REVISTA GESTÃO & SUSTENTABILIDADE AMBIENTAL ISSN 2238-8753 unisul ecossistema ânima

ALTERAÇÃO DOS PARÂMETROS FÍSICO QUÍMICOS DOS SOLOS DE ÁREAS ÚMIDAS IMPACTADAS PELA AGRICULTURA E MINERAÇÃO (MG)

CHANGE OF PHYSICAL CHEMICAL PARAMETERS OF WETLAND SOILS IMPACTED BY AGRICULTURE AND MINING (MG)

Larissa Vieira Zezzo[1]
Vania Silvia Rosolen[2]
Fábio Braz Machado[3]
Andreia Medinilha Pancher[4]
José Silvio Govone[5]
Priscila Pereira Coltri[6]

RESUMO

Áreas úmidas localizadas na região oeste de Minas Gerais vem sendo convertidas em terras agrícolas e de mineração de argila. O objetivo desse artigo foi avaliar as diferenças na concentração e distribuição de macro, micronutrientes e outros parâmetros físicos em solos de áreas úmidas usados para produção agrícola desde 1970 ou pela mineração, comparando com áreas úmidas naturais ou não impactadas, durante a estação seca. Para isso, amostras de solo foram coletadas em diferentes profundidades em 6 pontos. Por meio de trabalhos de campo, foi possível avaliar as mudanças morfológicas do solo e coletar amostras para realizar análises físico-químicas. As análises granulométricas e a química forneceram informações para melhor compreender a extensão dos impactos ambientais em

[1] Doutoranda do Programa de pós-graduação em Ensino e História das Ciências da Terra na Universidade Estadual de Campinas (UNICAMP) E-mail: larisvz@gmail.com
[2] Docente do Instituto de Geociências e Ciências Exatas (IGCE) – Departamento de Geologia, na Universidade Estadual Paulista "Júlio de Mesquita Filho" (UNESP) E-mail: vaniarosolen@gmail.com
[3] Docente do Departamento de Geologia na Universidade Federal do Paraná (UFPR) E-mail: fabio.machado@ufpr.br
[4] Docente do Instituto de Geociências e Ciências Exatas (IGCE) - Departamento de Geografia e Planejamento Ambiental, na Universidade Estadual Paulista "Júlio de Mesquita Filho" (UNESP) E-mail: amedinilhapancher@gmail.com
[5] Docente do Instituto de Geociências e Ciências Exatas (IGCE) - Departamento de Estatística, Matemática Aplicada e Computação, na Universidade Estadual Paulista "Júlio de Mesquita Filho" (UNESP) E-mail: jsgovone@gmail.com
[6] Docente do Instituto de Geociências, no Programa de pós-graduação em Ensino e História das Ciências da Terra da Universidade Estadual de Campinas (UNICAMP) e Diretora do Centro de Pesquisas Meteorológicas e Climáticas Aplicadas à Agricultura (CEPAGRI) E-mail: pcoltri@cpa.unicamp.br

decorrência de atividades econômicas desenvolvidas na área. Dentre os pontos analisados, notou-se mudanças morfológicas nas áreas de cultivo agrícola e principalmente na área de mineração, onde ocorre erosão laminar. A análise granulométrica mostrou mudança textural nos locais de cultivo agrícola, enquanto que os demais pontos foram classificados como textura argilosa ou muito argilosa. A análise química mostrou que as áreas de cultivo agrícola apresentaram teores elevados de macro e micronutrientes nas camadas superficiais e a saturação por bases foi muito baixa em praticamente todos os pontos estudados. O local da Mineração se mostrou como o mais degradado e menos propício ao crescimento vegetal.

Palavras Chave: Wetlands; Conservation; Environmental Impacts; Legislation.

Abstract

Wetlands located in western region of Minas Gerais state have been converted in agricultural land and clay mining. The objective of this article was to evaluate differences in concentration and distribution of macro, micronutrients and other physics parameters in wetland soils used for agricultural production since 1970 or mining comparing with natural and non - impacted wetland soils, in dry season. For that, soil samples were collected at different depths at 6 sites. Through field work, it was possible to assess the morphological changes of the soil and collect samples to perform physicochemical analyses. Particle size and chemical analysis provided information to better understand the extent of environmental impacts resulting from economic activities carried out in the area. Among the points analyzed, morphological changes were noted in agricultural cultivation areas and especially in the mining area, where laminar erosion occurs. The particle size analysis showed a textural change in the places of agricultural cultivation, while the other points were classified as clayey or very clayey texture. The chemical analysis showed that the agricultural cultivation areas presented high levels of macro and micronutrients in the superficial layers and the base saturation was very low in practically all the studied points. The mining site proved to be the most degraded and least suitable for plant growth.

Key words: *Wetlands; Conservation; Environmental Impacts; Legislation.*

1. INTRODUCTION

Soil and water are the two critical components of the Earth's Critical Zone (LIN et al., 2015). One the most perfect synergistic relations between water and soil is found in wetlands areas. The ecological functions and environmental services provided by wetlands contribute significantly to the biodiversity, they have a "sponge effect" filtering residues of fertilizers and pesticides, store soil carbon and provide fiber and fruits for traditional communities (TILTON, 1995).

However, the natural wetlands remain one of the most vulnerable ecosystems because have been losing area and affecting their capacity to maintain the functionality between hydric soil and water (GIBBS, 2000). In Brazil, statistical data on wetland conversion, degradation and a plan for restoring previously converted cropland not exist, despite their geographic extension in the Brazilian territory (approximately 30% of the total area) and their diversity and economic importance (JUNK et al., 2013).

Wetlands are widespread in Cerrado Biome in western region of Minas Gerais state. The shallow depressed areas are waterlogged during rainy seasons, are covered by grasses resistant to aquic conditions and present soil profiles enriched with soil organic matter (SOM) contrasting to surrounded upland. Previous studies carried out in this landscape have shown that wetland soils concentrate large amounts of micronutrients from intensive agriculture because their shape (depressed topographic zones) and wide distribution over the plateau benefit the entry of point and non-point pollution sources (ROSOLEN et al., 2015a).

The Gleysol presents in waterlogged areas is as natural sink due to its capacity of retaining chemicals inorganic elements through the adsorption of soil organic matter (SOM) (GAO et al., 2013). In addition, the concave shape represents a zone of the convergence flow from rainfall, increasing the risk of runoff towards depressed areas. In the Minas Gerais state, the conversion of natural wetlands in agricultural lands started in the 1970'years.

Historically, artificial drainage was techniques used to convert wetlands for agricultural land, allowing the crops expansion from the border toward the center of the depression. The land use conversion was encouraged and financed by the

Brazilian government (Provarzeas or National Program for the Use of Irrigable Floodplains - Federal Decree n. 86146/81).

Nowadays, the practice is prohibited by federal environmental regulations (Forest Code – Federal Law n° 12.651 of 2012) which considered wetlands Permanent Preservation Areas. Nevertheless, the compliance with legislation is not effective and the conservation is uncertain (ROSOLEN et al., 2015b). It is known that once drained and along the time, wetlands soil can loss water and organic matter, changing its natural properties (EWING and VEPRASKAS, 2006). Because the studied area is inserted in a central area of agribusiness, producing mainly corn and soybean, wetlands receive the input of fertilizer and lime at least two times per year, before planting, in order to increase the fertility of the lateritic soils. Agricultural production is responsible to release macro and micronutrients that potentially accumulate in soils of wetlands, reflecting on the reduction of plants diversity and loss of water quality (BEDFORD et al., 1999; EWING et al., 2012).

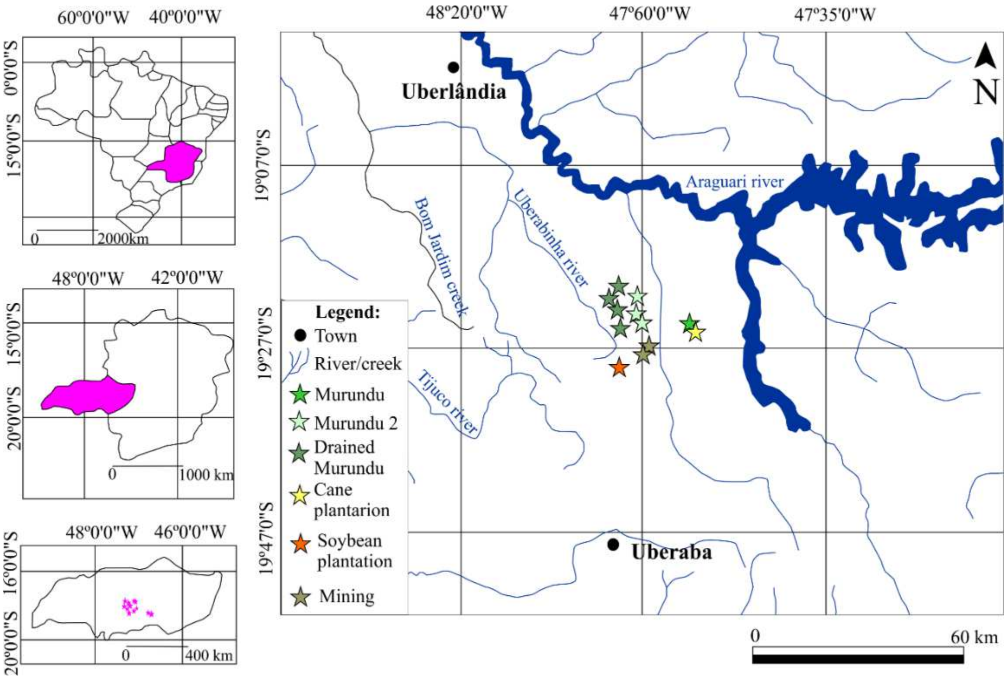
In view of the expose, the objective of this article was to assess differences of concentration and distribution of macro, micronutrients and other physics parameters in soils of wetlands used for crop production since 1970 or mining comparing to natural and not impacted wetlands soils. We hypothesized that after several years receiving limes and fertilizers from agriculture and because of the revolving of the soil by the mining, the natural chemical, physical and morphological characteristics of soils in wetlands have sensitively changing.

2. MATERIALS AND METHODS

The area of study has approximately 728.43 km^2 and is located in Minas Gerais state, between the municipalities of Uberaba and Uberlândia (19º 26 "51 'S and 47º 53" 83' W) on a sedimentary flat plateau (Figure 1).

This plateau is a branch of the Brazilian Central Plateau, which was originally covered by the Cerrado Biome vegetation. The Cerrado Biome is the last Brazilian agricultural frontier areas under native vegetation, and the high seasonality with extensive dry periods annually associated with low fertility soils demanding water availability for irrigation and appropriate management for land use expansion (RODRIGUES et al., 2018).

Figure 1: Study area, with presentation of collection points and soil analysis in the region between the municipalities of Uberlândia and Uberaba (MG)



Source: Prepared by the authors.

The average altitude is 970 m.a.s.l. and the climate is characterized by a pronounced dry season (from May to October) and a rainfall season during summer months (from November to April). The average annual rainfall is 1,516 mm, and the average annual temperature is 23°C.

Sandstones of the Marilia Formation (Bauru Sub-basin - Upper Cretaceous) characterize the geology (BASILICI et al., 2012). In wetlands dominate Gleysol typical of environment with excess of water. The soils may be permanently or temporarily waterlogged, according to the rise and fall of the groundwater level following the alternating wet and dry seasons. Grass dominates in anoxic soil conditions (VEPRASKAS et al., 1994).

Wetlands are surrounded by soybean and maize crops and their borders (transition zone between dry and wet soils) were converted to tillage system after removal of the original herbaceous and shrubby vegetation.

2.1 Soil Description and Sampling

For the description and morphological sampling of the soil, six different areas were selected. Trenches were opened according land use, representing natural wetlands and wetlands converted into agriculture and mining (Table 1).

Table 1: Points where soil samples were collected, with information on altimetry and observed depths.

Collected samples	Denomination (land use)	Altimetry (m)	Depths sampled
P1	Murundu	942	0-20 cm; 20-40 cm; 40-60 cm; 60-80 cm
P2	Murundu 2	963	0-20 cm; 20-40 cm; 40-60 cm
P2.1		963	
P2.2		963	
P3	Drained Murundu	984	
P3.1		983	
P3.2		974	
P3.3		980	
P4	Cane plantation	942	
P5	Soybean plantation	982	
P6	Mining	976	0-20 cm; 20-40 cm
P6.1		976	

Source: Prepared by the authors.

In total, were opened 12 trenches and denominated P1 (Murundu), P2, P2.1 and P2.2 (Murundu 2), P3, P3.1, P3.2 and P3.3 (Drained Murundu), P4 (Cane plantation), P5 (Soybean plantation), P6 and P6.1 (Mining) were opened.

The points "Murundu" and "Murundu 2" correspond to natural hydromorphic areas, without anthropic use. The points called "Soybean plantation" and "Cane plantation" are areas of agriculture. The "Mining" point refers to an old area of clay extraction. The other areas refer to the areas that do not have natural vegetation, being denominated "Drained Murundu".

Soil profiles were described by layers according to the FAO Soil Description Manual (2006) and Vepraskas et al. (1994). In each described layer, soil samples were collected for chemical and physical analysis.

In the description of soil profiles based on the FAO proposal (2006), the properties of color (MUNSELL Soil Color Charts, 2000), texture, structure and cohesion were considered.

The Munsell color system is a means of visually identifying and matching colors using a scientific approach, where the first step is to understand the three colors attributes (hue, value and chroma, also known as HVC). In this sense, hue is a color, such as green, red, or blue, for example. Value tells how light or dark a color is, while chroma refers to how weak or strong a color is (MUNSELL Soil Color Charts, 2000).

Soil color descriptions should be determined out of direct sunlight and by combining a broken ped with the color chip from Munsell's soil color charts. Furthermore, it is noteworthy that early morning and late evening readings are not accurate.

The other characteristics were evaluated from the visualization of the appearance of the samples and through touch. Soil structure and soil cohesion were described in terms of grade, size and type of aggregates. In this case, when a soil horizon contains aggregates with different characteristics, each aggregate type must be described separately.

In order to evaluate the water saturation time using only morphological features in the field, the color and the presence of the stained horizons of the wetlands Gleissolos were considered according to the proposal by Vepraskas et al. (1994). In this proposal, the authors attribute the permanence time of water in the soil and the saturation time (oxi-reduction) by the presence of spots and by the chroma of the soil. The stains refer to the concentrations of Fe oxides, so the amount and chroma (< 2) of the stains are directly related to the duration of water in the soil profile.

To assess the water table level, descriptions made for points of the same altitude were compared, specifically analyzing the depth at which the water level was observed.

2.2 Physical Analytical Procedures

The granulometric analysis was made to obtain the size of particles and percentage of occurrence used to obtain the soil particle distribution curve and was used in the soil textural classification (NOGUEIRA, 2005).

Initially the sample was dried in an oven at 45ºC and buffered in agate mortar. Each sample was weighed and placed in beakers. In this test were used 45.7 g of sodium hexametaphosphate (deflocculant) for each 1L of water, 125 ml of this solution was added in each sample (NOGUEIRA, 2005). Later, each sample was placed on an agitator and then washed on a cylinder. The sands that remained in the sieve were transferred to beakers and placed in an oven at 45ºC. In relation to the sieving, the aim was to separate the different sizes of sand (coarse, medium and fine), using a set of sieves of varied diameters (0.053mm<0.074mm<0.149mm<0.250mm<0.297mm<0.042mm<0.059mm<1.19mm <2.00mm<4.76mm). The material of each beaker was deposited in the upper sieve of diameter of 4.76mm. The set was agitated for 5 minutes, and at the end of the agitation period, the material retained in each sieve was weighed (NOGUEIRA, 2005).

With respect to the silt and clay present in the cylinders, the samples were mechanically agitated and the measurement of the sedimentation time of the silt and clay fractions was started. Measurements were made with the densimeter at each pre-determined time period, in the test tubes (NOGUEIRA, 2005). With the values of the test it was possible to obtain the gran size curve.

2.3 Chemical Analytical Procedures

In the laboratory, soil samples were homogenized and oven dried at 50°C then sieved (nylon mesh) to obtain the fraction of < 2 mm (fine earth fraction).

The samples were analyzed for the Sortivo Complex and other parameters, as a matter organic (MO), aluminum saturation (m), bases saturation (V), micronutrients (Cu, Zn and Fe) and macronutrients (Ca^{2+} and Mg^{2+}).

Ca^{2+} and Mg^{2+} were extracted by ion exchange resin and determined by atomic-emission spectrophotometer. The exchangeable Al was obtained by colourimetry and extracted with potassium chloride 1 mol L^{-1}. Base Saturation (V) was calculated as the sum of K+, Ca^{2+}, and Mg^{2+}. Aluminum Saturation (m) was obtained by the relationship between the exchangeable base contents in the soil and the aluminum concentration. Mn, Cu, Zn and Fe were determined by Atomic Absorption Spectrometry (AAS). The analyses were made in the Laboratory of Soil and Soil Fertility of Federal University of Viçosa (Viçosa, Brazil).

2.4 Statistical Analysis

In order to statistical analysis the similarities and differences between the samples, was used the Kruskal Wallis statistical test.

The Kruscal-Wallis test is the nonparametric test used when comparing three or more independent samples with respect to a single variable. This test indicates whether there is a difference between at least two of the samples (McKNIGHT and NAJAB, 2010).

3. RESULTS AND DISCUSSION

Based on the application of the methodological procedures, results were obtained regarding the profiles, granulometric composition and soil chemistry.

3.1 Characterization of soil profiles

The morphological features in each profile were described by layers (Figure 2), grouped as they present common characteristics, in order to assess the morphological differences present in the sampled areas and which may be associated with different land uses.

- P1 (Murundu)

This point is located at 942 m of altitude and refers to a natural hydromorphic area, having been described four layers of soil up to 80 cm.

According to the characteristics presented, the 60-80 cm layer is considered as the typical lateritic spotted horizon, with the presence of hardened red spots and small iron nodules, whose genesis is associated with the presence of a high water table in periods of year (VEPRASKAS et al, 1994).

- P2 (Murundu 2)

Refers to a natural hydromorphic area, having been described three layers of soil up to 60 cm. This profile, also without anthropic influence, differs from P1 (Murundu) by presenting a color that indicates characteristics close to the matrix of the yellow Latosol, showing that it is a transition profile.

There was no significant change in the color of the first layer comparing P2 (Murundu 2) with P1 (Murundu), while the other layers showed a change in hue, which was 2.5 in P2 (Murundu 2) and 7 .5 at P1 (Murundu) for the 20-40cm layer.

The massive structure and very hard when dry, a characteristic present in all layers, reflects the little structural development common in areas with excess water in the soil. This characteristic makes the soil susceptible to greater erodibility by providing greater surface runoff (CAPECHE, 2008).

At P2 (Murundu 2), the water table did not outcrop and the presence of ferruginous nodules in the profile was not observed. The absence of water table and oxidation-reduction characteristics may be related to the higher altitude of this profile, with 963 meters, compared to P1 (Murundu) which is at 942 meters of altitude. Thus, the higher altitude observed in P2 (Murundu 2) may justify the fact that the water table is deeper.

- P3 (Drained Murundu)

It represents an area where drains were installed for the cultivation of soybean and corn. This soil profile has an excessively hard consistency, which is related to soil densification, a type of natural compaction that generates limitations in the physical nature of the soil with regard to plant development, which can cause chemical limitations, alternating soil capacity in absorbing nutrients, for example (EMBRAPA, 2018).

This point is located at 984 meters of altitude, a fact that may justify the non-upwelling of the water table. The colors of the layers in P3 (Drained Murundu) are similar to the colors observed in P1 (Murundu), although there are changes in one of the soil color variables, such as hue, which in P3 (Drained Murundu) is 10, while at P1 (Murundu) it is 7.5 for the 20-40cm layer.

- P4 (Cane plantation)

In P4 (Cane plantation), a trench was opened up to 60 cm and described in three layers. This profile differs from P1 (Murundu) due to the lower contrast between the surface (0-20 cm) and subsurface (20-40 cm) layers, a fact possibly related to soil disturbance for planting.

In the superficial layer (0-20 cm), a change in the color of the soil was observed, being darker in P4 (Cane plantation) when compared to P1 (Murundu), probably due to agriculture that turns the soil and incorporates a greater amount of organic matter (SANTOS, 2007).

In this profile, the soil was massive, therefore without structure in the most superficial layer, unlike P1 (Murundu), which presented a lumpy structure. The lack of soil structure, among other factors, may be related to agricultural cultivation.

In P4 (Cane plantation), the height of the water table was 40 cm deep, while in P1 (Murundu) the water table was observed at 24 cm, and these two points are at the same altitude (942 meters), highlighting a lowering of the sheet level.

It is noted that there is no development of the spotted horizon as in P1 (Murundu), a fact that may be related to sugarcane cultivation practices, since agriculture influences the soil, changing its structure and the height of the water table (EWING et al., 2012).

- P5 (Soybean plantation)

P5 (Soybean plantation) refers to a soybean growing area with trench opening up to 60 cm. When comparing this soil with P1 (Murundu), it is clear that there are structural and color differences between these profiles.

Regarding the soil structure, P5 (Soybean plantation) presents a micro aggregated structure, while P1 (Murundu) presents a lumpy structure in the first layer and massive in the others.

The color of P5 (Soybean plantation) has a red hue, while the color of P1 (Murundu) is an orange hue, with regard to the surface layer (0-20 cm).

In this soil profile, the water table was not observed, which may be related to the higher altitude of this point, which is at 982 meters, compared to profiles P1 (Murundu) and P4 (Cane plantation), which are at a lower altitude of 942 meters. Thus, the water table does not outcrop up to 60 cm at P5 (Soybean plantation) due to its higher altitude.

- P6 (Mining)

Two trenches were opened and two layers (0-20 and 20-40 cm) of soil were described for each one. The first layer of P6 (Mining) was described as a microaggregated and non-cohesive clay.

Another characteristic observed in the two trenches opened for P6 (Mining) refers to soil compaction, which was described for the second layer (20-40 cm). This characteristic hinders the infiltration of water in the profile and makes it more susceptible to laminar erosion, compromising the reestablishment of vegetation (SANTOS, 2007; STUMPF et al., 2011).

With the closure of the mining pits and the incorrect handling of the soil, it becomes more compact, providing the occurrence of laminar structure (CAPECHE, 2008; STUMPF et al., 2011).

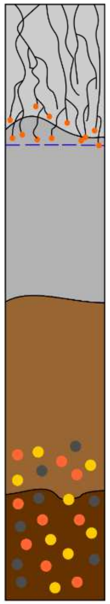
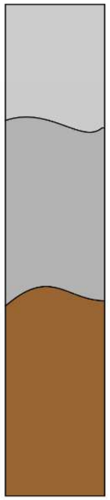
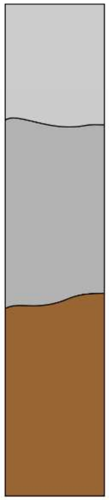
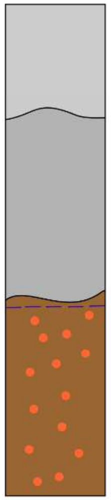
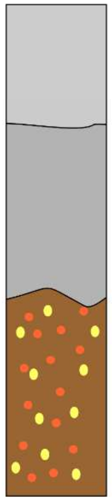
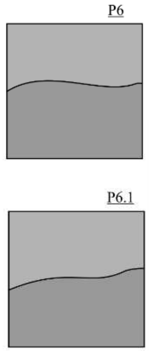
Laminar erosion is a common type of erosion in these structures and is associated with water runoff on the soil surface when it presents poor infiltration, providing the removal of superficial soil layers (TROEH & THOMPSON, 2007).

This erosive process is associated to inadequate land use practices, which include mining activities when there is no correct recovery of the area (TROEH & THOMPSON, 2007).

Among the soil profiles presented in this study, P6 (Mining) stood out for the great change in structural morphological features compared to the other points, showing that the performance of mining activities generates important and negative changes in the soil.

REVISTA GESTÃO & SUSTENTABILIDADE AMBIENTAL ISNN 2238-8753 unisul ecossistema ânima

Figure 2: comparison of soil profiles, with description of morphological characteristics identified through observation and sampling at the points mentioned.

Layer (cm)	COMPARISON												
	P1 (Murundu)	**Description P1 (Murundu)**	**P2 (Murundu 2)**	**Description P2 (Murundu 2)**	**P3 (Drained Murundu)**	**Description P3 (Drained Murundu)**	**P4 (Cane plantation)**	**Description P4 (Cane plantation)**	**P5 (Soybean plantantion)**	**Description P5 (Soybean plantantion)**	**P6 (Mining)**	**Description P6 (Mining T2)**	**Description P6.1 (Mining T4)**
0-20		Olive light bruno (2,5Y 5/4), clayey, occurrence of small lumps hardened clay (in the same color), porous, presence of many fine roots (<0.2 mm) and saturated.		Very dark greyish bruno (2,5Y 3/2), massive structure and very hard.		Olive light bruno (2,5Y 5/6), massive structure and overly hard.		Dark yellowish bruno (10YR 4/4), clayey, sticky, massive, without roots and homogeneous.		Brown (10 YR 4/3), clay, microaggregate lightly structure and yellow volumes from the horizon lower.		White clay, friable, microaggregate, not cohesive and moist.	White clay, friable, microaggregate, not cohesive and moist.
20-40		Live bruno (7,5YR 5/8), clayey, massive, presence of many fine roots (<0.2 mm), occurrence of patches oxidation around the roots, very porous and saturated.		Olive bruno (2,5Y 4/3), massive structure and very hard.		Yellowish bruno (10YR 6/8), massive structure and overly hard.		Yellow bruno light (10YR 6/4), clayey, sticky and homogeneous.		Horizon of transition diffuse by color.		White clay, laminar structure, tightly compacted and massive.	White clay, laminar structure, tightly compacted and massive.
40-60		Yellowish bruno (2,5Y 6/3), clayey, sticky, massive, presence of micropointments of yellow iron oxides and red with sizes varied and microporous.		Yellowish bruno (10YR 6/6), massive structure and very hard.		Live bruno (7.5 YR 5/8), massive structure and overly hard.		Very pale bruno (10YR 7/3), clayey, sticky and yellow matrix with red nodules isolated.		Yellowish red (5YR 5/8), clayey, small red nodules and red very pale nodules, also small.		Nonexistent	Nonexistent
60-80		Red (2.5YR 4/8) of the nodules, yellow (2,5Y 6/3) and gray (2.5 Y 7/1).		Nonexistent		Nonexistent		Nonexistent		Nonexistent		Nonexistent	Nonexistent

Source: Prepared by the authors.

3.2 Grain Size Composition of Soils

The granulometry has great importance in the characterization of the soil and in the identification of natural or anthropic processes that occur in it (RAIJ, 2011). The study of mineral fractions reflects soil characteristics, profile drainage and cation exchanges (ARAUJO et al., 2012). In general, the samples analyzed with respect to the mineral fractions were classified as very clayey in places where the soil is used to agriculture or where the soil was drained (Table 2).

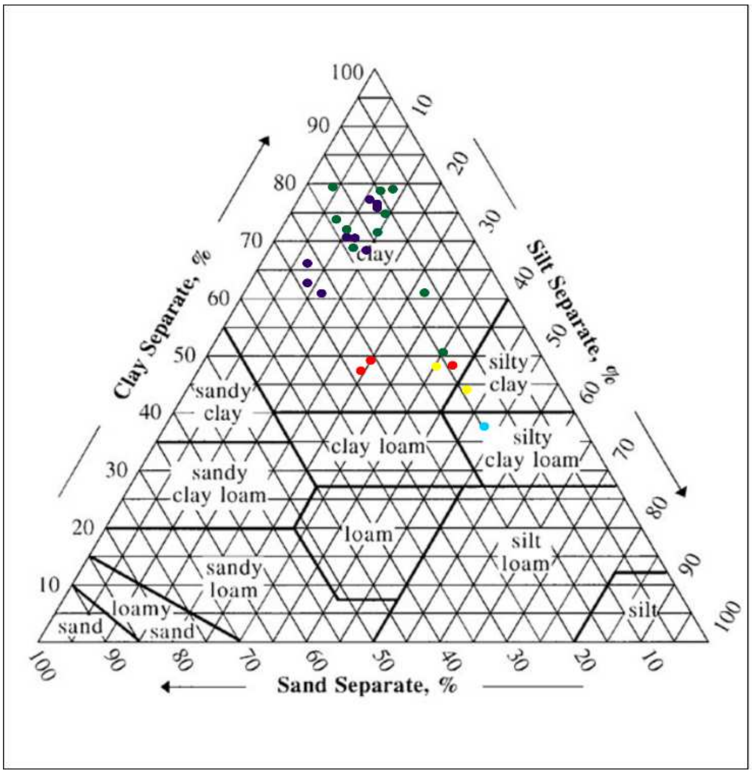
Table 2: Particle size distribution of soils sampled in the study area, with determination of the textural category.

SITES	Samples	Depth (cm)	Coarse Sand	Fine Sand	Silt	Clay	Texture Category	Colors of the USDA-USDA Texture Triangle representation
			Percentage (%)					
Murundu	P1	0-20	12	3	37	48	**Clay**	
		20-40	23	5	25	47	**Clay**	**Red**
		40-60	24	4	24	48	**Clay**	
		60-80	23	3	25	49	**Clay**	
Murundu 2	P2	0-20	24	4	9	63	**High clay**	**Purple**
		20-40	17	4	14	65	**High clay**	
		40-60	15	4	11	70	**High clay**	
	P2.1	0-20	9	3	11	77	**High clay**	
		20-40	9	2	13	76	**High clay**	
		40-60	9	2	13	76	**High clay**	
	P2.2	0-20	24	3	6	67	**High clay**	
		20-40	23	4	13	60	**High clay**	
		40-60	15	4	11	70	**High clay**	
Drained Murundu	P3	0-20	8	4	27	61	**High clay**	**Green**
		20-40	9	3	9	79	**High clay**	
		40-60	12	3	6	79	**High clay**	
	P3.1	0-20	9	5	36	50	**Clay**	
		20-40	12	5	12	71	**High clay**	
		40-60	11	5	11	73	**High clay**	
	P3.2	0-20	8	3	14	75	**High clay**	
		20-40	7	2	14	77	**High clay**	
		40-60	10	3	15	72	**High clay**	
	P3.3	0-20	8	3	12	77	**High clay**	
		20-40	14	4	14	68	**High clay**	
		40-60	14	4	8	74	**High clay**	
Cane plantation	P4	0-20	15	1	36	48	**Clay**	**Yellow**
		20-40	13	2	41	44	**Silty clay**	
Soybean plantation	P5	20-40	13	2	48	37	**Silty clay loam**	**Blue**
Mining	P6	***	***	***	***	***	***	**No representation**
	P6.1	***	***	***	***	***	***	

Source: Prepared by the authors.

From the obtaining of the percentages of the three mineral fractions (sand, silt and clay) the texture of the analyzed soils was determined, using the USDA-USA textural triangle (Figure 3).

Figure 3: UDSA-USA Texture Triangle, with identification of the soil texture from the plotting of information for each point analyzed in the study area



The characteristics of the studied soils are linked to the biochemical and physical weathering processes that act on the parent material, the Marília Formation sandstones. In this sense, the transformation of the parent material occurs with the disaggregation of the rock and the gradual mineral change, leading to the generation of new minerals, called secondary (TROEH & THOMPSON, 2007).

The sand fraction corresponds to the primary minerals of the parent material, such as quartz and other resistant minerals, while the clay fraction corresponds to secondary minerals formed by weathering processes (TROEH & THOMPSON, 2007).

Table 2 shows that of the 27 samples analyzed, 25 of them showed a predominance of the clay fraction in the different layers of the profile.

In general, samples classified as very clayey are found in the northwest portion of the study area, places where the soil is used for mining and soybean cultivation or where there has been a change in vegetation cover.

The samples from P1 (Murundu) were classified as clayey, but they are at the limit of the clayey-silty fraction, as well as the most superficial layer of P4 (Planting sugarcane).

Sample P5 (Soybean planting) was classified as silty-clay loam and sample P4 (Sugarcane planting), in the 20-40 cm layer, was classified as silty-clay. It is noteworthy that not enough sample was collected in P6 (Mining) because the soil was completely compacted and mixed with laterite residues.

The occurrence of clayey soils is related to fertile soils, since clay presents particles with electrical charges, attracting plant nutrient ions to the surface and making them available to plants.

Clay stores more water in the soil profile, retaining it and making aeration more difficult. Thus, it is noticeable that some physical properties of the soil are directly associated to its textural class.

Clayey and very clayey soils stand out due to their greater porosity and high cohesion, providing poor drainage of water in the profile. Furthermore, these soils are characterized by their great susceptibility to compaction (REINERT & REICHERT, 2006).

It should be noted that the clayey soils of the South American erosion surface, in the Triângulo Mineiro region, are a product of the weathering of other sedimentary material that covered the Marília Formation (Marques et al., 2003).

The high presence of clay in the soil is related to the geological age of the material and the intense weathering process to which the rock was subjected. These soils have a kaolinitic composition with a strong presence of iron and aluminum oxides (MOTTA et al., 2002; COELHO, 2017).

Thus, the occurrence of a higher percentage of the silt fraction in some samples shows soils that are in the process of alteration and are capable of forming more clay, replacing what is lost by processes such as erosion, in addition to providing nutrients for plant growth by weathering (TROEH & THOMPSON, 2007).

As for the economic activity developed in P4 (Planting of sugarcane) and P5 (Planting of soy), or the alteration of the soil in P3, P3.1, P3.2 and P3.3 (Murundu Drenado), it is not possible to establish a direct relationship between soil management and the observed textural change.

3.3 Chemical Composition of Soil Profiles

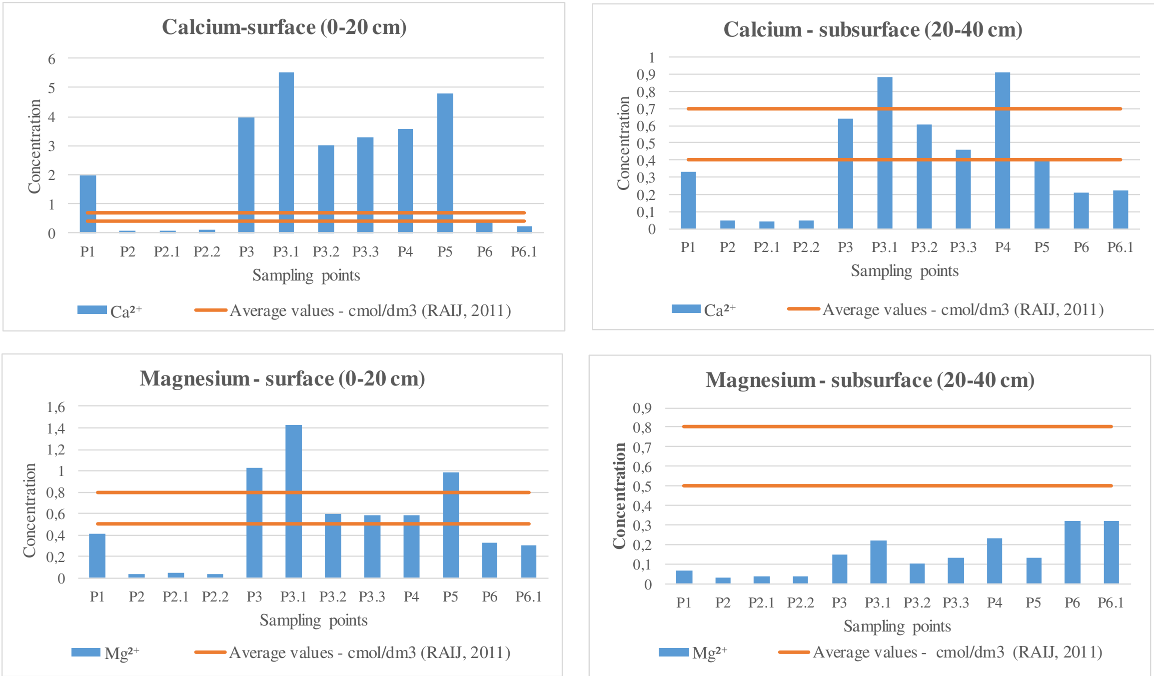
The statistical results of the nonparametric Kruskal Wallis test showed that the samples presented similarity between the points for the analyzed parameters, being possible to make a comparison between the chemical data of these points.

Graphics were constructed for the surface layer (0-20 cm) and subsurface layer (20-40 cm) for a better understanding of the changes in relation to the parameters analyzed. The graphs only contemplate these layers because they are the only ones described and analyzed for the P6 (Mining), enabling the comparison.

The chemical data indicated a higher concentration of macronutrients (Ca and Mg) in the surface layer (0-20cm) at almost all points (Figure 4), with the exception of P2. The subsurface layer (20-40cm) showed, mainly, low to medium levels for calcium and magnesium at the points analyzed in comparison to the reference values of Raij (2011).

The high levels of these macronutrients in the surface layers can be attributed to the fertilization (EWING et al., 2012). Prolonged agricultural cultivation also influences the high levels of calcium and magnesium in the most superficial layers of the soil. The presence of organic matter in the surface layer favors the fixation of these macronutrients, increasing their levels (EWING et al., 2012).

Figure 4: Calcium and magnesium concentration graphs in surface and subsurface analyses.



Source: Prepared by the authors.

Regarding the micronutrients (Figure 5), the zinc contents varied from medium to high values in the surface layer (0-20cm) and low to medium in the subsurface (20-40cm), in the same way as the manganese. The occurrence of high concentrations of zinc may be related to the addition of pesticides and fertilizers to the soil (BJERREGAARD and ANDERSEN, 2007; KELEPERTZIS, 2014).

The values of iron varied from medium to high in the surface layer (0-20cm) and in the subsurface layer (20-40cm) with the exception of P6 and P6.1 (Mining). The values corroborate the fact that tropical soils are enriched with iron oxides, considered in this case, as secondary residual product of the weathering process on the Marilia sandstone.

Zinc and iron can become toxic to plants, inhibiting their growth and leading to root necrosis and consequently death of vegetation, being considered soil contaminants (ALEXANDRE et al., 2012).

The copper presented medium to high levels at all points (Figure 5), both for the surface layer (0-20cm) and for the subsurface layer (20-40cm), a fact that is related to the affinity of this element with the soil clays, linking to them (BJERREGAARD and ANDERSEN, 2007).

Figure 5: Zinc, iron and copper concentration graphs in surface and subsurface samples.

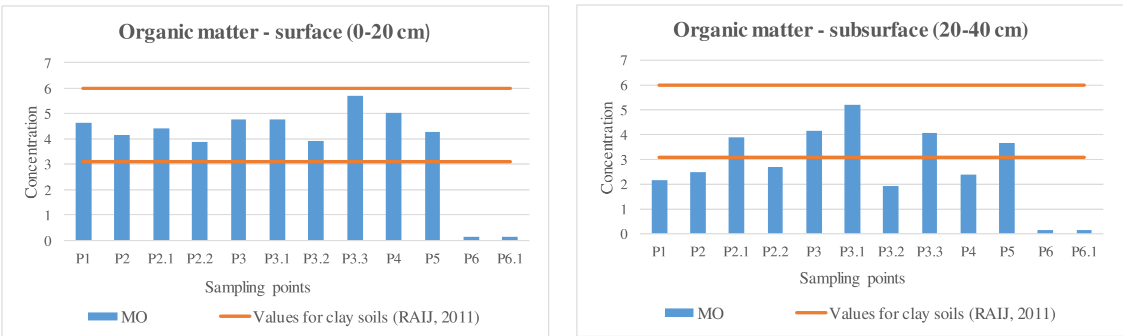
Source: Prepared by the authors.

Wetlands function as sinks for some elements, such as metals, the use of these areas for agriculture poses a great environmental risk by adding some metals to the soil (LAU, 2000). Changes in vegetation cover, drainage and fertilizer addition to the soil are practices that alter some chemical properties (BRULAND et al., 2003; GATHUMBI et al., 2005; WORKU et al., 2014).

The organic matter presented values ranging from low to medium in the surface (0-20 cm) and subsurface layer (20-40 cm) (Figure 6). At the points P6 and P6.1 (Mining), the values obtained were 0.13dag/kg (RAIJ, 2011), due to the lack of vegetation at that point. However, because this has been a highly modified soil, the organic matter content reflects the complete removal of the surface layer, with subsequent impact on the deeper layers.

The base saturation on the surface layer (0-20cm) ranged from low to high, while values for the subsurface layer (20-40cm) were quite low (Figure 7).

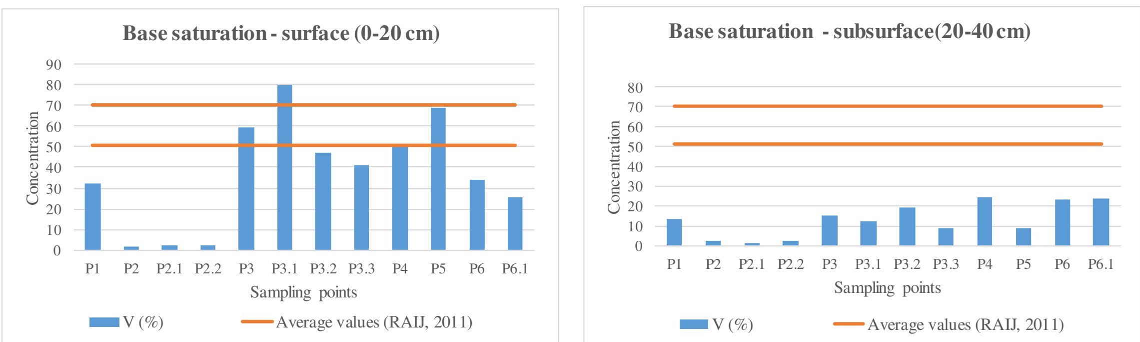
Figure 6: Surface and subsurface organic matter concentration graphs at sampled points



Source: Prepared by the authors.

Figure 7: Surface and subsurface base saturation graphics at sampled points

Source: Prepared by the authors.



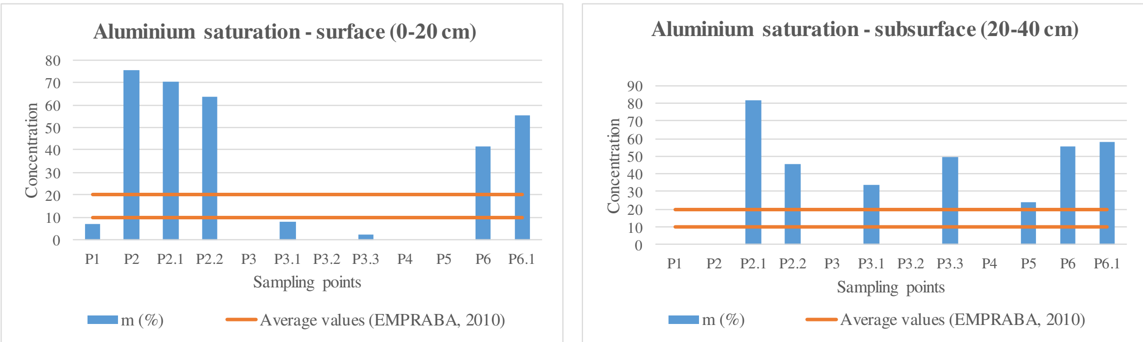
The aluminum saturation presented low values in most of the sampled points (Figure 8), except for the P2, P2.1 and P2.2 (Murundu 2) and P6 and P6.1 (Mining) for the surface layer (0-20 cm). This parameter was detected in high quantities in P2.1 and P2.2 (Murundu 2), P3.1 and P3.3 (Murundu Drained), P5 (Soybean Planting), P6 and P6.1 (Mining) in the subsurface layer (20-40cm).

According to Embrapa (2010), the amount of aluminum in the soil is related to the content of kaolinite clay, since aluminum is present in this type of clay. The large amount of aluminum is inversely proportional to the occurrence of the sand fraction in the soils, and as observed in the particle size analysis (MARQUES et al., 2003), the sand fraction represents only about 10% of the composition of these soils.

The studied soil is abundant in kaolinite in the deeper layers, whereas the gibirite is present mainly in superficial and subsurface layers (COELHO, 2017).

The high amounts of aluminum may be harmful to plant development, however, according to Jansen et al. (2003), for some native plants of the Cerrado the aluminum oxides gain importance when participating in the composition and construction of the soil structure.

Figure 8: Aluminum concentration graphs at different collection points and depths



Source: Prepared by the authors.

The impacts observed in relation to changes in soil structure, lowering of the water table, higher concentration of macro and micronutrients, excess of aluminum and other changes, are a reflection of the inefficiency of the actions in favor of the wetlands conservation. Even with a large number of laws related to conservation and protection of the environment, environmental legislation is not clear about wetlands.

4. CONCLUSION

Six points were analyzed, with the collection of 12 samples to identify physical-chemical changes and in the morphology of the studied soils, as well as alterations in the water table.

Through the characterization of the soil profiles, it was possible to observe some morphological changes in the soils of P3, P3.1, P3.2 and P3.3 (Murundu Drained), P4 (Cane planting), P5 (Soybean planting), P6 and P6.1 (Mining). There was a change in the water table at P4 (Sugarcane Planting) compared to P1 (Murundu), which are at the same altitude, while in the other points the water table was not found, possibly due to the higher altitude.

As for granolumetric analysis, most samples were classified as clayey or very clayey, with the exception of the sample (20-40 cm) from P4 (Sugarcane plantation) and P5 (Soybean plantation), which were classified as silty clay and silty clay loam, respectively. However, the changes observed in particle size were not directly related to the use of these soils for agricultural purposes.

The chemical analyzes showed high levels of micro and macronutrients in these soils, mainly in the superficial layers of P4 (planting sugarcane) and P5 (planting soy), low base saturation in most points and high aluminum concentrations, mainly in P6 and P6.1 (Mining). Through chemical analyses, changes derived from land use for agricultural purposes were perceived, as well as by mining.

Thus, the analysis carried out in the study area confirmed the initial hypothesis, due to changes in the chemical, physical and morphological characteristics of the soil. Thus, prolonged agricultural cultivation and mining activities cause changes in soil characteristics, such as changes in nutrient concentrations, soil structure and plant growth.

Wetlands around the world present an essential role in the natural ecological balance, as they are home to different animal species and are habitats for a wide variety of plant species with specific characteristics. In addition, they perform economic and social functions by storing and purifying water, storing organic carbon, regulating the regional climate, in addition to being suitable for the development of tourist and economic activities.

This research demonstrated the need for more studies in wetlands, which help in territorial planning actions, as well as in the establishment of clearer and more specific legislation regarding the conservation and protection of this biome due to its importance.

5. ACKNOWLEDGEMENT

The authors would like to thank FAPESP (Fundação de Amparo à Pesquisa de São Paulo - Processo nº 2017/14168-1), and CAPES (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior) to support the research developed.

6. REFERENCES

Alexandre, J. R., Oliveira, M. L. F., Dos Santos, T. C., Canton, G.C., Da Conceição, J.M., Eutrópico, F.J., Cruz, Z.M.A., Dobbss, L.B., Ramos, A.C. 2012. Zinco e ferro: de micronutrientes a contaminantes do solo. Revista Natureza online, 10, 23-28.

Basilici, G., Sgrbi, G.N., Führ Dla`Bó, P.F. 2012. A sub-Bacia Bauru: Um sistema continental entre deserto e cerrado. In: Yociteru Hasui; Celso Dal Ré Carneiro; Fernando Flávio Marques de Almeida; Andrea Bartorelli (Eds.), Geologia do Brasil, 1, 420-543, São Paulo: Beca.

Bedford, B. L., Walbridge. M. R., Aldous. A. 1999. Patterns in nutrient availability and plant diversity of temperate North American wetlands. Ecology, 80, 2151–2169. https://doi.org/10.1890/0012-9658(1999)080[2151:PINAAP]2.0.CO;2

Bjerregaard, P. and Andersen, O. 2007. Ecotoxicology of metals: sources, transport, and effects in the ecosystem. In: Nordberg, G.F., Vouk, V.B. (Eds.), Handbook on the Toxicology of Metals. 251–280, California.
https://doi.org/10.1016/B978-0-444-59453-2.00021-4

Brasil. Decreto nº 86.146 de 23 de Junho de 1981. Dispõe sobre a criação do Programa Nacional para Aproveitamento de várzeas Irrigáveis. < https://www2.camara.leg.br/legin/fed/decret/1980-1987/decreto-86146-23-junho-1981-435419-publicacaooriginal-1-pe.html>

Brasil. Lei Federal nº 12.651 de 25 de maio de 2012. Dispõe sobre a proteção da vegetação nativa; altera as Leis nos 6.938 de 31 de agosto de 1981, 9.393, de 19 de dezembro de 1965, e 7.754, de 14 de abril de 1989, e a Medida Provisória nº 2.16 -67, de 24 de agosto de 2001; e dá outras previdências.Acesso em: 14 de junho de 2018. < http://www.planalto.gov.br/ccivil_03/_Ato2011-2014/2012/Lei/L12651.htm>

Bruland, G.L., Hanchey, M.F., Richardson, C.J. 2003. Effects of agriculture and wetland restoration on hydrology, soils, and water quality of a Carolina bay complex. Wetlands Ecology and Management, 11, 141–156. https://doi.org/10.1023/A:1024244408577

Capeche, C.L. 2008. Noções sobre tipos de estrutura do solo e sua importância para o manejo conservacionista. Comunicado Técnico. Pesquisador da Embrapa Solos. Rio de Janeiro.

Coelho, C.V. De Sousa. 2017. Caracterização Petrográfica, Geoquímica e Mineralógica do Arenito da Formação Marília e Processos de Alteração. Dissertação (Mestrado). Rio Claro: Instituto de Geociências e Ciências Exatas – UNESP.

Embrapa–Empresa Brasileira de Pesquisa Agropecuária. 2010. Conceitos de fertilidade do solo e manejo adequado para as regiões tropicais. Embrapa Monitoramento por Satélite. Campinas, São Paulo.

Ewing, J. M., Vepraskas. M. J. 2006. Estimating primary and secondary subsidence in an organic soil 15, 20, and 30 years after drainage. Wetlands, 26, 119–130. https://doi.org/10.1672/0277-5212 (2006)26[119:EPASSI]2.0.CO;2

Ewing, J.M., Vepraskas, M.J., Broome, S.W., White, J.G., 2012. Changes in wetland soil morphological and chemical properties after 15, 20, and 30 years of agricultural production. Geoderma, 179-180, 73–80. https://doi.org/10.1016/j.geoderma.2012.02.018

Fao-Food and Agriculture Organization of the United Nations. 2006. Guidelines for soil descriptions, 4th edition, Rome.

Gao, H., Bai, J., Xiao, R., Liu, P., Jiang, W., Wang, J., 2013. Levels, sources and risk assessment of trace elements in wetland soils of a typical shallow freshwater lake, China. Stochastic Environmental Research and Risk Assessment, 27, 275–284. https://doi.org/10.1007/s00477-012-0587-8

Gathumbi, S.M., Bohlen, P.J., Graetz, D.A. 2005. Nutrient enrichment of wetland vegetation and sediments in subtropical pastures. Soil Science Society of America Journal, 69, 539–548.

Gibbs, J. P. 2000. Wetland loss and biodiversity conservation. Conservation Biology, 14(1), 314–317. https://doi.org/10.1046/j.1523-1739.2000.98608.x

Jansen, S., Smets, E., Haridasan, M. 2003. Aluminum accumulation in flowering plants. In: Blumel D, Rappaport A (Eds.), McGraw-Hill Yearbook of Science and Technology, 11-13, McGraw-Hill, New York.

Junk, W.J., Piedade, M.T.F., Lourival, R., Wittmann F., Kandus, P., Lacerda, L.D., Bozelli, R.L., Esteves, F.A., Nunes Da Cunha, C., Maltchik, L., Schongart, J., SCHAEFFER-NOVELLI, Y., Agostinho, A.A. 2013. Brazilian wetlands: their definition, delineation, and classification for research, sustainable management, and protection. Aquatic Conservation: Marine and Freshwater Ecosystems. 24, 5–22. https://doi.org/10.1002/aqc.2386

Kelepertzis, E., 2014. Accumulation of heavy metals in agricultural soils of Mediterranean: insights from Argolida basin, Peloponnese, Greece. Geoderma, 221–222, 82–90.

Lau, S.S.S. 2000. The significance of Temporal Variability in Sediment Quality for Contamination Assessment in a Coastal Wetland. Water Research, 34, 387-394. https://doi.org/10.1016/S0043-1354(99)00344-9

Lin, H.S., MacDonell, J.J., Nimmo, J.R., Pachepsky, Y.A. 2015. Hydropedology: Synergistic integration of soil science and hydrology in the Critical Zone. Hydrologycal Processes, 29, 4559-4561. https://doi.org/10.1002/hyp.10686

Marques, J.J., Schulze, D.G., Curi, N., Mertzman, S.A. 2003. Major element geochemistry and geomorphic relarionships in Brazilian Cerrado soils, Geoderma, 119, 179-195.

Mcknight, P. E. and Najab, J. 2010. Kruskal-Wallis Test. The Corsini Encyclopedia of Psychology, John Wiley & Sons, Hoboken, NJ. https://doi.org/10.1002/9780470479216.corpsy0491

Motta, P.E.F., Carvalho-Filho, A., KER, J.C., Pereira, N.R., Carvalho Jr. W., Blancaneaux, P., 2002. Relações solo-superfície geomórfica e evolução da paisagem em uma área do Planalto Central Brasileiro. Pesquisa Agropecuária Brasileira, 37, 869–878.

Munsell Soil Color Chats. 2000. GretagMacbeth, 21p.

Nogueira, J.B. 2005. Mecânica dos Solos – Ensaios de Laboratório. Universidade de São Paulo, Escola de Engenharia de São Carlos. Departamento de Geotecnia. São Carlos

Raij, B.V. 2011. Fertilidade do solo e manejo de nutrientes. International Plant Nutrition Institute, Piracicaba.

Rodrigues, R. del G., Scanlon, B.R., King, C. W.,1, Scarparec, F.V., Xavier, A.C., Pruski,F.F. 2018. Biofuel-water-land nexus in the last agricultural frontier region of the Brazilian Cerrado. Applied Energy, 231, 1330-1345. https://doi.org/10.1016/j.apenergy.2018.09.121

Rosolen, V., De Campos, A. B., Govone, J. S., Rocha, C. 2015a. Contamination of wetland soils and foodplain sediments from agricultural activities in the Cerrado Biome (State of Minas Gerais, Brazil). Catena, 128, 203-210. https://doi.org/10.1016/j.catena.2015.02.007

Rosolen, V., Oliveira, D. A., Bueno, G. T. 2015b. Vereda and Murundu wetlands and changes in Brazilian environmental laws: challenges to conservation. Wetlands Ecology and Management, 23, 285-292. https://doi.org/10.1007/s11273-014-9380-4

Santos, J.D. 2007. Alterações das Propriedades físicas e químicas do solo em função de diferentes sistemas agrícolas – São José da Lapa (MG). Dissertação (Mestrado). Minas Gerais: Belo Horizonte: Departamento de Geografia - UFMG.

Stumpf, L., Pauletto. E.A., Da Silva, T.S., Suzuki, L.E.A.S., Fernandes, F.F., Timm, L.C., Garcia, G.F. 2011. Atributos físicos de um solo construído em área de mineração de carvão, cultivado com diferentes espécies vegetais. Universidade Federal de Pelotas, Pelotas, Rio Grande do Sul, 1-9.

Tilton, D. L. 1995. Integrating wetlands into planned landscapes. Landscape and Urban Planning, 32 (3), 205-209. https://doi.org/10.1016/0169-2046 (95)07001-B

Troeh, F.R and Thompson, L.M. 2007. Solos e Fertilidade dos Solos. Organização Andrei Editora Ltda. Tradução: Neto, D.D and Dourado, M.N.

Vepraskas, M.J., Wilding, L.P., Drees, L.R. 1994. Aquic conditions for Soil Taxonomy: concepts, soil morphology and micromorphology. In: A.J. Ringrose-Voase and G.S. Humphreys (Eds.), Soil Micromorphology: Studies in Management and Genesis. Roc. IX Int. Working Meeting on Soil Micromorphology, Townsville, Australia, July 1992. Developments in Soil Science, 22, Elsevier, Amsterdam, 117-131.

Worku, G., Bantider, A., Temesgen, H. 2014. Effects of Land Use/Land Cover Change on Som Soil Physical and Chemical Properties in Ameleke micro-Watershed, Gedeo and Borena Zones, South Ethiopia. Journal of Environment and Earth Science, 13-24.