ISSN: 2447-3359

REVISTA DE GEOCIÊNCIAS DO NORDESTE

Northeast Geosciences Journal

v. 8, nº 2 (2022)

https://doi.org/10.21680/2447-3359.2022v8n2ID28987

Soils of the tablelands of the Recôncavo Baiano (Brazil): genesis, transformation and neotectonism

Solos de tabuleiro do Recôncavo Baiano (Brasil): gênese, transformação e neotectonismo

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Abstract: The process of transformation of the Yellow Latosoil - Spodosoils with high contents of organic matter were the subject of this study. They developed on the Barreiras Group sediments, in a Recôncavo Baiano tablelands located in Santo Amaro county, Brazil. The starting point was the toposequencial soils analysis which were characterized regarding the morphology, micromorphology and physical, chemical and mineralogical attributes. The pedological system is complex, showing depressions related to faults and/or fractures crossing that indicate the neotectonism how started process of transformation. The relationships between the oxic and the hidromorphic domain point to Latosoil transformations linked to conditions of cyclic hydric saturation and to the action of organic composites of low molecular weight. The high contents of organic matter accumulated by reduction of mineralization under acids conditions and temporary anaerobiose propitiate the evolution of humus with the formation of mobile organic composites and acids which act on the transformation of the Latosol, through the installation of processes of podzolisation with partial acidolysis, acting from downstream to upstream in the versant. On the pedogeochemical aspect the destruction of primary minerals and the disorganization of the secondaries, indicate a route predominantly organic in the transformation, process, under the influence of reducing environments.

Keywords: Barreiras Group; Podzolisation; Acidolysis.

Resumo: Os Tabuleiros Costeiros constituem uma unidade geomorfológica desenvolvida sobre o Grupo Barreiras com grande extensão territorial no nordeste brasileiro. Os solos dessa unidade sustentam diversas atividades produtivas, mas apresentam complexos sistemas de transformação pedológica. O estudo genético desses solos permite compreender a dinâmica dos processos, possibilitando seu uso e manejo mais sustentável. Neste trabalho, através de análise topossequencial, procedeu-se a caracterização morfológica, micromorfológica, física, química e mineralógica dos solos para entender os processos de transformação Latossolo – Espodossolo com elevados teores de matéria orgânica desenvolvidos sobre os sedimentos do Grupo Barreiras em um tabuleiro do Recôncavo Baiano, no município de Santo Amaro, Brasil. O sistema pedológico é complexo, apresentando depressões relacionadas ao cruzamento de falhas e/ou fraturas que sugerem o neotectonismo como o processo que inicia a transformação pedológica. As relações entre o domínio latossólico e o hidromórfico apontam que a transformação dos latossolos é promovida por condições de saturação hídrica cíclicas e pela ação de compostos orgânicos de baixo peso molecular. Os elevados teores de matéria orgânica, acumulada por redução da mineralização sob condições ácidas e de anaerobiose temporária, propiciariam a evolução do húmus com a formação de compostos orgânicos móveis e ácidos que atuam na transformação dos Latossolos Amarelos, através da instalação de processos de podzolização com acidólise parcial de jusante para montante da vertente. Geoquimicamente a destruição de minerais primários e desorganização dos secundários indicam uma rota dominantemente orgânica no processo de transformação, sob influência de ambientes redutores

Palavras-chave: Grupo Barreiras; Podzolização; Acidólise.

Received: 24/05/2022; Accepted: 23/09/2022; Published: 10/11/2022.

1. Introduction

Located in Brazil, the state of Bahia has 25,510 km² occupied by coastal tableland soils. Despite the climatic and vegetation diversities, the soils developed on these boards are basically distributed within the classes of Yellow Ferralsols, Yellow Acrisols, Gray Acrisols and Spodosols (RIBEIRO, 1998; UCHA, 2000; FORTUNATO, 2004). These soils are arranged in different pedological sets distributed in the landscape in an orderly way, but it has been frequent to associate the occurrence of Spodosols with slightly lowered areas, which constitute the model of depressions (UFLA/UFV, 2004; SILVA et al., 2013) .

With the objective of knowing the genetic relationships and verifying the active processes, an investigation of a Yellow Ferralsol - Spodosol system in the Recôncavo Baiano region was carried out as a means of subsidizing the rational agricultural exploitation of these areas.

2. Methodology

The toposequence is located at Fazenda Engenho Novo/Usina Nova Paranaguá on a coastal board in the Recôncavo Baiano region, municipality of Santo Amaro / BA – Brazil, delimited by the coordinates 12°33'46.50"- 12°33'53.72" S e 38°48'44.39" - 38°48'40.40 W (Figure 1).

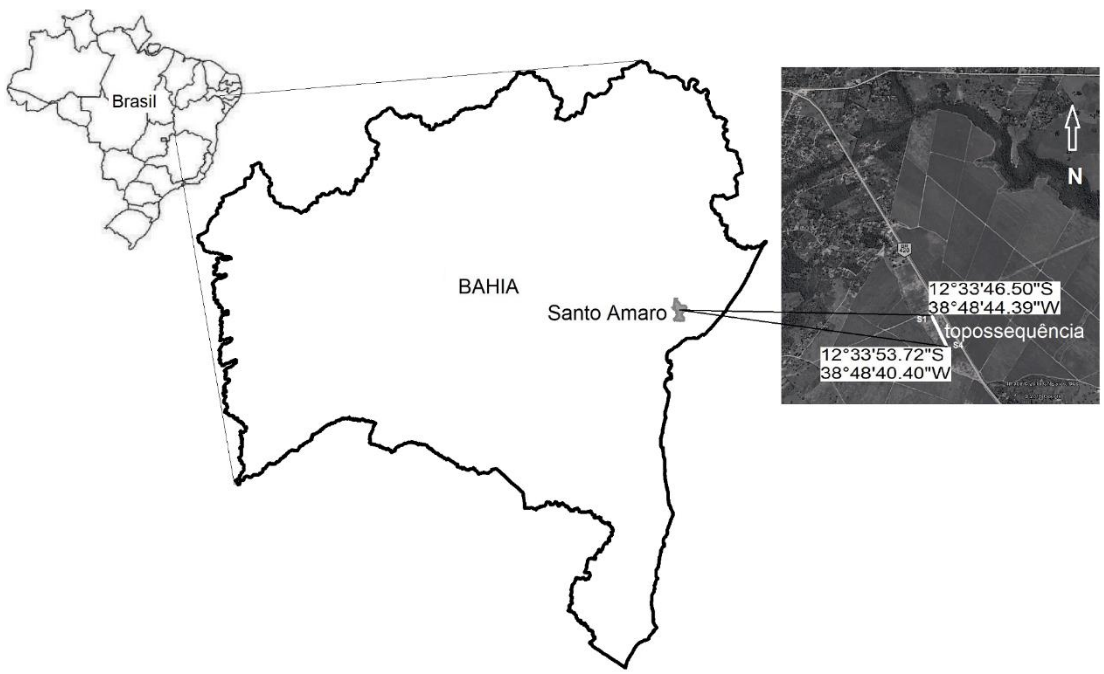

Figure 1 – Location of the toposequence in the study area.
Source: Authors (2022).

The study of toposequence initially analyzed its context in the landscape. The description of 4 profiles was performed (CAL 1, 2, 3, e 4) and 3 sampling points was carried out (Av 1, 2 e 3). The investigation was based on morphological, micromorphological, mineralogical and chemical and physical analysis criteria.

Morphological analyzes were performed according to Santos et al. (2013) and the granulometric and chemical according to Embrapa (2017). The undisturbed samples were impregnated with polyester resin, with styrene monomer as solvent, subjected to vacuum, dried at a temperature of 40ºC and subsequently laminated (Embrapa, 2017).

The geological characterization was carried out from the description of the lithological profile and structural analysis through photointerpretation.

The evaluation of clay minerals by X-ray diffractometry (XRD) was carried out in clay sheets oriented and irradiated in the range of 5° to 45° (2θ). Subsequently, the slides were intersalted with 85% hydrazine and kept in an oven for two hours at a temperature of 60° (JACKSON; ABDZL-KADER, 1978). Part of the sample underwent removal of organic matter and deferrification, being saturated with magnesium and potassium. The K-saturated slides underwent successive heat treatments at temperatures of 25°C, 110°C, 350°C and 550°C.

3. Results and discussion

3.1 Characterization of the physical environment

The Barreiras Group constitutes an essentially siliciclastic sedimentary cover, of continental and marine origin, aged between the Lower/Middle Miocene and the Pliocene (VILAS BOAS et al., 2001; ARAI, 2006; ROSSETTI; DOMINGUEZ, 2012). In the study area, it is sandy-clay, consisting of kaolinites, iron oxides, traces of feldspars and is located on rocks of Cretaceous age of the Santo Amaro Group (CARVALHO, 2001).

The area is located at the top of the board, altitude of 190m, flat to gently undulating relief and with long slopes with gentle slopes that vary between 1 and 8%. Closed and semi-closed rounded depressions are common, shallow and with a few tens of meters in diameter, normally humid, some with water throughout the year. The distribution of closed depressions has a relationship with structural alignments (Figure 2). In the region, some faults were active during the Quaternary, and the main ones remain active until today (CORREA-GOMES; UCHA, 2012), emphasizing the decisive role of this process in the origin of contemporary topography.

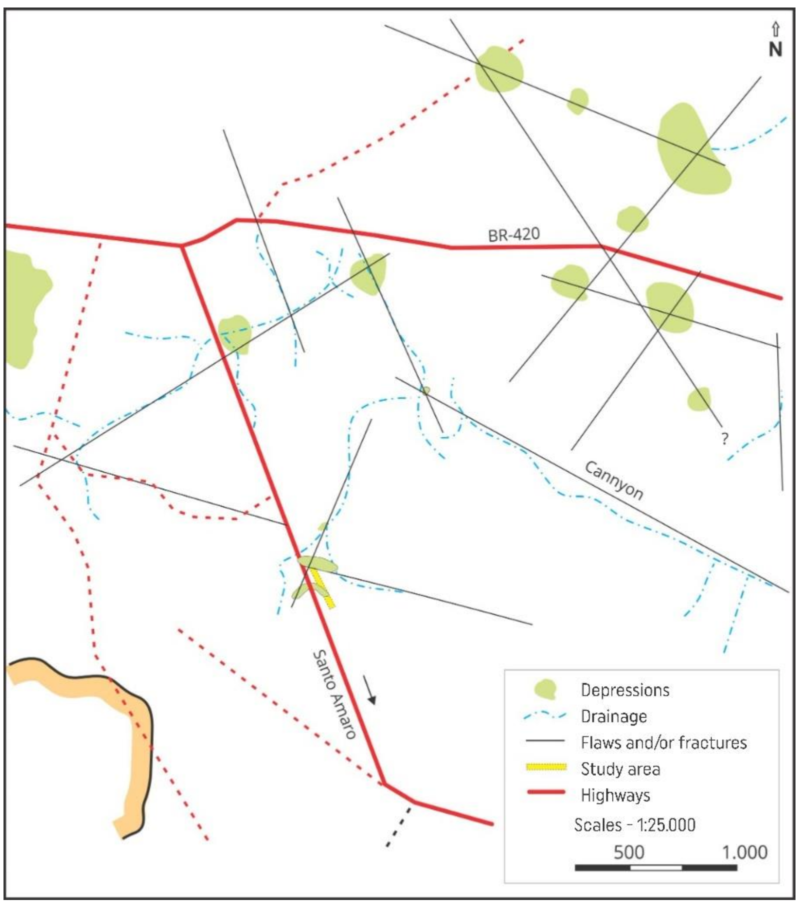

Figure 2 – Structural lineaments in the study area. Photo interpretation: images of Cruzeiro do Sul SA, flight D-53, Scale: 1:25,000. Photos 3764-3766, 3752-3754. Source: Authors (2022).

The climate is humid, type B1rA'a', according to Thornthwaite and Mather (1955), with a slight deficiency in the first three months of the year, megathermic, with average annual rainfall and evapotranspiration of 1,614.6 mm and 1,194 mm, respectively, and a total water surplus of 460 mm. The Submontane Dense Ombrophilous Forest was almost entirely replaced by secondary vegetation and sugarcane cultivation.

3.2 Morphological characterization

The morphological description reconstituted as much as possible the arrangement of the different materials, providing a two-dimensional image of the soils in the toposequence. The toposequence was subdivided into 4 sectors, differentiated by soil and relief characteristics (Figure 3), and has two depressions: a smaller one, located in sector 2, with a slope perpendicular to the slope of the slope and; a larger one, located at the base, in sector 4.

The morphological examination identified 4 sets in the toposequence: superficial, transitional, latosol and solid and hardened horizons. The attributes related to the constituent horizons of these sets can be seen in Figure 3.

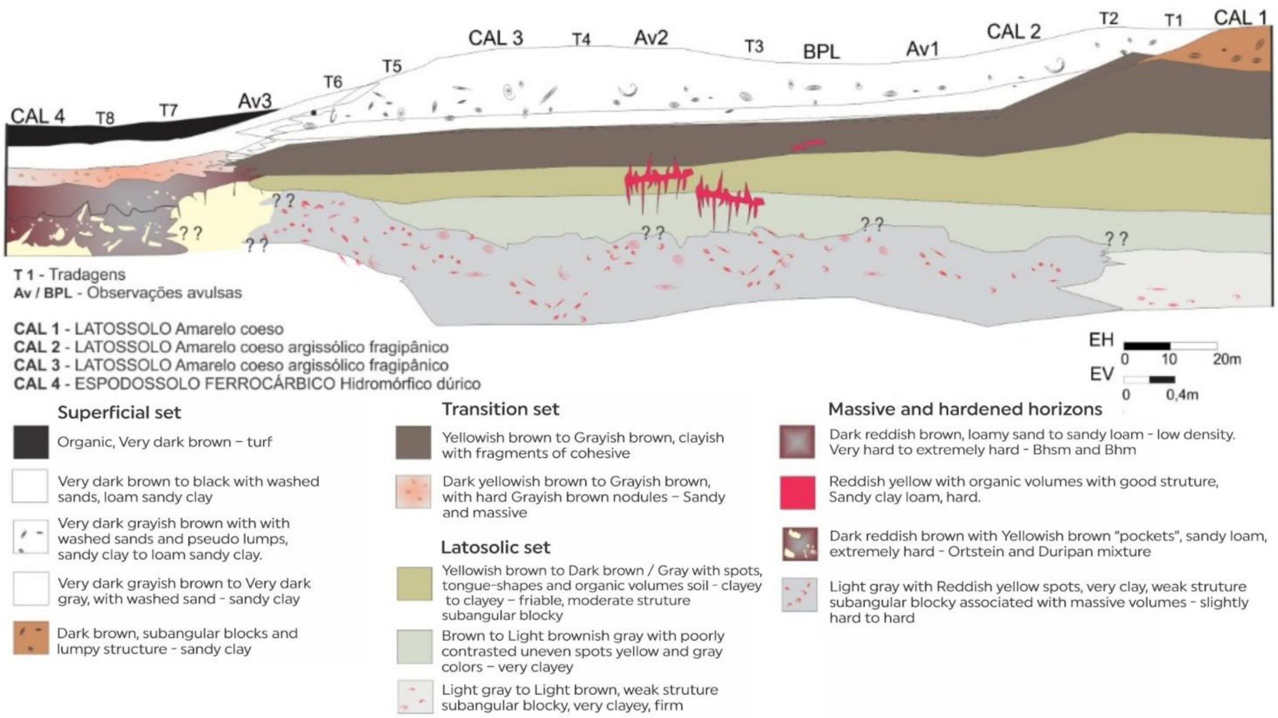

Figure 3 – Two-dimensional organization of soil toposequence. T1-T8: auger soundings; Av/BPL - complementary samples. CAL 1 - CAL 4: according to the Brazilian Soil Classification System (SANTOS et al., 2018).
Source: Authors (2022).

Sector 1. Located in the highest part, it has deep, well-drained soil with areas enriched in organic matter. The surface horizons gradually advance towards Sector 2, at the expense of a transformation of the latosol horizon.

Sector 2. located in a flat, depressed area, has moderate drainage and horizons rich in organic matter. The soils are still latosolic, but in the process of transformation and with organic matter resembling MOR-type humus. The surface horizon is very friable, the organic matter is poorly bound to the mineral fraction, it has washed sand and marked tubular porosity. In the transition set, hardened, sandy-clay and reddish-yellow volumes are observed.

The latosol horizon is friable with lamellae and tongues of organic matter. In the middle of the set, light yellowish-brown spots can be observed, of latosol material not yet impregnated with organic compounds. The biological activity is intense, associated with the presence of crotovins and old root canals. Vertically and laterally, the material progressively changes to a hard consistency, constituting, in general, more structured portions, associated with lighter solid discontinuous parts with fragipanic characteristics. Between sectors 2 and 3, there are discontinuous hardened sandy-clay (BPL) and reddish-yellow (7.5 YR 7/6) pockets within the transition set, which are associated with more cohesive volumes similar to fragipans.

Sector 3. The surface set has a higher organic matter content and better drainage than Sector 2. In the transition set there are stains associated with hardened fragments, similar to fragipans, which are not impregnated with organic matter. The transition to Sector 4 is abrupt, associated with a change in relief and the appearance of a seasonal water table, which fluctuates in its base level as a function of rainfall.

Sector 4. Located within the major depression, it has a peaty A horizon over a transition set with small hardened, grayish brown nodules, which compose relics of the latosol horizon. The spodic horizon is rich in organic matter, presents well-defined yellowish brown pockets, constituting a mixture of duripan and ortstein. These impermeable horizons and their position in the relief favor the periodic elevation of the water table and accentuate the oxidation-reduction processes.

3.3 Micromorphology

Along the toposequence, the soil skeleton undergoes a process of increasing degradation from the base to the top of the profiles. The process is stronger in the intermediate latosol horizons, where zones enriched with organic matter and quartz grains with corroded surfaces and gulfs of dissolution were observed (Figure 4a). These features probably result from the action of free fulvic acids that alter and reduce quartz grains. This may be determining the relative increase in fine sand content in relation to total sand at depth.

In the latosol set of Sector 1, the soil plasma is yellowish-brown, similar to the yellow latosols in the region (NUNES et al, 2020; FORTUNATO, 2004). However, towards Sector 2, it presents impregnations of organic colloids. The organization in aggregates gradually decreases from the first to the third Sector. Cuttans lining the walls with voids and filling cracks evidence the displacement of this material within the profiles, with export and redistribution both in depth and laterally in the toposequence (Figure 4b).

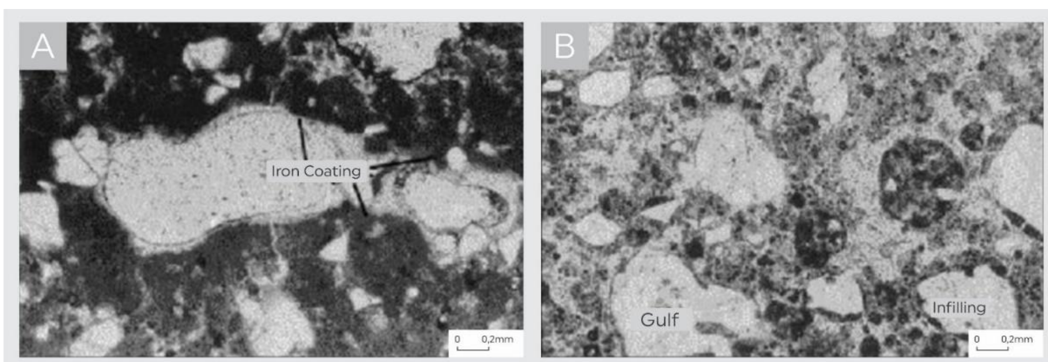

Figure 4 – a) displacement of iron and ferrargilan in vacuum; b) aglomeroplasmic structure, clay-humic plasma, fractured quartz, with a collar of organic matter and dissolution gulfs (flat light).
Source: Authors (2022).

From upstream to downstream, the base of the latosol profiles presents a more closed factory arrangement, with a yellowish-brown main plasma filling voids and increasing quantitatively towards the base of the slope. This material seems to constitute, in the duripan and in the spodic horizon, a kind of cement.

3.4 Physical and chemical attributes

Soils are of low fertility (values varying between 4 and 29%) and the values of calcium (Ca^{+2}), magnesium (Mg^{+2}) and potassium (K^{+}) increase slightly in the surface horizons, a fact related to the use of fertilizers and corrective measures in areas close to the one studied, mainly the contributions of organic matter. There is a tendency to increase the values of Ca^{+2}, Mg^{+2} and K^{+} from the highest and flatter part of the toposequence to the lowest part. This displacement according to the slope gradient points to the depressions as a place of “reception” of the leached elements.

Al^{+3} values are high at surface horizons, especially at CAL 2 and CAL 4, but decrease at depth. Organic matter also decreases towards the base, but the values are still very high and different from the standards for Yellow Latosols (ALVARENGA et al, 2013; PRAGANA et al, 2012).

Soils are acidic, with an average pH in water of 4.3. It is observed that even with a reduction in the values of $H^{+}+Al^{+3}$ and organic carbon in depth, the pH shows a slight reduction in the transition set and in the top of the latosol set, indicating that the nature of the organic matter gives more characteristics acid to these volumes (Table 1). Soil pH indicates that values are being influenced by low molecular weight organic fractions, notably fulvic acids, according to Ribeiro (1998) and Santos (2003) in the studied area.

Table 1 – Physical and chemical attributes.

Horiz	pH		g kg^{-1}		Sorption complex (mmol$_e$ kg^{-1})							%	g kg^{-1}	Granulometry (g.kg^{-1})					
	H_2O	KCl	M.O	C	Ca^{+2}	Mg^{+2}	K^{+}	Na^{+}	Al^{3+}	$H^{+}+Al^{3}$	T	V	Fe_2O_3	TS	CS	FS	S	C	DC
Perfil CAL 1																			
A1	4,5	3,6	104,9	61,0	27	14	2	0,7	18	105	148,7	29	2,1	480	310	170	60	460	180
A2	3,7	3,5	25,4	14,8	6	7	0,3	0,2	18	44	57,5	24	2,6	430	240	190	20	550	110
AB	3,7	3,5	24,8	14,4	5	2	0,2	0,2	16	71	78,4	9	2,4	390	280	110	40	570	60
BA	3,5	3,3	22,2	12,9	7	5	0,2	0,2	15	67	79,4	16	2.6	380	270	110	20	600	30
Bw1	4,0	3,5	16,3	9,5	7	5	0,1	0,1	15	58	70,2	17	2,5	330	260	70	80	590	20
Bw2	3,8	3,5	9,3	5,4	9	4	0,1	0,2	14	58	71,3	19	2,8	350	240	110	10	640	0
Bwh3	3,8	3,2	11,4	6,6	9	5	0,1	0,2	13	40	54,3	26	2,3	310	210	100	10	680	0
Bw4	3,8	3,4	10,6	6,1	7	5	0,1	0,2	13	37	49,3	25	2,4	300	210	90	0	700	0
Bw5	3,9	3,5	11,1	6,5	7	5	0,1	0,2	9	30	42,2	29	2,5	290	240	50	0	710	0
Perfil CAL2																			
A1	4,0	3,5	84,2	49,0	8	6	0,7	0,4	23	160	175,1	9	1,7	540	390	150	40	420	80
A2	4,0	3,6	91,2	53,0	7	3	0,4	0,4	22	119	129,8	8	1,4	530	340	190	40	430	70
ABh/E	3,7	3,4	109,8	63,8	7	6	0,5	0,3	31	155	168,8	8	1,4	580	420	160	50	370	90
BAh	4,0	3,6	36,3	21,1	7	3	0,3	0,2	15	97	107,5	108	1,6	450	290	160	30	520	30
Bwh1	4,2	3,7	27,1	15,8	6	5	0,2	0,2	18	79	90,4	13	1,8	310	190	120	100	590	0
Bwh2	4,3	3,8	23,4	13,6	5	3	0,2	0,2	18	79	87,4	10	2,0	420	240	180	50	530	20
Bw3	4,3	3,7	20,4	11,9	6	4	0,2	0,2	18	63	73,4	14	1,8	400	230	170	60	540	10
Bw4	4,3	3,6	12,1	7,0	7	3	0,2	0,5	15	45	55,7	19	1,5	350	240	110	10	640	0
Perfil CAL 3																			
A1	4,1	3,5	104,9	61,0	19	8	1,3	0,8	17	132	161,1	18	0,6	710	440	270	0	290	70
A2	4,0	3,6	48,0	27,9	7	6	0,5	0,5	15	113	127,0	11	1,4	530	340	190	20	450	50
AB	4,5	3,7	32,5	18,9	7	7	0,6	1	18	116	131,6	12	1,7	510	370	140	10	480	10
BA1	4,3	3,8	32,7	19,0	4	3	0,4	1,1	18	98	106,5	8	1,6	400	250	150	20	580	0
BA2	4,5	3,8	29,5	17,2	8	5	0,4	1,6	15	87	102,0	15	1,8	370	220	150	10	620	0
Bwh1	4,3	3,7	18,9	11,0	8	3	0,3	1	18	74	86,2	14	1,6	320	260	60	30	650	0
Bwh2	4,5	3,7	16,0	9,3	7	5	0,6	0,6	11	50	63,2	21	1,9	340	200	140	20	640	0
Bw3	4,2	3,6	10,5	6,1	6	6	0,3	1	18	60	73,6	18	1,9	380	240	140	0	620	0
Bwx4	4,4	3,5	10,1	5,9	7	4	0,1	0,3	13	37	48,4	24	2,0	360	250	110	0	640	0
Perfil CAL 4																			
Hp	4,0	3,7	164,1	95,4	29	14	1,3	0,9	23	271	316,2	14	0,7	860	550	310	70	70	40
Ap	4,2	3,8	135,2	78,6	7	6	0,8	1,2	18	197	212	7	0,6	740	470	270	160	100	20
A	4,5	3,9	147,1	85,5	8	5	0,7	1,4	15	220	235,1	6	0,7	710	460	250	150	140	20
Bs/Eh	4,4	4,1	114,0	66,3	7	4	0,4	0,4	12	199	210,8	6	0,7	810	460	350	170	20	10
Bhm1	4,8	4,3	68,1	39,6	8	5	0,5	0,8	13	193	207,3	7	0,5	860	490	370	100	40	30
Bhsm2	4,9	4,4	146,1	85,0	5	4	0,6	1,5	10	241	252,1	4	0,8	810	390	420	230	20	10

TS - Total sand; CS - Coarse sand; FS - Fine sand; S - Silt; C - Clay; DC- Dispersed clay.

Source: Authors (2022).

The fine sand/total sand ratio shows a tendency to increase fine sand contents in Bwh2 and Bwh3 when compared to the underlying horizons, suggesting that organic matter acts differently in these horizons. This fact may be associated with the fraction of predominant organic compounds in the constitution of organic matter accumulated in depth. The micromorphology of these horizons corroborates this idea, with a sharp increase in fragmented quartz with corroded edges being observed.

3.5 Mineralogy

In landscapes where more stable relief features are inserted, it is possible to find thick and highly evolved soils. The records of its evolution or its current evolutionary stage can be inferred through the associated mineralogy, morphology, chemical and physico-hydric characteristics. In the studied soil toposequence, the predominant clay mineral is kaolinite. There was no expansion of the clays treated with hydrazine. The presence of low intensity peaks suggests that kaolinite is poorly crystallized, identified in other Yellow Latosols of Coastal Tablelands (GOMES et al, 2012; LIMA NETO et al., 2010; CORRÊA et al., 2008ab, MÖLLER; ARAKI, 1984).

The climate of the region and the source material (Tercio-Quaternary sediments of the Barreiras Group) are conducive to the occurrence of less crystalline kaolinites (HUGHES; BROWN, 1979). Kämpf et al. (2003) also emphasize that the mineralogical assemblage of a soil is conditioned by the source material and by pedogenesis, including stages of stability, transformation and neoformation of minerals.

The morphology of the cohesive set demonstrates a correlation with the mineralogy. Vrdoljack (1998), in his microscopic study with samples from Latosols, in Northern Brazil, observed that the fundamental unit of aggregation in these soils is constituted by kaolinite plates arranged face to face, and goethite particles. The analysis of the clay fraction of the soil allows us to understand the dynamics of the transformation processes, but also useful in classification, being a criterion used in the differentiation of taxonomic classes, such as the Yellow Latosols (SANTOS et al., 2018). For Correa et al. (2008a), the genesis of cohesive horizons in Coastal Tablelands soils is derived from the translocation of very fine clay of kaolinitic composition. The greater densification of these horizons would then be related to the face-to-face adjustment of these kaolinite (LIMA NETO et al., 2010; FERNANDES et al., 2016).

X-ray diffractometry shows that the mineralogy of the profiles of sectors 1, 2 and 3 basically consists of disordered kaolinite, goethite, quartz and traces of anatase. Sector 4 differed from the others presenting kaolinite/smectite interstratified and traces of rutile and anatase. Located at the base of the toposequence and inserted in a shallow relief feature, this sector has slow leaching, favored by the poor drainage of the environment, which enables neoformation processes.

3.6 Pedogenesis and formation processes

The soils have surface horizons rich in organic matter, differentiating them from most existing soils in the coastal tablelands. Along the slope, the surface horizons have a pH in water ranging from 3.7 to 4.5 (Table 1). Acidity interferes with the potential of microorganisms to mineralize organic matter and promotes changes not only in its quality, but also in the composition and quantity of microorganisms involved in the transformations (ANDRADE et al., 1995), which contribute to the accumulation of organic matter.

In Sector 2 and 4, where depressions occur, the temporary hydromorphy caused by a reduction in the infiltration velocity due to the small topographic difference and the presence of low permeability horizons in the subsurface. This determines anaerobic conditions favorable to bacterial reduction and the formation of low molecular weight organic compounds, which promote acidity.

The sediments of the Barreiras Group, which are essentially kaolinitic (RIBEIRO, 1998), impart acidic characteristics to the soils, a fact that combined with the vegetation and local topography, corroborates the establishment of the necessary conditions for the accumulation of organic matter.

The pedogenetic process that acts prominently is partial acidolysis. The pH values between 4 and 4.5 and the high levels of Al^{+3} along the slope confirm this assumption. This assumption is also compatible with the solubilization of clays, due to solutions containing organic acids from the partial anaerobic decomposition of the phytomass.

Laterally, the genetic relationship between the soils, expressed in the progressive modification of the yellowish-brown to grayish-brown color in the latosol set, is determined by slow subsurface flow, favored by the presence of cohesive and cemented horizons. Organic matter also influences the color of the soils, perceived by the dark spots in different shades of bruno at the top of the latosolic set and in the transition set. In depth, a progressive change in color is observed, which turns gray in almost the entire massive set, except in Sector 4.

The surface set gradually becomes more sandy from upstream to downstream, less structured, richer in organic matter and less thick. The structure in subangular and lumpy blocks of the surface set (Sector 1) is transformed along the toposequence, and in Sector 2 and 3 they appear associated with washed sands and fragile lumps. At the base of the toposequence, simple grains are observed. In the latosol set there is a gradual change from the subangular to massive block structure.

The degradation of the structure of the surface horizons must be related to the type of organic compound predominant in the process of mineralization of organic matter, notably fulvic acids, which would favor the displacement and loss of silica, aluminum and iron released in the process of clay dissolution (RIBEIRO, 1998). Si, Al and Fe transported by organic substances would be responsible for structural instability in the subsurface (VOLKOFF; ANDRADE, 1976; RIBEIRO, 1998) and for the appearance of cemented horizons (UGOLINI; DAHLGREN, 1986; PEDRO, 1987; PEDRO, 1978).

The analysis of aerial photographs of the region showed that depressions usually occur at the intersection of faults or fractures, with alignments that follow a preferential direction, indicating neotectonism as the initiator of the podzolic transformation process. Crossings would determine preferential drainage flows, implying material exportation, surface subsidence and establishment of hydromorphic conditions, as suggested by Barbiero (1995), Filizola and Boulet (1996), Dubroeucq (1999), Ucha (2000), Carvalho (2001), Fortunato (2004) and Nunes et al. (2019). The reduction of surface runoff flow is imposed by the new relief condition and accentuated by the presence of cohesive horizons that reduce the infiltration velocity.

Once the hydromorphy is installed at the base of the slope, there is an accumulation of organic matter in Sector 4, due to a decrease in mineralization by temporary anaerobiosis and the formation of humus rich in acidic organic compounds (LEFEBVRE-DROUET et al., 1993; RIBEIRO, 1998). These acidic organic compounds would cause the disorganization of the structure of the clays, selective dissolution of iron oxyhydroxides, manifested in the gradual change of color, with yellowing, followed by whitening and progressive loss of structure in aggregates to massive, less porous, poorly permeable and prone to waterlogging. The lateral flow of solutions over a kaolinitic material and containing acidic organic compounds would determine the establishment of high acidity in the soil and the accumulation of organic matter by reducing the mineralization rate.

The wetting and drying cycles, governed by climatic conditions, would be responsible for the translocation of organometallic compounds and the installation of podzolization processes. The subsequent cementation of subsurface horizons would promote the appearance of a surface water table and advance podzolization.

The fluctuations of the water table in the periods of greater and lesser precipitation form a wedge-shaped relief, which thins upstream, between its maximum and minimum influence limit. This configuration indicates that podzolization takes place in a regressive and less intense way at shallower points and further away from the center of the depressions, with the export of material being guaranteed by the recharge and emptying of the water table.

The appearance of gray horizons occurs from upstream to downstream of toposequence. The process can be perceived at the base of the toposequence, as a discontinuous and gradual evolution of fragipanic features, which seem to develop close to small accumulations of iron.

The water table influence can be seen by the presence of mottles in the lower latosol horizons. The evidences is the change in color, associated with reduced drainage and iron segregation marks, typical of environments temporarily saturated by water. In this case, they are due to the speed with which the water crosses the soil and the intervention of the water table in the soil, that is, the residence time of water in the soil.

Friable materials and darkened by organic matter penetrating old ravine channels or associated with the decomposition of old roots seem to determine, locally, a reorganization of the structure. Rounded, firm and dark-brown materials found at about 1 meter depth are probably the result of the filling of organic material from biovoids. These materials are more common after Sector 2, and from Sector 3 onwards, they are harder and slightly increased in size. Os níveis endurecidos e impermeáveis, na parte inferior da vertente - Setor 4, originaram um nível de base local do lençol freático que nas condições climáticas atuais chega a superfície.

Between Sector 1 and 2 there is a rounded, reddish-yellow, hardened and massive pocket, with discontinuous vertical penetrations. Its origin seems to be related to the decrease in infiltration velocity in the subsurface horizons. Mobile iron appears to have migrated and accumulated in larger pores, biological cavities and places where there are cohesive volumes. The rounded pocket is more common in the flat and slightly lowered area of Sector 2, and its morphological features suggest the development of a Bsh horizon.

In the transition set, the cohesive horizons temporarily cause the appearance of suspended water table, which favors the mobilization of organic solutions and the appearance of zones enriched in organic matter. The Bhm and Bhsm horizons of Sector 4, center of the depression, are extremely rich in organic matter, hardened and with low density. In this sector, the soils would be in balance with the local conditions and, together with the organic matter, establish a front of ascending transformation that can imply a modification of the landscape. Within the depression, an E horizon evolution towards Sector 3 is observed, evidenced by the presence of washed sands, yellowish-brown materials and relics of the latosol horizon in the Bh/E and BA transitional horizons.

In Sector 2, the process appears more markedly. The greater amount of water captured, due to the reduction in the flow of surface runoff, determines a more prolonged hydromorphy and accumulation of organic matter. Thus, the joint action of hydromorphy and organic acids would cause the disorganization of clays, the appearance of washed sands, the precipitation of translocated organometallic compounds and the cementing of horizons. This would promote the advancement of podzolization at more distant points and at higher levels than those found in depression.

4. Conclusions

1. The pedological system is complex, with closed depressions related to crossing points of faults and/or fractures, evidence of the influence of tectonic processes in the evolution of the relieve.

2. The characterization and organization of the latosol-spodosol sequence shows evidence of the existence of a dynamic governed by the presence of organic matter, with a predominance of low molecular weight organic fractions, notably fulvic acids, which interfere in the geochemical processes and in the chemical and physical properties of soils. The reduced values of CEC, base saturation, the low pH values and the amount of clays dispersed on the surface, reinforce this assessment, since the values of organic matter found are high and, despite gradually decreasing in depth, they still remain raised to the base of the profiles.

3. The destruction of primary minerals and the disorganization of the secondary ones recorded in the micromorphological, chemical and X-ray analyses, point to the translocation of iron and humus, indicating a predominantly organic route in the transformation process, under the influence of reducing environments.

4. The toposequence evolves from downstream to upstream, with accumulation of organic matter in Sectors 2 and 4, indicating a process of change in the structural organization more evident in Sector 2, influenced by the relief, the water table level and the morphology of the horizons, which present cohesion and cementation.

5. The accumulation of organic matter, under acidic and temporary anaerobic conditions (in depressions), favors the formation of mobile and acidic organic compounds that act in the transformation of Yellow Latosols, through the installation of podzolization processes with partial acidolysis.

6. The organic matter that resembles MOR type humus, promotes the degradation of the soil structure and the appearance of washed sand, a consequence of a gradual dissolution of constituents from the surface horizons.

7. The morphological analysis allows us to affirm that the toposequence soils are influenced by the water table. Periodic saturation of depressions favored the formation of organic horizons, production of less evolved humic substances, podzolic transformation and formation of duripan and fragipan horizons.

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