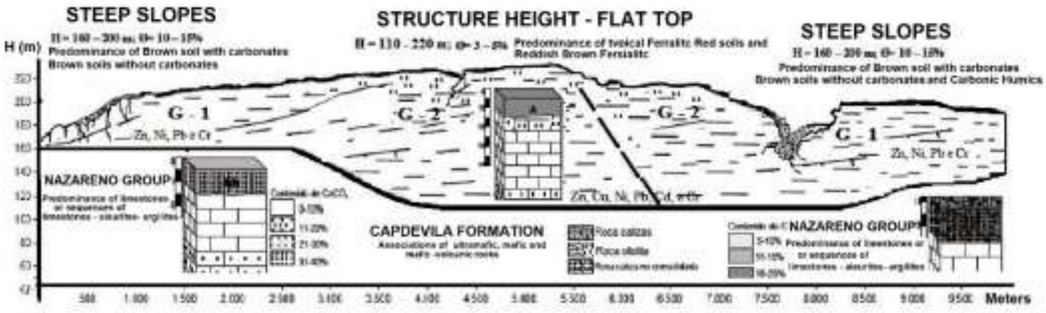

Figure 1. Spatial distribution of Red Ferralitic soils in the Nazareno Heights, Mayabeque province, Cuba

Taking these aspects into consideration (18), it specified the need to differentiate at least three main magnitudes of relief (macro, meso and micro-relief), to which the set of processes that participate in the formation or degradation of pedological coverage must be referred to. , so that the karst forms are recognizable (scales 1: 5 000; 1: 2,500 and higher), and are considered as manifestations that can objectively limit the productivity of Red Ferralitic soils. The application of geostatistical methods and spatial analysis techniques for such environments will help solve some of these difficulties in the future (19).

Reality: Ignorance of the influence of the geological environment

The Cuban archipelago is characterized by the intense manifestation of karst phenomena, particularly the Mayabeque and Artemisa provinces that have between 80-85 % of its karstified territory (19), where the exokárst forms such as sinkholes, grapes and filled micro valleys generated by the dissolution of the carbonated substrate, given its ability to collect, transform, or drain surface and groundwater (20). Despite the abundance of literature on the influence of bedrock and weathering crusts, the geological and lithostructural conditions of soil erosion in the karst regions have generally been little studied (Table 1) (21).

Table 1. Values of the formation rates of Red Ferralitic soils in Cuba

Characteristics	**Training rates (mm year^{-1})**	**References**
Age of limestone floods in the Southern Plain of the Mayabeque and Artemisa provinces		
Derived from rocks with 10 % impurities it takes a million years to reach 15 m depth	0.05	(22)
Limestone derivatives with 1% impurities. it would take about two million years to reach two meters depth	0.01	(23,24)

Among the classic works that have considered this approach, those carried out (25) at the "Ciro Redondo" Company in the Agramonte municipality, Matanzas province; (26) in Melena del Sur; (27) in Catalina de Güines; (28) throughout Cuba to determine the structural-functional properties; (29) in the vicinity of a sinkhole in the Quivicán region (30) and in the karst regions of western Cuba.

Geophysical investigations carried out in the San José de Las Lajas polje confirm the action of a series of complex internal and external processes that have led to the formation of a particular modeling (Figure 2), in which CO_2 of biogenic origin has been one of the main factors involved in the dissolution of limestones and the generation of karstification processes that take place through innumerable cracks and fissures with different diameters (from capillaries to 2 mm in width) and lengths (up to 15-20 m), which spread spatially throughout the karst massif (31).

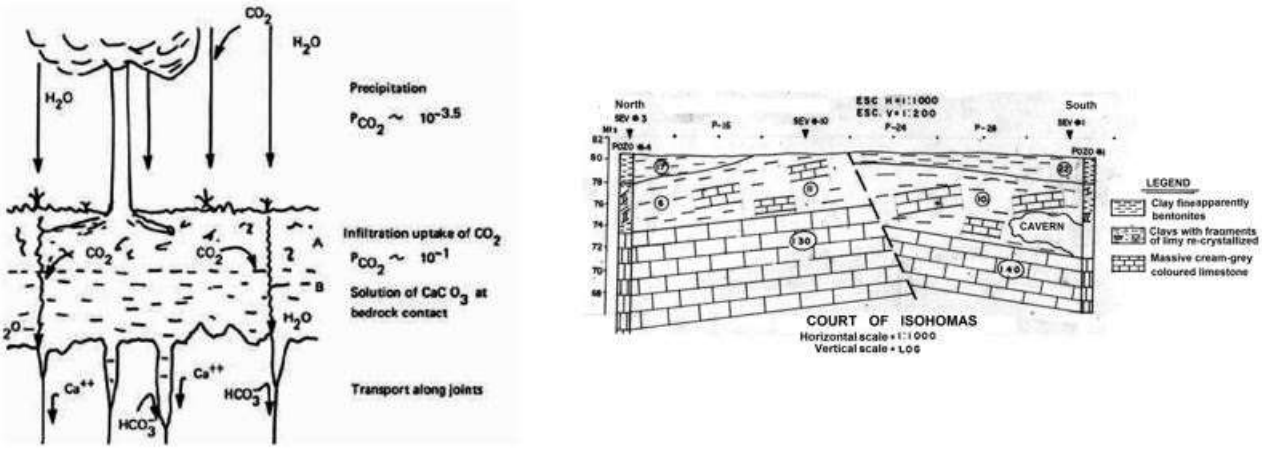

Figure 2. (a) Dynamics of karst processes (31) and (b) vertical electric sounding in sinkholes in the polje of San José de Las Lajas, Mayabeque province (30), Cuba

As for the Bejucal - Madruga - Coliseo Group Heights, the karst, bare and partially bare karsts show practically all the characteristics of the reliefs of karst denudation (32). Lithology is therefore the essential factor in these environments, since it determines the very existence and irreversibility of the karst process (unidirectional evolution) and modulates almost all of the edaphogenic processes through constantly evolving forms.

Reality: Degradation of the properties of Red Ferralitic soils

Regarding the modification of the properties (Table 2), the most notable effects are mainly expressed at the depths of the diagnostic horizons $A+B_{0\text{-}50\ cm}$ with the progressive decrease in the content of organic matter, increases in pH, compaction values with apparent density thresholds higher than 1.34 mg m^{-3}, reinforcement of the karst - erosive processes, salinization, among others, with a marked tendency to increase, which has received different names such as “agrogenic formation of soils” (15,33) and irreversible degradation (34). According to the initial content of organic matter in these soils exceeded by far 10 % (35,36), currently it is between 3-4 % and apparently does not stop decreasing, deteriorating in unison the physical properties that characterized them (37).

Table 2. Statistical behavior of some soil properties in the Southern Karst Plain Habana - Matanzas, Cuba (38)

	Total measurements	**Values**			**Deviation standard**
		Minimum	**Maximum**	**Average**	
Ca	229	3,00	62,50	*22,32	13,32
Mg*	229	1,10	50,00	6,14	4,27
P*	229	0,10	901,00	96,16	141,94
CCB	229	4.70	71.75	29,22	15,43
MO	229	0,05	6,90	2,00	1,23
pH (H_2O)*	226	5,48	8,32	7,62	0,56
pH (K Cl)*	226	4,96	7,77	6,92	0,60
Da	229	0,92	1,99	1,30	0,18
RP $_{10-15\ cm}$ **	94	0,40	3,80	1,51	0,76
RP $_{20-30\ cm}$ **	89	0,00	3,90	1,91	0,75
RP $_{35-40\ cm}$ **	79	0,33	4,4	1,94	0,75

* Logarithmic distribution ** Expressed in MPa

Regarding the acid-base balance (Table 3), the profound changes that have taken place over time are evident at present in the high average pH (7.62) (39). Likewise, it has verified this basification phenomenon (increase in pH) (40) and has associated it with climate change, mainly to the increase in the average annual temperature and the minimum annual temperature recorded in the last 20 years, especially in areas destined for various crops. Additionally indicate that the alkalization (current or potential) of the soils in the Red Plain Havana - Matanzas also obeys anthropogenic factors (41), related to the use for decades of calcium bicarbonate waters for agricultural irrigation.

Table 3. Average pH values in (H_2O) by depths in leached Red Ferralitic soils, according to agricultural use (40)

Type of profile	**Number of profiles**	**Depth (cm)**			
		0 – 20	**20 - 40**	**40 - 60**	**60 - 100**
Pattern	6	6.89	6.46	6.18	6.16
Conserved	14	6.79	6.70	6.46	6.47
Cultivated	18	7.19	7.05	6.99	6.83

It is to say that in more than two decades there have been no studies on the soils in Cuba that can provide more updated information on these parameters. There is, however, an immense amount of studies on various soils in particular, from which this information could be extracted, after much cabinet work (42).

Myth: Red Ferralitic soils do not erode

The use of different nomenclatures and measurement techniques have generated comparison problems and estimates of dissimilar losses of the soil erosion status in the country are frequent (43). In this context, it is relevant to mean that the methods and indicators selected by the Ministry of Agriculture (44,45) to determine the degree of erodability, have not fully evaluated the geological formation environments, overvaluing the depth, such as the index of fundamental diagnosis (46) from a very shallow adaptation of the Soil Survey Staff Classification (47) to the edaphoclimatic conditions of Cuba, as evidenced in Tables 4(47) and 5 (45,48).

Table 4. Soil Survey Staff, U.S. classification

Degree of erosion	Losses
Light erosion	Removal and drag of 25 % of the tillable surface layer (less than 5 cm)
Moderate erosion	Removal and drag of 25 - 75 percent of the topsoil layer (5 - 15 cm)
Severe erosion	Removal and dragging of more than 75 % of the arable surface layer and part of the subsoil (more than 15 cm)
Very severe erosion	Removal and dragging of most of the soil profile

The latter was expressed in the maps of current and potential erosion prepared (48,49) and more recently (32), in which deep soils such as the Red Ferralitics are classified as non-eroded (100 points) (50), while that the few evolved or skeletal are classified as eroded.

Table 5. Evaluation of soil losses due to erosion

Degree of erosion	Losses
Very little or no erosion	Horizon A losses by 25 %
Moderate erosion	Horizon A losses between 25 – 75 %
Severe erosion	Losses of horizon A by 75 % and up to 25 % of horizon B
Very severe erosion	Horizon B losses between 25 – 75 %

However, investigations carried out in the Pedroso - Mampostón sub-basin (51) with the application of the Morgan, Morgan and Finney model (52), report an average removal towards the karst depressions between 13.4 - 17.4 t ha^{-1} $year^{-1}$ that exceed the permissible limits in terms of erosion (Table 6), with a forecast of losses for future scenarios (period of 25 and 50 years) of 1.07 mm $year^{-1}$ of the surface horizon, which exceeds the tolerance values proposed by the USLE (53) and the formation rates of soils derived from limestone rocks in Cuba (24).

Table 6. Soil losses in the sinkholes applying the MMF model (52) in the localities "Rosafé Signet" and "Aljibe" (5)

Stage 1986 - 2009									
C_1 (Apparently not eroded)									
Dolina	**Horizon A (0 – 490 mm)**								
Nu.	**Soil loss (t ha^{-1} year^{-1})**				**Soil loss (mm year^{-1})**				**C.V. (%)**
	1986	**1997**	**2009**	**Mean**	**1986**	**1997**	**2009**	**Mean**	
1	15.957	17.82	17.649	17.227	1.228689	1.37214	1.358973	1.326479	5.97
2	17.631	16.917	20.208	18.46	1.357587	1.302609	1.556016	1.42142	9.37
3	21.357	22.128	23.613	22.554	1.644489	1.703856	1.818201	1.736658	5.08
4	14.847	14.244	14.262	14.442	1.143219	1.096788	1.098174	1.112034	2.37
5	10.011	8.355	11.91	10.345	0.770847	0.643335	0.91707	0.796565	17.19
6	9.39	9.729	10.425	9.876	0.72303	0.749133	0.802725	0.760452	5.34
7	10.686	17.142	12.042	13.894	0.822822	1.319934	0.927234	1.069838	24.5
8	12.024	10.029	12.381	11.566	0.925848	0.772233	0.953337	0.890582	10.95
9	9.012	10.143	10.668	10.142	0.693924	0.781011	0.821436	0.780934	8.34
10	10.725	11.514	12.306	11.58	0.825825	0.886578	0.947562	0.89166	6.82
11	16.068	20.226	19.419	18.885	1.237236	1.557402	1.495263	1.454145	11.67
12	13.038	13.077	14.319	13.548	1.003926	1.006929	1.102563	1.043196	5.38
13	16.653	18.12	18.816	17.97	1.282281	1.39524	1.448832	1.38369	6.14
14	10.275	11.628	13.038	11.814	0.791175	0.895356	1.003926	0.909678	11.69
15	---	---	14.073	---	---	---	1.083621	---	---
16	---	---	36.897	---	---	---	2.841069	---	---
Mean	12.329	13.292	13.707	---	0.949333	1.023484	1.05543	---	---

Reflecting on these approaches, they proposed an integrating system of qualitative and quantitative methods (Table 7) (54), which makes it possible to specify the main agents that intervene as causes, the components of the geographical environment, which participate as factors and cause the emergence and differentiation of the processes and erosive forms present.

Table 7. Methodological sequence and contributions of the main research methods to evaluate soil erosion in Cuba

	Description for its application
Geographic - comparative	It characterizes the geological formation environment in which the pedogenesis - karstogenesis processes take place both in the current context and in the paleogeographic 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 of the micro-relief flexures. b. Morphologist - genetics description of soil horizons. c. Sampling by depths every 10 cm. from the surface to the depth of the erosive diagnostic horizons $A + B_{0\text{-}50\ cm}$. From that level onwards every 20 cm. to depths never less than a meter. d. Selection in the transept or toposequence of profiles with complete horizons (without apparent erosion), as reference profiles or standards. e. Use of the new Classification of Soils of Cuba (55).
Morphoedaphological	From a genetic perspective it allows access to the biophysical environment both in its description and in its dynamics, and to specify the phases of the erosive processes (incipient or paroxysmal).
Geophysical (vertical electrical sounding) and electrical profiling	In the karst regions it allows to characterize the morphostructural conditions of the subsoil and the degree of development of the karst processes.
Thematic mapping of factors in a SIG environment	Qualitatively assesses the potential and current erosion risk of soil cover. a. CORINE method (56), for the generality of morphoedaphological environments. b. EVERC method (52), for karst geosystems.
Erosion models	a. Quantitatively evaluate the magnitude of soil loss. b. Depending on the availability of the data, some of those proposed by the specialized world literature will be selected. c. In the karst regions corresponding to the phase of karst morphogenesis (incipient or paroxysmal), it is suggested to use the MMF model (57).

They also emphasize that in the karst regions it is not possible to apply the same methods, means and scales of representation used for other geoecosystems, therefore it would be strategic for the 62 polygons or demonstration areas of Soil, Water and Forest Conservation that the Ministry of Agriculture (MINAG) has distributed throughout the country (58), at least one was established in areas of Red Ferralitic soils.

Uncertainty: The effects of climate change

Predictions made in the different climate change scenarios indicate that rainfall in Cuba will increase in some regions, while in others drought will increase, in a rather irregular temporal and spatial distribution (6,59–61).

However, in the Havana-Matanzas Karst Plain there are no significant changes in the main climatic variables (Table 8), especially in the average surface temperature and average precipitation levels, so it is not conclusive to categorically attribute the influence of the change climatic processes of soil degradation (60), although yes to the rain erosion associated with extreme meteorological events to which are added more than 50 years of inadequate agricultural practices of exploitation of the edaphic cover and use of resources in a way irrational, which makes their productivity very vulnerable to future climate variations; resilience will depend on the magnitude of the threats and the success of management practices.

Table 8. Main climatic variables of the Karst Plain Havana - Matanzas, Cuba

Weather stations	**Reference (1960 - 1990)**				**Reference (1991 - 2011)**			
	T max (ºC)	**T min (ºC)**	**T average (ºC)**	**Prec (mm)**	**T max (ºC)**	**T min (ºC)**	**T average (ºC)**	**Prec (mm)**
Stgo de LasVegas	29.6	20.2	24.9	128.3	29.8	20.2	25.0	134.4
Güira de Melena	30.2	19.5	24.9	108.4	30.5	19.7	25.1	133.8
Batabanó	30.2	19.6	24.9	97.70	30.3	19.5	24.9	121.2
Güines	30.2	19.4	24.8	123.8	30.4	19.3	24.9	124.1
Bainoa	29.5	18.4	24.0	116.4	29.7	18.0	23.9	131.9
Bauta	29.4	19.2	24.3	111.0	29.7	19.5	24.6	126.9
Tapaste	29.2	18.9	24.1	126.6	29.4	19.1	24.3	124.8
Melena del Sur	30.6	19.0	24.8	124.9	30.5	19.5	25.0	130.3
Unión de Reyes	30.9	19.8	25.4	110.5	30.8	19.6	25.2	129.5
Jovellanos	30.3	18.7	24.5	126.5	30.7	18.8	24.8	128.1
Jagüey Grande	31.3	18.8	25.1	123.5	31.4	18.7	25.1	128.1
Colón	31.1	19.3	25.2	108.7	30.6	19.3	25.0	126
Mean stations	30.2	19.2	24.7	117.2	30.3	19.3	24.8	128.3

On the other hand, if as a result of the application of a management strategy, the percentage of C increased by only + 0.1 %, it would entail an increase in the dissolving capacity of the waters by 1.3 times (Equation 1), the most obvious manifestations of which will be the extent of corrosion cracks ("early shear"), a process that in recent years has begun to experience variations in response to natural or induced stimuli (60).

$$nCaCO_3 + (n + 1.3)\ CH_2CO_3 \leftrightarrow (n + 1.3)\ (Ca^{2+} + 2HCO_3-) \quad [1]$$

Consequently, the sequestration of C in karst areas coinciding with CO_2 sinks has a dual effect, that is; beneficial for the soil and the geoecosystem in general by mitigating future effects of climate change (Figure 3), but which at the same time increases karstogenesis by acidifying the edaphic environment, a dynamic that until now has been insufficiently investigated in Cuba (62).

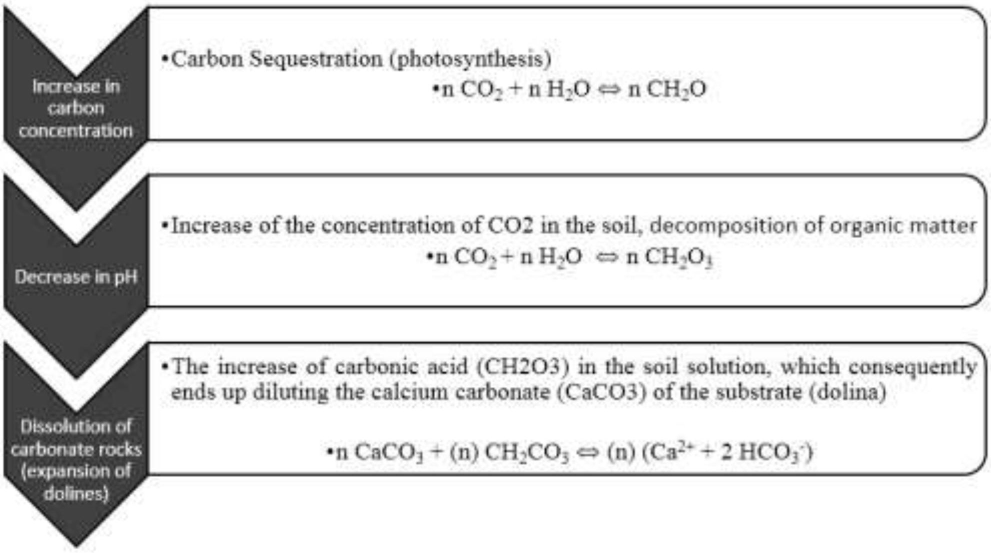

Figure 3. Process that promotes the increase of carbon in the soil and the dissolution of the carbonated substrate

Reality: The advance of karst morphogenesis or karstogenesis

In the investigated localities, an erosive modality inherent in the Red Ferralitic soils is developed, called subsurface erosion, as a result of their removal into the karst cavities, a phenomenon described in the pioneering works in these territories (63). Karst gullies with "U" and "V" shaped valleys are frequent, which, as geomorphological barriers, are arranged transversely to the general slope that the slopes show, intercepting runoff, as well as the products of erosion which, due to this pathways are redistributed throughout the region (Figure 4).

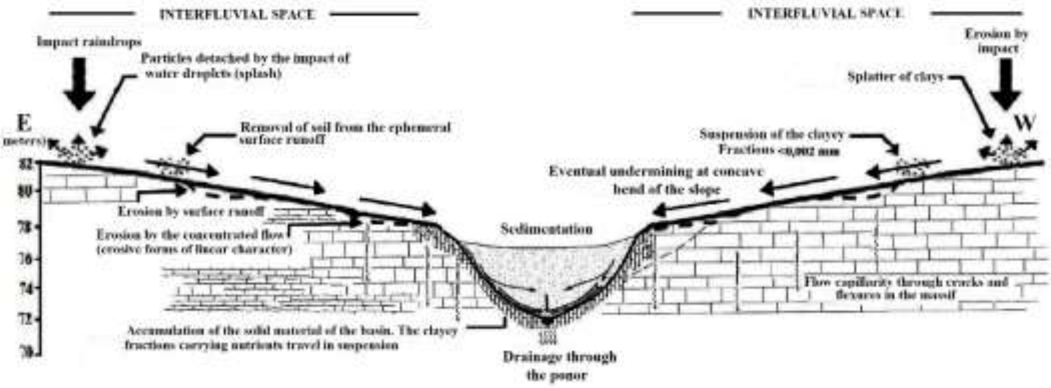

Figure 4. Dynamics of the karst - erosive processes in an interfluvial space in the Karst Plain - Merdional Habana – Matanzas, Cuba

This "regulating" effect of surface flow is often one of the basic elements of hydrographic tissue, where the absorption forms and their component elements exercise some control of surface and subsurface runoff, which coincides with the descriptions of some authors (64,65).

Consequently, the diffusion of the products of erosion varies from one sector to another of the interfluvial space, in accordance with the peculiarities of the relief and the permeability of the supporting material, in some cases its incorporation will be direct in the drainage network, while in others they are incorporated in a diffuse way into the network of karst glands of "organized heterogeneity" where they can reside for a long time, depending on the case, dynamics that clearly differentiate these regions from any other (66).

Uncertainty: The resilience of Red Ferralitic soils

When it is intended to describe the situation of Red Ferralitic soils in a spatio-temporal context, any review goes through the states of their aptitude that can favor, limit or inhibit resilience, since it is a multifactorial process, conditioned not only by the properties intrinsic to edaphic coverage, but dependent on geological - geomorphological conditions and conditions of use (21).

According to the selected rates for the rate of formation of the Red Ferralitic soils (Figure 5), 100 % of the horizon $A_{0\text{-}490\ mm}$ would be renewed under normal agricultural practices from a reference profile located in an area in biostasis to the 50 years, while with the percentage of impurities that the limestones possess, the same depth would be restored at 100 and 600 years respectively (21).

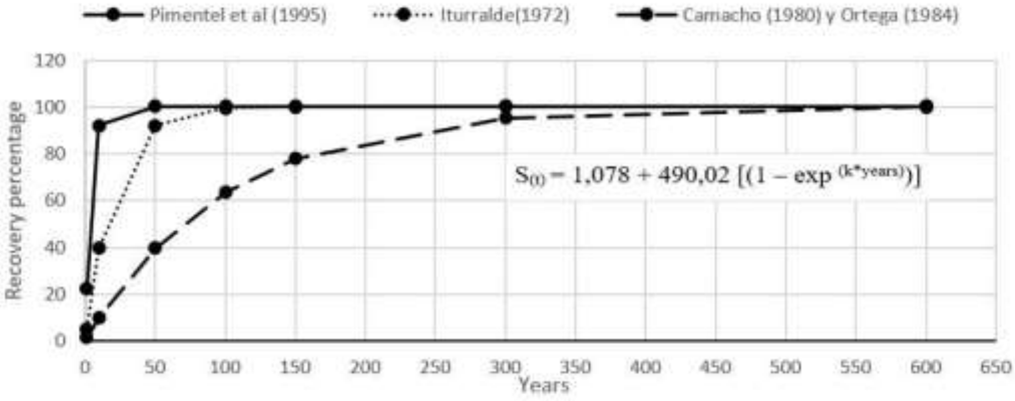

Figure 5. Resilience of Red Ferralitic soils in the localities "Rosafé Signet" and "Aljibe". Mayabeque province, Cuba

Likewise, a comprehensive evaluation of the polje of San José de Las Lajas confirms an evolution of the karst-erosion process in the last thirty years practically impossible to reverse by overcoming the buffering capacity of the soils in this peculiar ecosystem, which has largely prevented get an overview of this problem. In any case, karst ecosystems are subject to constant disturbances that hinder resilience research work. Ignoring or underestimating these processes has led to one of the most widely spread myths in Cuban soil science regarding the immunity of these soils to erosion (62).

Reality: Relationship between erosion-sedimentation-contamination processes

The edaphic cover "archives" traits and properties inherited from past climatic and geological phases, which are not in balance with current edaphogenic processes (67), this is particularly important in different environments (flat and hillside karst) and performance levels (Figure 6), where links between sedimentation and contamination processes coexist with the manifestations of soil erosion referred in Lebanon (68), in Southwest China (69) and in Red Ferralitic soils from Cuba (70).

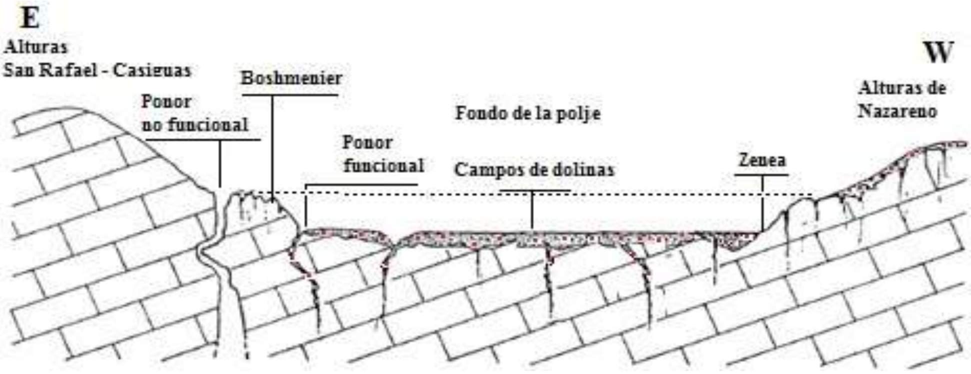

Figure 6. Dynamics of the erosion - sedimentation - contamination of soils by heavy metals in different environments in Mayabeque province

This has been confirmed in the comparative analysis of the natural values of heavy metals in the main soils of the Nazareno Heights with respect to the internationally used reference values (Table 9).

Table 9. Natural values of MP in the soils in Alturas de Nazareno in relation to the reference values proposed by the international literature

	Cu	**Zn**	**Mn**	**Ni**	**Cd**	**Pb**	**Fe**	**Cr**
				mg kg^{-1}				
F.P.R.[1]	84,0	171,5	2599	161,1	3,1	50,3	28639	90,3
F.R.T.[2]	129,5	469,1	2725	308,1	11,3	65,4	48120	290,0
P.C.[3]	44,4	65,9	992	57,7	2,4	44,4	21567	33,2
RQ[4]	35	60	*	13	0,5	17	*	*
Prev.[5]	60	300	*	30	1,3	72	*	*
Inv.[5]	200	450	*	70	3	180	*	*
Fadigas[6]	2 - 119	6 - 79	*	5 - 35	0,3 - 1,5	3 - 40	*	19 - 65
Holanda[7]	36	140	*	35	0,8	85	*	100
Mundo[8]	0,3 - 495	1,5 - 264	80 - 1315	0,7 - 269	0,005 - 2,4	0,5 - 135	*	6 - 80

[1]Reddish Brown Physialitic; [2]Typical Red Ferralitic; [3]Brown with Carbonates; [4]Quality reference (72); [5]Prevention and research (73); [6]Quality guideline values for Brazilian soils (74); [7]Reference values of Dutch soils (75); [8]Range of PM concentration in world soils (76).
*Values not reported

In this locality the Red Ferralitic soils show natural values above these limits in undisturbed areas (71), which is evidenced in the sediments retained in the karst depressions, which usually present high concentrations of heavy metals from the surface itself (level 0-30 cm), coinciding with the results obtained in the Mayabeque province (77–79).

In some cases these soils can be classified as "contaminated". However, these concentrations were found naturally (little disturbed areas), due to the presence of these elements in the constituent minerals of the rocks, coinciding with studies carried out in similar regions (71,80).

Reality: Lack of knowledge about soil conservation strategies

The forms of karst absorption impose peculiar characteristics on the relief, so that the rainwater when drained does so in a diffuse way but basically directed towards the bottom of the different depressions, as these function as local base levels with well-defined micro-basins, eventually filling with sediments when the weight is obstructed or not functional, so they are generally cultivated when this complex process is unknown or undervalued. Likewise, the burning of the characteristic vegetation or the violent opening of the same is not admissible since they accelerate the karst-erosive process (81).

Consequently, it should be considered that the karst depressions have a hydrological function since they represent the natural drainage routes that these regions have for the evacuation of the liquid surpluses and products of erosion from neighboring automotive surfaces, therefore it should be promoted in its area of influence is minimum tillage, contour planting and live barriers among other alternatives for conservation agriculture.

Investigations carried out in localities of San José de Las Lajas (82), suggest in very necessary situations to fill the depressions with rocks of different diameters and of a chemical-mineralogical composition similar to the underlying stone material (Figure 7), so as to facilitate drainage of the waters, but eventually retaining the solid suspensions.

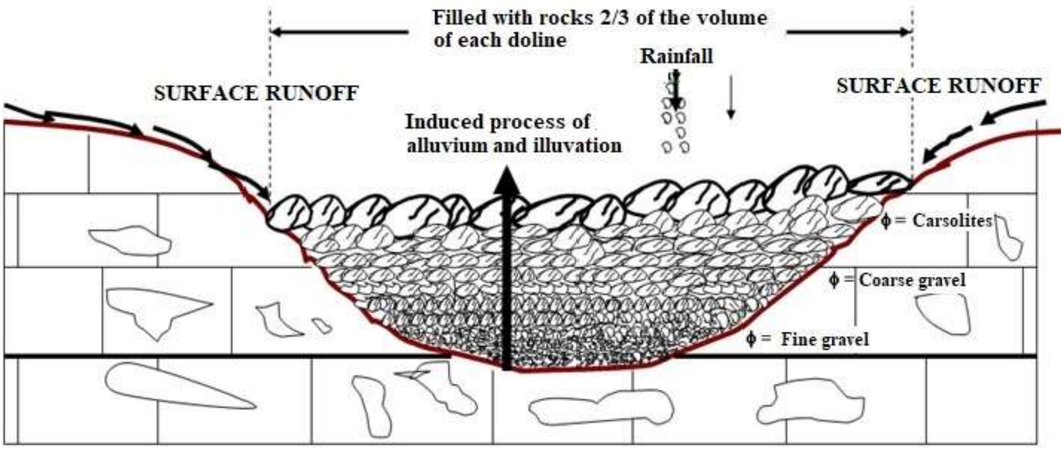

Figure 7. Proposal of an agroecological strategy for the control of soil erosion in the karst cavities

Rehabilitation is estimated to be achieved in approximately three to five years, in accordance with the dimensions of the forms of absorption. Likewise, karst must be accepted as a natural and geological process with which it must inevitably coexist.

Reality: Ignorance of the cost of erosion of Red Ferralitic soils

Assessments of the economic consequences of soil degradation in Cuba (Table 10), indicate that the GDP is affected by $ 191 million dollars in direct and additional economic costs caused by the effects of soil erosion of classes I and II to which correspond the Red Ferralitic soils (83).

Table 10. Economic cost of soil degradation in Cuba due to erosion and environmental impacts

Erosion degree	**Soil loss t ha^{-1} year^{-1}**	**Affected area M ha^{-1}**	**Total Loss Mt ha^{-} year^{-1}**	**Total cost of soil loss (USD ha^{-} year^{-1})**	
				Value x ha^{-1} USD	**Total M USD**
I Weak	4.2 – 4.8 mean 4.5	1 745.4	7854.3	14.12	11 0902.72
II Mean	9.0–10.8 mean 9.9	645.5	6390.45	12.50	79 880.63
Totals				Mean	95.38

Based on these results (84) they estimated in the polje of San José de Las Lajas (Table 11), the costs of the loss of productivity of Red Ferralitic soils per hectare for future scenarios through the forms of karst absorption (sinkholes), using the equation proposed (85).

$$Ci = Pm * \Delta y_{ij}$$

Where:

Ci: is the cost of erosion per hectare at site i, Pm: is the market price per ton of agricultural product and Δy_{ij} is the loss of product in t ha^{-1} associated with the loss of centimeters of soil in site i.

Table 11. Forecast of soil losses in the next 50 years using the MMF model in the localities "Rosafé Signet" and "Boshmenier - Zenea"

Scenarios 1986 - 2009 **C_1 (No apparent erosion)** **Horizon A(0 – 490 mm)**	**Scenarios year 2034** **C_1(Moderate erosion)** **Horizon A (0 – 221,50 mm)**		**Scenarios year 2059** **C_1(Severe erosion)** **Horizon A (0 – 39,48mm)**	
	Y (mm $year^{-1}$)	**Y (cm $year^{-1}$)**	**Y (mm $year^{-1}$)**	**Y (cm $year^{-1}$)**
	268,52	26,80	450,52	45,00

The vertical axis (Figure 8) shows the cost per hectare and the horizontal axis, the centimeters of eroded soil. For scenario I (1986 - 2009) $\bar{x}_{(15\ years)}=0.11$ cm $year^{-1}$ of eroded soil was obtained, superior to the method runoff lots, but still in the conservative range estimated by SAGARPA of 0.15 t ha^{-1}. However, for scenarios II ($\bar{x}_{2\ (25\ years)} = 1.08$) and III ($\bar{x}_{3\ (50\ years)} = 1.80$), the magnitudes of losses intercept the critical scenario with a maximum of 0.300 t ha^{-1}. The combination of both estimates determines that the costs for loss of productivity are in the range of USD \$ 16.2 to USD \$ 32.4 ha^{-1}, while the replacement cost of the lost nutrients amounts to USD \$ 22.1 ha^{-1} with a marked tendency to increase.

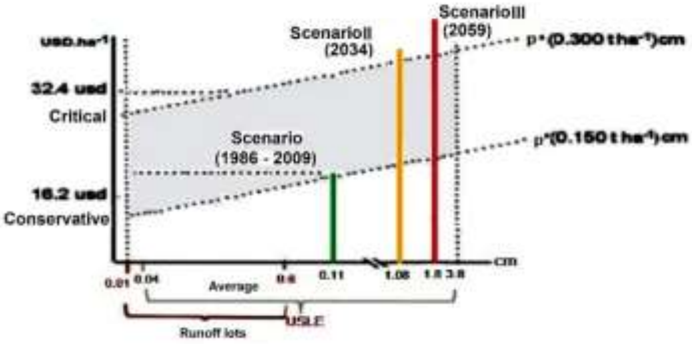

Figure 8. Costs per hectare under two scenarios of loss of productivity per centimeter of eroded soil

Considering the conservative scenario (where one cm of eroded soil causes a reduction of 150 kg in yield), the total cost of both locations amounts to USD $ 44.921.54, which corresponds to a value of $ 16.2 USD ha^{-1}. With the critical scenario (where a little more than one cm of eroded soil causes the loss of 300 kg) the cost amounts to USD $ 89 843,089 or $ 32.4 USD ha^{-1}.

Although it must be aware that the total economic value of something will rarely (if ever) be known for sure (86), a more complete appreciation of the value of soils requires studies that emphasize on the various environmental services provided by them, beyond production.

CONCLUSIONS

- Soil Science in Cuba must definitively apply the results obtained for more than 50 years in determining the specific modalities assumed by the erosion of Red Ferralitic soils, so that their degradation ceases to be a myth and become a matter of National Security.
- The results of the investigations of the Red Ferralitic soils in the karst regions show that the lack of harmonized methods of monitoring and transfer of information constitute one of the causes that causes the persistence of uncertainty about the state of degradation and protection strategies that should be applied to these soils in Cuba.

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