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Original Article

Irreversibility of the degradation of red ferrallitic soils in areas of karstic depression influence

Irreversibilidad de la degradación de los suelos ferralíticos rojos en áreas de influencia de las depresiones kársticas

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ABSTRACT: The characterization of conditions of the karst environment at a detailed level contributes to the study of soils in areas of low relief contrast and a window of knowledge where geographic-cartographic information has been overgeneralized and underestimated. Based on studies carried out for more than three decades in the Southern Karstic Plain Havana - Matanzas, specifically in the polje of San José de Las Lajas, the objective was to analyze by means of three integrated indicators the irreversible trend of the degradation of Red Ferrallitic soils in areas of influence of karstic absorption forms (dolines and uvalas), where the geological structure and karstification show different phases of development. The characterization carried out from a baseline in the period $t0:_{1986 - 1996}$ and subsequent monitoring during the interval $t1:_{1996 - 2019}$, allowed obtaining criteria on the sequential modification of the karst landscape; changes in the nature and properties of soils and in the unidirectional and irreversible evolution of karst morphogenesis, with a marked tendency towards endorheism in this peculiar ecosystem.

Key words: Karst, erosion, soil, degradation.

RESUMEN: La caracterización de las condiciones del entorno kárstico a nivel detallado contribuye al estudio de los suelos en zonas de bajo contraste de relieve y una ventana de conocimiento donde la información geógrafo - cartográfica se ha sobre generalizado y subestimado. Con base a estudios realizados por más de tres décadas en la Llanura Kárstica Meridional Habana - Matanzas, específicamente en el polje de San José de Las Lajas, se planteó como objetivo analizar mediante tres indicadores integrados la tendencia irreversible de la degradación de los suelos Ferralíticos Rojos en áreas de influencia de las formas de absorción kársticas (dolinas y uvalas), donde la estructura geológica y la karstificación muestran diferentes fases de desarrollo. La caracterización realizada a partir de una línea base en el período $t0:_{1986 - 1996}$ y posterior monitoreo durante el intervalo $t1:_{1996 - 2019,}$ permitió obtener criterios sobre la modificación secuencial del paisaje kárstico; cambios en la naturaleza y propiedades de los suelos y en la evolución unidireccional e irreversible de la morfogénesis kárstica, con marcada tendencia hacia el endorreísmo en este peculiar ecosistema.

Palabras clave: Karst, erosión, suelo, degradación.

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INTRODUCTION

All thermodynamic processes that occur in nature are irreversible processes, i.e., they take place spontaneously in one direction, but not in another, such as pedogenetic processes whose results originate soils with different characteristics and properties. The spatial variability of the soil cover in Cuba is an example of this, where more than 39 genetic types have been identified (1). Each of them performs a different set of functions and has a different degree of vulnerability to different pressures. In any case, soil is a limited resource, and although some of its functions can be recovered, it is not a renewable resource in the time necessary for its regeneration (2).

For more than three decades, several articles have argued that the loss and degradation of soils in karst regions are generally irreversible processes in their unidirectional evolution, specifically in the areas of influence of karst absorption forms (3), since the resilience of Red Ferrallitic soils, according to the formation rates and the percentage of impurities in limestone, would be renewed between 100 and 600 years (4-6).

In Cuba, the soil sometimes experiences irreversible losses and degradation as a result of the increasing and often conflicting demands of practically all economic sectors (7). Reflecting on this background, the present work has among its objectives to characterize the irreversible trend of degradation of Red Ferrallitic soils located in areas of influence of karst depressions in San José de Las Lajas polje.

MATERIALS AND METHODS

Description of the investigated areas

The research was carried out in the central portion of the Southern Karstic Plain Havana - Matanzas, specifically in San José de Las Lajas polje, Mayabeque province, with an approximate extension of 469.80 km^2 (Figure 1), where the karstic-erosive dynamics show different degrees of development in accordance with the conditions of use and management to which the soils have been subjected during the last decades (8).

This agroecosystem has been classified as one of the most humid of the Cuban plains, receiving around 76-80 % of the precipitations that occur in the provinces of Mayabeque and Artemisa (9, 10). The most widespread soils are predominantly of the Ferrallitic Red Leached Type, which can be correlated with the Rhodic Eutric Nitisol (11) and the Oxisol order of the Soil Taxonomy (12), where the differences are given by the type of land use and the distribution of horizons.

The methodology was based on the application of the Integrating System of Qualitative and Quantitative Methods

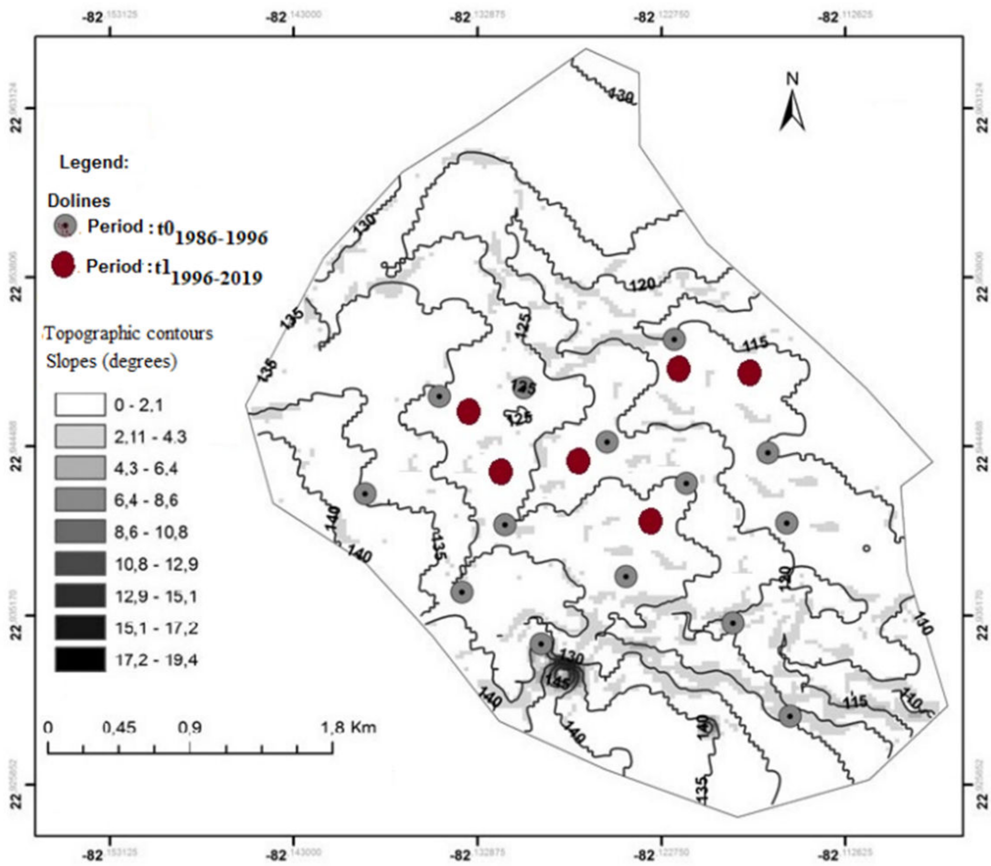

Figure 1. San José de Las Lajas Polje of irregular contours that receives all types of sediments from neighboring automorphic surfaces. Mayabeque Province, Cuba

for karst regions (13), characterizing the karst depressions and their flooding regimes, as well as 12 main profiles at depths of 0-20 cm, as well as at the level of the erosive diagnostic horizons A+B 0-50 cm in correspondence with geological-geomorphological variations and agricultural use.

The geophysical works were carried out through 15 profiles traced in NW - SE direction and distances between them of 100 m; using electrical profiling methods. The SEV points were carried out through the profiles, with distances between points of 100 m (14).

To characterize the dynamics and irreversibility of the karst-erosive processes, three integrated indicators were selected: (1) sequential modification of the landscape, (2) changes in soil properties and (3) evolution of karst morphogenesis, which provided measurement criteria and changes in the system from a baseline during the period $t0:_{1986\text{ - }1996}$ and subsequent monitoring in the interval $t1:_{1996\text{ - }2019}$.

RESULTS AND DISCUSSION

Irreversible degradation and loss of soil productivity in sectors of influence of karst absorption forms

When attempting to describe the situation of the Red Ferrallitic soils in a long-standing spatio-temporal context, any analysis goes through the phases of karst morphogenesis in which they are found, with respect to their physical, chemical and biological attributes that can favor, limit or inhibit their resilience (15), given their capacity to slow down erosive processes and absorb pollutants, which means that damage is not perceived until a very advanced stage, so this is probably the main reason why the protection of these soils has not been sufficiently promoted in Cuba.

In this context and from the baseline $t0:_{1986\text{-}1996}$ and its follow-up during the period $t1:_{1996\text{-}2019}$, the changes in the main indicators are shown (Table 1), as a result of a multifactorial process conditioned not only by the intrinsic properties of the edaphic cover in the proximities of the karst depressions (dolines and uvalas), but also dependent on the geological-geomorphological and use conditions.

It should be noted that soil responses in karst ecosystems are complex, as they are the result of the interaction of numerous factors and strong links with climatic variability, which cannot be fully assessed in the short term, since they require the interpretation of different approaches (28), which will be examined in more detail on the basis of the three selected indicators.

Indicator 1. Sequential modification of the karst landscape

In the polje there is an intense karstic-erosive process that has given rise to wide and deep sinkholes that originate a dismemberment of the relief and, consequently, the existence of unproductive areas, which, like micro-basins, operate under its influence, reflecting the nature of the geological structure and the unidirectional and irreversible progress of karst morphogenesis in its different phases (29).

However, the ferrallitic soil cover can model by accumulation these depressions (dolines, uvalas) and mask in a certain way the described mechanism of action that has caused to a great extent the underestimation of this complex process, which will continue with the definitive removal of sediments to the bottom through countless cracks and fissures with different diameters (from capillary to 2 mm in amplitude) and lengths (up to 15-20 m in depth), which are spatially diffused throughout the karst massif as shown by the SEV carried out through 15 profiles (Figure 2) traced in NW - SE direction and at distances between them of 100 m (30).

The initially formed sinkholes modify the hydraulic gradient in their surroundings and increase the carbonation-dissolution processes, eventually originating new sinkholes or the union of these (uvalas), with the consequent increase in the removal of soil fractions towards the temporary flooding areas located below 50 m a.s.l, probably because the action of structural and climatic factors and the hydrophilic vegetation combined with the behavior of the subsurface water favor the dissolution of the limestone rock with greater intensity than in the other surfaces with greater hypsometry (14, 30).

As a hypothesis, it can be assumed that this condition of seasonality in flooding could be associated with changes in the static level of the aquifer throughout the year and as a consequence of infiltration processes, the development of fracturing of the carbonate package that is used by surface runoff to infiltrate into the interior of the massif with the irreparable loss of soils through the ponor.

Indicator 2. Changes in the nature and properties of soils

The initial organic matter content of these soils exceeded 10% by far, nowadays it is between 3 - 4 % (31), and it seems that it does not stop decreasing (Table 2), deteriorating at the same time the physical properties that used to characterize them (32).

With respect to the modification of the properties of the soil cover, the most notable effects are expressed mainly at the depths of the diagnostic horizons A+B0-50cm with the progressive decrease in organic matter content, increases in pH, compaction values with bulk density thresholds higher than 1.34 Mg m^{-3} that decreases total porosity and aeration (Table 3), reinforcement of karstic-erosive processes, salinization, among others, with a marked tendency to increase, which has received different denominations such as "agrogenic soil formation" (39) and irreversible degradation (40).

Complementarily, the acid-base balance is currently highlighted by the profound changes that have taken place over time, evidenced in the high average pH (7.62) (24). This phenomenon of basification (increase of pH) has been proved (41, 42), relating it to climate change, mainly to the

Table 1. Main manifestations of karst-erosive processes of soils in karst depressions. Rosafé Signet" locality. Polje San José, Mayabeque Province

Period establishment of the baseline t0:1986-1996	Period of monitoring t1:1996-2019	Method/model applied
SEQUENTIAL MODIFICATION OF THE LANDSCAPE		
Reference profile: $C_{1\ (apparently\ not\ eroded)}$. Horizon A $_{(0-490\ mm)}$ (13)		
Soil depth (mm year^{-1}): 48	469.45	Geospatial (16-18)
Soil losses (t ha^{-} year $^{-1}$): 12.89 High	15.28 High	MMF (19)
Erodibility index: > 0 - 3 Low	> 3 - 6 Moderate	CORINE (20)
Stoniness (%): 11	17	
A horizon removal (mm. year $^{-1}$): 0.97	1.19	R/USLE(21)
Topographic index: < 5 Very soft	5 - 15 Suave	MDE (22)
Slightly dismembered plain	Slightly dismembered plain	
CHANGES IN SOIL PROPERTIES		
Organic matter (%): 1.63	1.27	Integral soil evaluation (23, 24)
Bulk density (Mg m^{-3}): 1.29	1.34	
pH: 7.2	7.4	
Carbon content (%): 0.99	0.76	
Carbon reserve (t ha^{-1}) Horizon A $_{(0-20cm)}$: 20 Horizon A + B $_{(0-50cm)}$: 48	18 45	
EVOLUTION OF KARST MORPHOGENESIS		
Evolution of morphometric parameters		Morphometric (25-27);
Circularity index (CI): 1.58	CI: 1.38	
Flattening index (FI): 10.18	FI:8.49	
Diameter ratio (Rd): 27.08	Rd: 17.26	
Karstification index: 5 - 10 Low	> 10 - 15 Moderate	
Doline density (ha^{-1}): 15	19	
Dolinized surface (%): 35	50 and growing	
Doline with temporary flooding: 5 5	11	
Uvala with temporary flooding: 0	2	
Doline physiography: "V" shape.	“U” form	
Incipient stage of development. Karstic type - suffosive.	Advanced phase. Corrosive type of - sinking.	

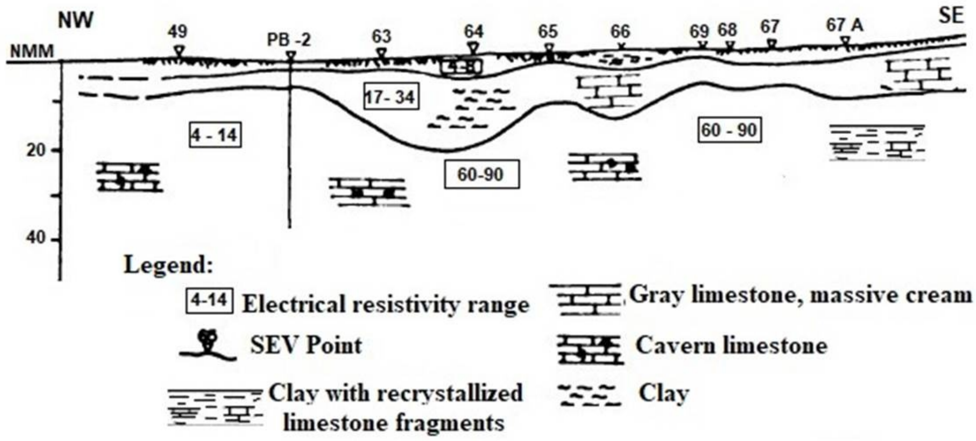

Figure 2. Geological-geophysical section. Location "Rosafé Signet" in the San José polje. Mayabeque Province

Table 2. Behavior of organic matter through time in reference localities of Mayabeque province

Soils	Percentage of organic matter	Source
	LOCATION OF ARTEMISA	
Matanzas Clay. red purple phase	4.74	(33) (1)
Matanzas clay. red purple phase	7.35	(34) (2)
Artemis series	2.83	(35) (3)
Typical humified red Ferrallitic	2.58	
	LOCATION OF QUIVICÁN	
Matanzas clay. red - chocolate phase	7.30	(36) (4)
Typical Red Ferrallitic	3.23	(37) (5)
Eutric Rodic Nitisol	1.75	(38) (6)
	POLJE OF SAN JOSÉ. MAYABEQUE	
Ferrallitic Red Leached	4.48	(33) (4)
Ferrallitic Red leached	3.56	(37) (5)
Eutrichic Rodic Nitisol	3.02	(38) (6)

(1) Table 4. The Soils of Cuba; (2) Table 56. Soils of Havana province; (3) Table 26. Doctoral Theses and (4) Table 2. Soils and Agriculture; (5) Table 26. PhD Theses and (6) Table A2. Land Degradation & Development, 20: 522-534

increase of the average annual temperature and the minimum annual temperature registered in the last 20 years, especially in the areas destined to various crops (Table 4).

The alkalinization (actual or potential) of soils is also due to anthropic factors related to the frequent use of calcium bicarbonate water for agricultural irrigation, a phenomenon accentuated at the bottom of karst depressions where sedimentation enriched with CO_3 H_2Ca takes place, as a consequence of the continuous decarbonation process that limestone undergoes (30). All the above evidences a tendency to the progressive deterioration of its properties with the consequent regression of its productive capacity.

Indicator 3. Unidirectional and irreversible evolution of karst morphogenesis

The increase in the morphometric dimensions of the dolines from the baseline t0:1986-1996 and subsequent monitoring during the period $t1:_{1996\text{-}2019}$ (Table 5) allows us confirming that an erosive process or modality inherent to the Red Ferrallitic soils is developing whose most evident manifestations are the amplitude of its average dimensions at the expense of the reduction of the interfluvial spaces and the emergence of other forms of absorption in various stages of exploration (dolines 15 and 16 detected in 1996 and another five during 2019), which confirms the irreversible advance of karstification in its unidirectional evolution (30).

In fact, the flattening index (FI) shows values that morphologically are expressed in dolines with little dissection, as a result of a process of vertical dismemberment in development. Thus, doline No. 3 has a sustained flattening trend in the period t0 - t1: (5.65 - 5.40 m^2) product of an imbalance between areal erosion and corrosion in favor of flattening which favors the detachment and migration of the finer fractions of the *solum* that temporarily accumulates at the bottom and is irremediably lost by the ponor.

However in recent years this dynamic has begun to experience variations as a result of climate change increased hydromorphism by the progressive advance of the flooding regime in the depressions as well as the processes of carbonation - dissolution (43) whose most revealing expression is the appearance of ponors of different dimensions at the bottom of virtually all dolines and

Table 3. Behavior of the physical properties of oils. Rosafé Signet" unit in the San José polje. Mayabeque Province

Depth	% of fractions in mm				Mg m $^{-3}$		%
(cm)	Coarse Sand 2 - 0.2	Fine Sand 0.2 - 0.02	Silt 0.02 - 0.002	Clay <0.002	Soil density	Solid phase density	Pt
			FERRALLITIC RED LEACHED				
			Profile C $_{1(\text{No apparent erosion})}$ **Febles and Martín (1986)**				
0 - 10	1.96	14.00	10.00	74.00	0.98	2.61	62.50
10 - 20	5.96	13.00	12.00	69.04	1.00	2.72	63.20
20 - 30	0.96	5.00	5.00	89.04	1.09	2.76	60.50
30 - 40	1.96	3.00	2.00	93.04	1.04	2.77	62.50
40 - 50	2.96	3.00	2.00	92.04	1.03	2.78	62.90
			Profile C $_{1(\text{Slightly eroded})}$ **Gounou (1997)**				
0 - 10	3.61	21.54	14.25	60.00	1.38	2.68	58.00
10 - 20	5.63	15.86	14.42	64.09	1.40	2.69	51.02
20 - 30	1.93	10.03	13.20	74.84	1.44	2.73	57.40
30 - 40	2.88	9.86	11.60	75.66	1.36	2.71	55.30
40 - 50	3.98	9.30	11.45	75.27	1.34	2.70	55.10
			Profile C $_{1(\text{Slightly eroded})}$ **Febles and Vega (2009)**				
0 - 10	3.86	20.25	14.57	61.87	1.36	2.70	57.20
10 - 20	5.70	14.32	14.58	65.40	1.38	2.76	54.70
20 - 30	3.72	10.63	13.36	73.29	1.42	-	-
30 - 40	2.50	9.48	11.02	77.00	-	-	-
40 - 50	1.83	3.55	13.70	80.92	-	-	-
			Profile C $_{1(\text{Slightly eroded})}$ **Febles *et al.*. (2019)**				
	4.88	18.62	14.57	61.93	1.34	2.70	55.10
10 - 20	5.83	14.69	13.77	65.71	1.38	2.76	54.70
20 - 30	2.72	10.63	12.72	73.93		-	-
30 - 40	2.03	7.44	11.16	79.37	-	-	-
40 - 50	2.13	5.02	10.96	81.89	-	-	-

Table 4. Statistical behavior of some soil properties in the Southern Karstic Plain Havana - Matanzas, Cuba

Elements	Total measurements	Values			Standard deviation
		Minimum	Maximum	Medium	
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 M Pa

Source: (41)

the emergence of two other forms of absorption (period t1: $_{1996-2019}$ dolines No. 15 and 16) which were not reported in previous studies.

Regarding the circularity index (CI) there are no notable changes in the values between both periods (t0: 1.98 - t1: 2.04 m^2) conditioned to the characteristics of the cracking system and dissolution process of the massif with intercepting structural elements (14, 30). In addition of being subject to dissolution processes to give rise to the depressions coinciding with results obtained (7).

The diameter ratios (Rd) vary in a wide range (t0: 105.53 - t1: 5.17 m^2) which allows asserting that the genesis of the dolines develops under a non-surface lithostructural control related to the influence of aquifers and artificial recharge wells (14) affected by pollutant wastes from several industries in the area which increase the

Table 5. Volume of losses of Red Ferrallitic soils with surface removal equivalence values "Rosafé Signet" Unit, Mayabeque Province

Doline No.	Baseline/Monitoring t0:$_{1986\text{-}1996}$/t1:$_{1996\text{-}2019}$						Baseline t0:$_{1986\text{-}1996}$		Monitoring t1:$_{1996\text{-}2019}$	
	CI		FI		RD		Volume (t ha^{-1} year^{-1})	Superficial (mm year^{-1})	Volume (t ha^{-1} year^{-1})	Superficial (mm year^{-1})
	(m^2)									
1	1.70	1.72	8.65	8.57	6.50	5.66	16.89 H	1.24 H	17.87 H	1.30 H
2	1.74	1.47	8.51	6.12	9.01	6.96	17.27 H	1.29 H	20.16 H	1.46 H
3	1.52	1.36	5.65	5.40	14.84	9.82	21.74VH	1.59 VH	23.63 VH	1.74 VH
4	1.73	1.55	14.08	9.86	9.19	6.87	14.55 H	1.06 H	14.65 H	1.09 H
5	1.37	1.13	11.74	8.89	30.90	22.17	9.18T	0.67T	11.99 H	0.88 H
6	1.54	1.33	13.07	11.80	14.07	10.61	9.56 T	0.70 T	10.72 H	0.79 H
7	1.29	1.04	7.39	7.82	105.53	76.51	13.91 H	1.02 H	12.43 H	0.89 H
8	1.74	1.56	13.41	11.17	9.11	6.82	11.03 H	0.80 H	12.69 H	0.93 H
9	1.33	1.12	13.52	10.18	46.93	28.20	9.58 T	0.70T	10.87 H	0.80 H
10	1.38	1.28	9.67	9.66	29.66	21.23	11.12 H	0.81	12.55 H	0.91 H
11	1.98	1.85	9.66	8.96	6.71	5.17	18.15 VH	1.33 H	19.70 H	1.43 H
12	1.34	1.15	7.91	8.20	66.00	32.08	13.06 H	0.95 H	14.75 H	1.12 H
13	1.83	1.66	8.99	8.19	8.00	6.03	17.39 H	1.27 H	18.91 H	1.39 H
14	1.66	1.18	10.26	8.58	22.70	17.92	10.95 H	0.80 T	13.52 H	0.99 H
Mean	**1.58**	**1.38**	**10.18**	**8.49**	**27.08**	**17.26**	**12. 89 H**	**0.97 H**	--------------	
DOLINES DETECTED DURING THE MONITORING OF 1996										
15	----	1.26	----	8.53	----	12.88	------	0.49 T	14.53 H	1.39 H
16	----	1.52	----	3.87	----	7.17	------	0.76 T	15.55 H	1.97 VH
Mean	----	----	----	----	----	----	------	----	**15.28 H**	**1.19 H**
DOLINES DETECTED DURING THE MONITORING OF THE YEAR 2019										
17	---	1.70	---	8.17	---	5.45	--------------		8.23 T	0.38 T
18	---	1.49	---	7.23	---	8.01	--------------		9.05 T	0.41 T
19	---	1.33	---	9.48	---	15.67	--------------		10.69 H	0.63 H
20	---	1.29	---	7.66	---	9.28	--------------		8.97 T	0.46 T
21	---	1.44	---	6.65	---	7.73	--------------		9.45 T	0.74 T
Mean		**1.45**	---	**7.84**	---	**9.23**	--------------		**9.28 T**	**0.52 T**

L.B. (Baseline t0:$_{1986\text{-} 1996}$); M (Monitoring t1:$_{1996\text{-} 2019}$).

H: High; VH: Very High and T: Tolerable

chemical aggressiveness of groundwater carrying polycyclic aromatic hydrocarbons and polychlorinated biphenyls (44, 45).

This sequential evolution of the morphometric parameters leads to increases in the volumes of soil losses, as a consequence of the concavity of the wash collector type slopes (46), with slope values between 5 and 8 % that facilitate areal runoff through epigeal absorption forms, fundamentally dolines and uvalas, where the volumes of losses exceed the tolerance threshold values of 12.5 t ha^{-1} year^{-1}, which is the maximum acceptable value proposed by the USLE (47). Accordingly, in the period t0$_{(1986\text{-}1996)}$ 51.14 % of the dolines exceeded this limit value, which increased during t1$_{(1996\text{-}2019)}$ to 87.5 % of them, a dynamic that corroborates the observations (48) in similar regions.

According to previous research (49) it is predicted that during the next 37 years (2059 scenario) the rate of soil loss in the areas of influence will increase by just under 50 % and the reference horizon A$_{0\text{-}490\ mm}$ (13) would only have a thickness of 39.48 mm (Figure 3). This would mean a transition to the upper phase of karst morphogenesis (paroxysmal), without the possibility that neighboring automorphic surfaces could contribute clayey sediments to the karst depressions and "mask" this complex process, leaving unproductive areas that in the past were suitable for a wide range of agricultural, livestock and forestry uses (50).

However, the categories of soil loss due to erosion proposed by the Soil Institute (51), which overvalue depth as the fundamental diagnostic index, would classify this maximum phase in 2059 as severe erosion, which does not reflect the transcendence of this specific type of erosion of Red Ferrallitic soils in karst regions that has been reported in previous studies (29, 32).

It should be noted that this forecast has not taken into account the inevitable process of morphometric enlargement of the forms of karst absorption or "dolinization" (with a marked tendency towards endorheism), management practices and changes in the use of soil cover, extreme hydrometeorological events associated with climate change, etc., so that the magnitude of soil losses could be much more drastic and irreversible with a substantial reduction in the useful land base of the agroecosystem, which coincides with the results obtained (52, 53) in similar regions.

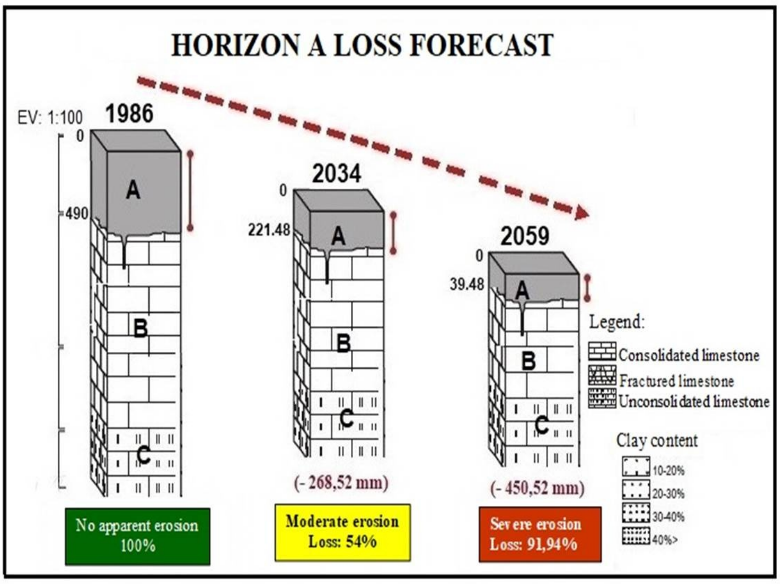

Figure 3. Prediction of soil loss due to erosion for the next 12 and 37 years in the areas of influence of the San José de Las Lajas polje

In any case, karst ecosystems have a very long evolution in time and only some of the processes described in their different evolutionary stages are preserved in the landscape, which hinder the research work on the resilience of soil cover, especially in soils that are the basis of agricultural production in the country.

CONCLUSIONS

The irreversible trend of the degradation of the Red Ferrallitic soils in the areas of influence of the karst depressions is manifested in the three indicators as follows:

- In the sequential modification of the landscape with the increase and extension of the areas of temporary flooding of the dolines formed in t0:$_{1986-1996}$ originating the dismemberment of the relief acceleration in the processes of carbonation-dissolution and increase in the removal of the soil towards the absorption depressions located below 50 m.
- Changes in the nature and properties of the soils; which are expressed mainly at the depths of the diagnostic horizons A+B0-50cm with a progressive decrease in the organic matter content, an increase in pH and bulk density values above 1.34 Mg m^{-3} with a marked tendency to increase.
- Unidirectional and irreversible evolution of karst morphogenesis; in both periods with the appearance of vugs of different dimensions at the bottom of practically all the depressions and the emergence of new ones with losses that exceeded 12. 5 t $ha^{-1}yr^{-1}$ in 51.14 % of the dolines in $t0_{(1986-1996)}$ and increasing during $t1_{(1996-2019)}$ up to 87.5 % of them which indicates the unidirectional and irreversible advance of karst morphogenesis with a marked tendency towards endorheism.
- Ignoring or underestimating these processes has led to one of the most widely spread myths in Cuban soil science regarding the immunity of Red Ferrallitic soils to erosion in karst regions. This will require greater collaboration between institutions in order to improve access to information, increase the comparability of data and avoid duplication of tasks.

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