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BURNINGS AS AGENTS MODIFYING THE PHYSICAL AND CHEMICAL ATTRIBUTES OF CERRADO SOIL IN VALE FUND REGION

QUEIMADAS COMO AGENTES MODIFICANDO OS ATRIBUTOS FÍSICOS E QUÍMICOS DO SOLO DO CERRADO NA REGIÃO DO FUNDO VALE

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ABSTRACT

The effect of fire has direct implications on soil attributes, whether from the physical or chemical point of view. Thus, the objective of this work is to quantify and understand the physical and chemical changes caused by the fire of Cerrado soil (red-yellow latosol). Were collected soil samples at 3 points of the study area in two depths (5 and 35 cm), before and after the action of fire for assessment of the physico-chemical parameters. The results indicate that the granulometry was slightly altered in the two conditions of the samples, however, the fire acts by modifying the more granular material in thinner material, causing lower surface permeability of the soil. With respect to the attributes of chemical of the soil, there was an increase of the concentrations of Mg^{+2}, Ca^{+2} and K^{+}, showing the transition from acidic pH to alkaline after the passage of the fire to the samples over the surface of the soil, in addition, the reduction of Al^{+3} (post burn and vegetation), making the soil less acidic, that is, the action of the fire improves conditions of solo fertility.

KEYWORDS: Fire. Red-Yellow latosol. Fertility.

RESUMO

O efeito do fogo no solo tem implicações diretas nos atributos do solo, seja do ponto de vista físico ou químico. É o objetivo deste trabalho quantificar e compreender as alterações físicas e químicas causadas pelo fogo no solo do Cerrado (latossolo vermelho-amarelo). Foram coletadas amostras de solo em 3 pontos da área de estudo, em duas profundidades (5 e 35 cm), antes e após a ação do fogo, para avaliação dos parâmetros físico-químicos. Os resultados indicaram que a granulometria foi levemente alterada nas duas condições das amostras, porém, o fogo atua modificando o material mais granular em material mais fino, ocasionando menor permeabilidade superficial do solo. Com relação aos atributos de química do solo, houve aumento das concentrações de Mg^{+2}, Ca^{+2} e K^{+}, evidenciando a transição do pH ácido para alcalino após a passagem do fogo para as amostras sobre a superfície do solo, além da redução de Al^{+3} (pós-queima e vegetação), tornando o solo menos ácido, ou seja, a ação do fogo melhora as condições de fertilidade do solo.

PALAVRAS-CHAVE: Fogo. Latossolo vermelho-amarelo. Fertilidade.

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INTRODUCTION

The geographic formation of Brazilians biomes is predominantly preserved by factors characteristic of each region, such as temperature, humidity, relief, rainfall, vegetation and others. The aspects of the Cerrado biome that best qualify are in two well-defined seasons of the year, with dry winters and rainy summers, ranging from seven to eight months each (Neto et al., 2009)

Cerrado is the second largest vegetation complex in South America and originally extended over an area of approximately two million square kilometers, with a large amount of water supplying river basins throughout the country (Miranda et al., 1996; Nascimento, 2001).

The predominant soil of the Cerrado is the latosol, present in sedimented areas and crystalline terrains (areas formed by magmatic rocks). Neto et al. (2009) mention that Cerrado soil has a high deficiency of calcium, magnesium and phosphorus, high aluminum concentration and accelerated carbon oxidation.

Cerrado's climate acts directly on the vegetation, the soil, the availability of water, fire's frequency and depth of the water table. Due to the weather to the action of fire, there is constant mention of the physical and chemical effects on soil and vegetation through fires (Nascimento, 2001; Costa and Rodrigues, 2015).

The high incidence of fire in Cerrado occurs mainly at the end of the dry season, which presents high temperatures, low humidity and dry plant cover. Besides those that happen naturally, there are the fires caused intentionally, used for handling and use of the soil.

The soil has chemical and physical characteristics that influence its structure, being the ones that most receive direct and indirect alterations of the effects caused by the fires. Bento-Gonçalves et al. (2012) emphasizes that for the understanding of the effects of fire on the properties of the soil it is necessary the behavior of the fire in ecosystems.

Soils physics presents properties as porosity, density, permeability, and moisture, which suffer direct modifications when are affected by the actions of the fires. However, soil chemistry have changes in properties, such as reduction of organic matter, increase in potassium, magnesium and nitrogen contents, and variations in hydrogen, hydrogenation potential (pH) and aluminum. Soil biological attributes are also affected by fire, affecting the availability of resources for microorganisms, directly affecting soil fertility (Dick et al., 2008; Redin et al., 2011; Silva et al., 2012; Costa and Rodrigues, 2015). However, Fontúrbel et al. (2012) shows that in low fire intensities the microorganisms do not undergo significant changes.

Therefore, the present article aims to quantify and understand the effect of fire on the physical and chemical parameters of the Cerrado soil.

1 THEORICAL FOUDATION

The Cerrado is one of the five largest biomes in Brazil and originally extended about two million square kilometers of Brazilian territory. The Brazilian Cerrado has a classified climate as Aw (tropical rainfall) of Köppen-Geiger, with average annual precipitation varying from 1,100 to 1,600 mm, with most frequency occurring in the rainy season and presenting a well-defined dry season (Miranda et al., 1996).

According to Neto et al. (2009), Cerrado biome is important due to its largeness, covering approximately a quarter of the national territory. It is ecologically and physiognomically related to the savannas, being almost totally tropical. In South America, savannas occupy 2.5 million km², and Cerrado occupies about 80% of this area. In Brazil, it is the second most important type of vegetation, being surpassed only by the Tropical Forest that occupies about 3.5 million km² (Miranda et al., 1996; Eiten, 1990; Silva et al., 1996).

Silva et al. (1996) highlight the most common savanna forms of the Cerrado, as: a) Cerradão, with kind of closed forest characteristics; b) Cerrado *stricto sensu*, with dense scrub of shrubs and trees; c) field Cerrado, denser and more the broader forms of open shedding; and d) rarer savanna forms or grasses, called dirty field.

The Cerrado is considered an interflowing vegetation with two groups that distinguishes, mainly by the structure and physiognomy: a savanna and other campestral, represented by Cerrado and Dirty field, respectively, typically on red or yellow latosols, with very, medium or little clay content. As described by Eiten (1990), the soil of the Cerrado in its natural state is well drained even when there is a high proportion of clay, because the clay is united in small grains of the size of sand, this makes the soil more penetrable by rainwater. The composition includes almost all rock types such as sandstone, quartz, quartzite, granite, shale, micaxist and certain forms of gneiss, or deposited soil matter.

The Cerrado biome's soil is, mostly, naturally acidic due to the weathering process (decomposition or disintegration of rocks and soils and their constituent minerals) and low levels of chemical components present in soil genetics (Costa and Rodrigues, 2015).

According to Silva et al. (1996), the occurrence of fire is common in all Cerrado types and Cerrado forms, and prevails especially where the stratum of grasses (dirty field) is more abundant, because this form is present in seasonally dry seasons. As for seasonality, there is a great biomass production during the rainy season and so the increase of vegetation combustion capacity due to the accentuated reduction in its water content during the dry season (Sato and Miranda, 1996).

With two well-defined seasons (dry and rainy), in the dry season there are many occurrences of natural and/or anthropic fires. Fires in the Cerrado are also used as a form of soil management, which cannot always be considered controlled actions, with the purpose of improving and increasing nutrients contents.

The degree of soil moisture is extremely important, since the fire and humidity change due to the changes in the rate of infiltration and the rate of transpiration, can consequently modify the soil water supply. Bodí et al. (2012) showed that the ash from the fire on the ground interferes with the direct drainage of the water, especially in wettable soils. Humid soils are less heated during fire and this is due to the fact that they have a higher specific heat and to lead the fire propagation with less intensity. In addition, unprotected soil offers a greater possibility of leaching (loss of nutrients and soil particles) by the action of water (Redin et al., 2011; Lourente et al., 2011).

The physiological response of plants to fire may vary within different foci of the same fire. This is due to the spatial variability of the fire, such as regime, intensity and duration of combustion against climatic elements (wind, air humidity, and temperature stratification), soil (inclination, formation) and vegetation (biomass available in this taking into account species, vigor and age) (Costa and Rodrigues, 2015).

1.1 Physical attributes of Cerrado soil

Soil physics studies and defines, qualitatively and quantitatively, its properties, as well as its measurement, prediction and control, with the main objective of understanding the mechanisms that govern its functionality and its role in the biosphere. The practical importance of understanding soil physical behavior is associated with its proper use and management, that is, to subsidize irrigation, drainage, soil and water conservation (Reinert and Reichert, 2006).

Soils of Cerrado, in Brazil, generally have favorable physical conditions to agriculture and has been gradually exploited with monocultures, pastures and others. With deep soil and good physical quality, the topography of the Cerrado has become one of the largest Brazilian agricultural frontiers being the most devastated. In order for this soil to be prepared with the purpose of receive the plantations and pastures of agriculture and agriculture, most of the time, the fire of natural vegetation, which causes physical changes in the soil. When the vegetation is lost by external factors, such as fires, the soil becomes more vulnerable to changes in the vegetation cover that occurs in the process (Neto et al., 2009; Lourent et al., 2011).

The elevated temperature in the soil during and after fire changes its attributes physical, altering its humidity, in function of the transformations in the rate of infiltration, density, porosity and texture (Costa and Rodrigues, 2015).

Also according to Cassol et al. (2004), after fire, the infiltration, transpiration and porosity of the soil are affected, making it possible to rise water and wind erosion due to the lack of vegetation devastated by fire. The physical factors that are affected by the degree of soil heating during fire are attributed to the dry vegetation that feeds the combustion giving intensity to the heat caused by the fire.

Studies by Spera et al. (2000) about the action of fire in the soil of the Cerrado, show that the content of coarse sand and fine sand does not differ significantly, while the silte content (mineral fragment or rock smaller than fine sand and larger than clay) and those of clay in the plots submitted to fire differ and this can be attributed to soil geological factors. As for the available water capacity, no significant differences were verified, however, the soil density increased when the availability of this water decreased, that is, the mass of dry soil increased, making the volume of water accessible.

The soils porosity is responsible for aeration, infiltration and water storage, since macroporosity is formed by the union of larger aggregates. Spera et al. (2000) showed that the voids index (pore volume ratio for the volume occupied by solid particles of soil) and macroporosity of the soil (pores > 0.05 mm) are determining factors for soil drainage and, consequently, for its permeability.

Still, according to Spera et al. (2000), the fire action did not significantly change the macroporosity of the soil. The average macroporosity was 60.2% after fire action, which is considered high, compared to the Cerrado soils. Regarding macroporosity without fire, on average, it was 1.0% higher (Table 1).

Table 1 - Averages of macroporosity and total pore volume, in different depths in plots submitted to fire, at Cerrado in Planaltina, Distrito Federal, Brazil, from 1988 to 1994.

Treatment	**Depth (cm)**	**Medium values**	
		Macroporosity (m^3 m^{-3})	**Total volume of poros (% by volume of ground)**
With fire	0 - 5	0.295	60.89
	5 - 10	0.309	59.35
	10 - 20	0.314	60.38
Without fire	0 - 5	0.283	61.44
	5 - 10	0.303	61.14
	10 - 20	0.311	61.05

Source: adapted by Spera et al. (2000).

In the evaluations of the physical properties made by Bono et al. (2013) in dystrophic red latosol, it was observed that the soil quality in the permeability is modified when considering different periods of the year (dry and rainy) in which the analyzes are performed, since they are different systems of use and management of the soil in Cerrado's region, its adaptation or behavior over time. The temporal monitoring of porosity, density and infiltration of water in the soil in different management systems can determine, in a more conclusive way, the importance of these properties in the evaluation of soil quality in the porosity.

Regarding the physical attributes of the soil, Giácomo et al. (2015) characterize the soil of the Cerrado in three phytophysiognomies, being: Mesophytic forest, Cerrado *stricto sensu* and Cerradão. Table 2 illustrates how the relationship of the textural class according to Reinert and Reichert (2006) is defined by the relative proportion of soil particle size classes in clay, silt and sand proportion, at different depths for each Cerrado physiognomy.

Table 2 - Soil textures of the areas of Mesophilic forest, Cerradão and Cerrado *stricto sensu*.

Phytophysiognomy	Layer (cm)	Sand (g Kg^{-1})	Silt (g Kg^{-1})	Clay (g Kg^{-1})	Class
Mesophilic forest	0 - 5	346	201	453	Clay
Cerradão		251	248	501	Clay
Cerrado *stricto sensu*		439	273	288	Franco-clayey
Mesophilic forest	5 - 10	327	227	446	Clay
Cerradão		246	217	537	Clay
Cerrado *stricto sensu*		417	284	299	Franco-clayey

Source: adapted by Giácomo et al. (2015).

The area of Cerrado *stricto sensu* presented higher sand contents than other analyzed areas, which presented more clayey soils with greater water retention to meet the water demand of the specific vegetation of each phytophysiognomy.

Reinert and Reichert (2006) report that the definition of a physically ideal soil is difficult due to the type and nature of the physical variations of the soils that occur along the depth. The same difficulty of definition also occurs on the surface of the landscape and over time. Quality, from the physical point of view, is associated with soil that: a) allows infiltration, retention and availability of water to plants, streams and subsurface; b) responds to management and resists degradation; c) allows the exchange of heat and gases with the atmosphere and roots of plants and; d) allows the growth of the roots.

1.2 Chemical attributes of Cerrado soil

The soil of the Cerrado has high acidity, low cation exchange capacity, high phosphorus binding capacity, high aluminum saturation and almost generalized deficiency of macro and micronutrients (Galrão and Lopes, 1982; Neto et al., 2009). The acidity is a factor that limits in proportions, the agricultural productivity of the soil, being necessary often to correct or to complement the same, with chemical constituents. Among the chemical attributes of the Cerrado are potential hydrogen (pH), potassium (K^+), calcium (Ca^+), phosphorus (P), magnesium (Mg^+) and organic matter (OM), the latter being considered as the scarce component of the soil, due to the different phytophysiognomies and textures of the same in the Cerrado (Giácomo et al., 2015).

According to Wendling et al. (2005), organic matter is the main agent for the formation and stabilization of aggregates, and therefore, the particle diameter is important for analyzing the aggregation model (crushed stone, gravel and natural sands, among others). Thomaz (2017) emphasizes that large grains of the soil in fires of high proportion and in short time, help in the maintenance of organic matter. In valley bottom regions, a significant amount of this chemical attribute (OM) is found, resulting from sediment transport from higher upstream sites. This amount of OM involves the aggregates, according to Silva et al. (2012), also improve physical soil conditions mainly in erosions.

The fire has a direct influence on the chemical characteristics of the soil and the frequency of fire in the vegetation can lead, in the medium and long term, the deterioration of its properties, being directly related to the changes of the pH, increase of carbon source and oxidation of organic matter. The increase in N^+, P, K^+, Ca^{+2} and Mg^{+2} levels after the passage of the fire and the enrichment of the soil in the topsoil as a function of the ash present high concentrations of these mineralized nutrients (Santos et al., 1992; Redin et al., 2011; Rheinheimer et al., 2003; Costa et al., 2011).

Among the problems of an acid soil, we can highlight the lower availability of some nutrients (especially phosphorus) and the toxicity of aluminum and manganese. To appear aluminum (Al^{+3}), the soil must first become acidic, since Al^{+3} is a consequence of acidity and not the cause. The soil acidity is the reciprocal of the amount of bases for its correction (Mosaic, 2005; Kaminski et al., 2005).

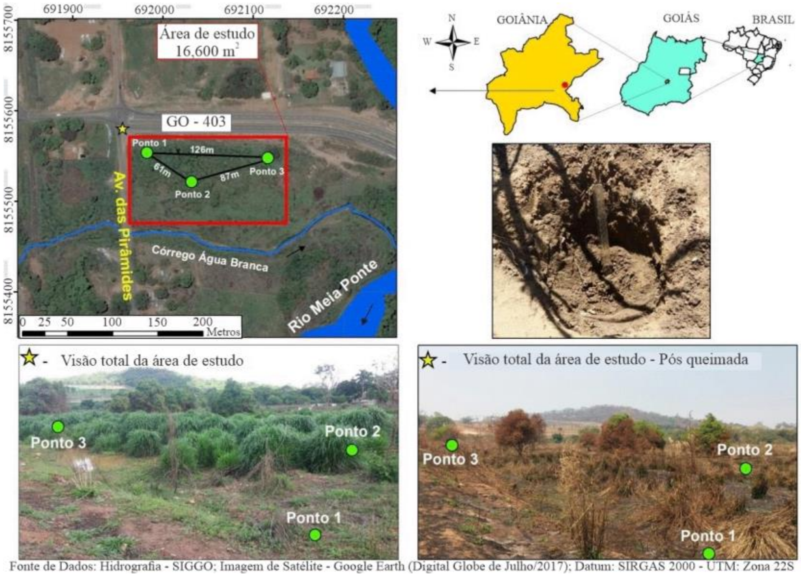
The sum of exchangeable bases (*BS*) of a soil, clay or humus ($BS = Ca^{+2} + Mg^{+2} + K^+$) represents the sum of the interchangeable cations contents except H^+ and Al^{+3}. The base saturation is an excellent indication of the general conditions of soil fertility, being used until as a complement in the nomenclature of the soils. Some dystrophic soils (characteristic directly related to low natural soil fertility), may be very poor in Ca^{+2}, Mg^{+2} and K+ and present very high exchangeable aluminum content (Ronquin, 2010).

According to Coutinho (1980), in terms of the organic matter of the soil under the effect of the fires, the results diverge when considering a rich or poor soil in this component. Pereira et al. (2012) shows that the type parameters and nutrient extraction in aqueous media in ashes, which when incorporated to the soil can help in the future plantations, suffer direct interference as to the intensity of the fire.

The increase of the temperature during and after the action of the fire also changes the P^{+2} and Mg^{+2} in the chemical characteristics of the soil, because it influences in a greater rate of decomposition of residues and mineralization of the organic matter, being the latter in turn influent the availability of nutrients (Rheinheimer et al., 2003; Costa and Rodrigues, 2015).

2 MATERIAL AND METHODS

In order to evaluate the effect of the fires on the physical and chemical attributes of the Cerrado soil, samples were collected first (Figure 1) of post burned soil in the study area located in Jardim Novo Mundo, Goiânia, state of Goiás, Brazil (Figure 1). The region near the river Meia Ponte, considered valley bottom, is classified according to Silva et al. (1996) of typical vegetation of campo Cerrado (with unnatural vegetation) with soil red-yellow latosol.



Fonte de Dados: Hidrografia - SIGGO; Imagem de Satélite - Google Earth (Digital Globe de Julho/2017); Datum: SIRGAS 2000 - UTM: Zona 22S

Figure 1 - Location and details of the study area.

According to Casseti (1992), the region receives deposits of holocene covers from higher upstream points, which imply a certain lack of hierarchization of the reworked material, acting on the physical part of the soil. These erosive processes are observed mainly from interfluvial to the bottoms of present valleys and water courses of different orders of magnitude usually altered by accelerated erosion, which results in the degradation of the riparian forest that protects it.

The fire occurs between September 9 and 10, 2017 with the collection of post fire soil samples on September 17, 2017. The soil samples collected after forest restoration (naturally vegetated soil) were performed on the 23rd of April 2018.

The collection sites of post fire and vegetated soil samples (three points) make a triangle in the study area (16,660 m^2) and their locality privileges the access and presence of some native plant species. At each collection point, deformed samples were taken at two depths (5 and 35 cm), each sample having 4.5 kg of soil in total (Figure 2) for analysis of soil physical and chemical parameters.

a) b)

Figure 2 - Collecting post fire soil (point 2): a) surface sampling, b) transportation preparation.

The chemical parameters analyzed were H^{+}, Al^{+3}, pH, MO, K^{+}, Ca^{+2}, Mg^{+2} and Al^{+3} and the physical parameters were granulometry (sieving and sedimentation) hygroscopic moisture and soil density, following the recommendations established by ABNT (2016a), ABNT (2016b) and ABNT (1984), respectively.

3 RESULTS AND DISCUSSIONS

Regarding the granulometry of the evaluated soil, it is post fire and naturally vegetated, the behavior is typically silty with presence of fine sand (Figures 3 and 4). The granulometry of the soil samples in revegetation shows a good graduation of the silt particles in a higher proportion (Figure 3) showing that the vegetation restructured the soil, that is, it has better water retention characteristics, mainly for surface depths. It is also worth noting that Figure 2 (closest to the watercourse) was the one that presented the greatest silt in its composition (thinner soil) due to the possible transport of material from higher regions to the floodplain area of the river Meia Ponte, adjacent to this point.

Still evaluating the granulometry presented in Figure 3, it is possible to notice amounts, even if low, of gravel and coarse sand that after the action of the fire underwent alterations (were disaggregated) in smaller fractions, that is, decreased the contents of gravel and coarse sand, maintained or increased the levels of medium and fine sand and decreased the levels of silts (Figures 3 and 4 and Tables 3 and 4).

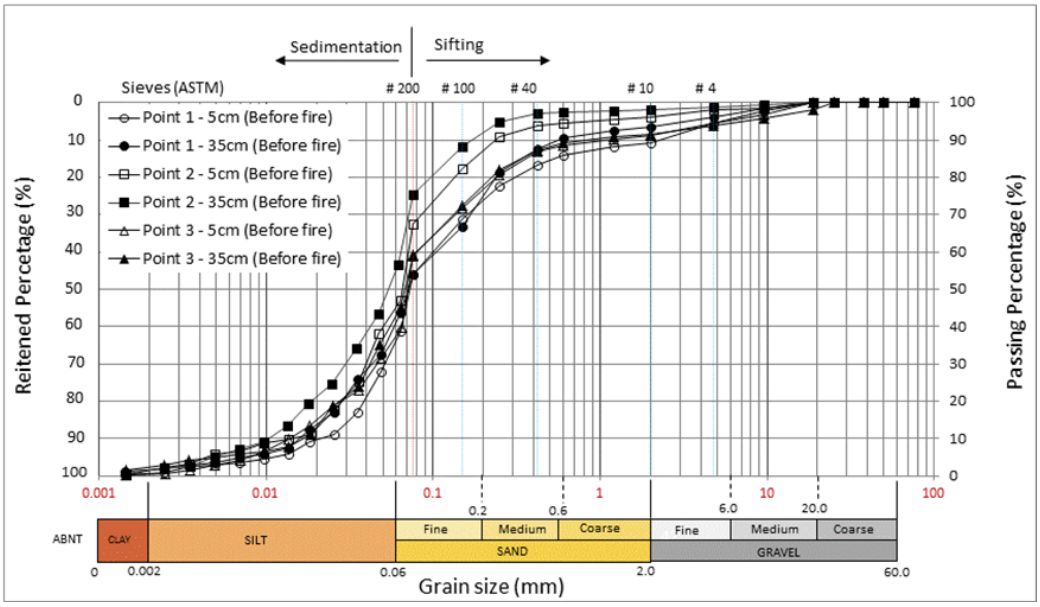


Figure 3 - Grain size curve of soil samples before fire (vegetated), without deflocculant.

The samples granulometry of post fire soil reinforces and reiterates the previous comment that the action of fire causes the increase of the values of smaller particles (fine sands and clay), that is, the thicker fraction of the soil dissociates in smaller particles increasing the percentage of fine sands in relation to the silt (Figure 4 and Table 4).

However, as described by Brady and Weil (2012), the silt has the property of retaining water, allowing a lower rate of drainage (water percolation), which in the dry season in which the burn occurred, was lower, affecting permeability (Table 4).

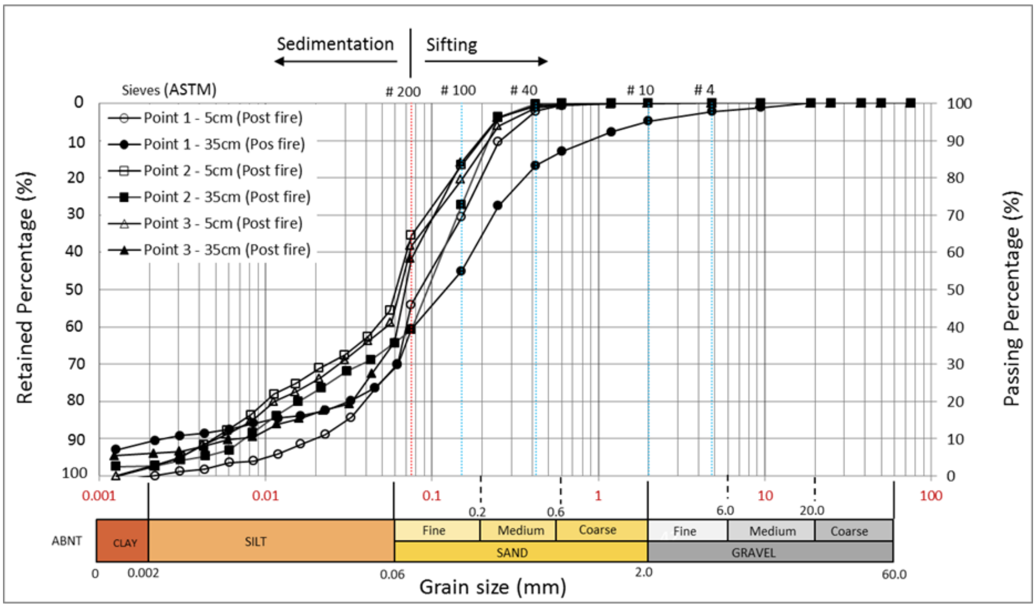


Figure 4 - Grain size curves of post fire soil samples, without deflocculant.

These components differ significantly post fire, as described by Spera et al. (2000), due to the geological formation of the soil, which is a latosol subject to dryness that varies in dry seasons of the year, and also exposed by Casseti (1992), as a valley bottom region, which explains better the analyzes made earlier of the fire, with boulder and silt entrapment in the surface quota of the samples, and fine sand in deep soil. Giácomo et al. (2015) show the correlation of textural classes in three phytophysiognomies of the cerrado, being clayey the characteristic that stands out in the soil studied by it, unlike the soil studied after fire.

Another way of evaluating the physical condition of the soil is through constituent percentages (Tables 3 and 4). The samples indicated soil penetration resistant (post fire), being medium compacted (silt) with fractions of sand (mainly fine), according to the classification of soils of ABNT (1982).

Table 3 - Percentages of the physical constituents of vegetated soil before and post fire of the samples from the study area.

Points	**Depth (cm)**	**Soil samples**												**CLASS**
		Gravel (%)		**Sand (%)**						**Silt (%)**		**Clay (%)**		
				Coarse		**Medium**		**Fine**						
		B	**P**	**B**	**P**	**B**	**P**	**B**	**P**	**B**	**P**	**B**	**P**	
1	5	11.5	0.0	3.3	0.6	12.7	19.9	37.4	50.1	34.2	29.4	1.0	0.0	Silty sand
	35	4.3	4.8	2.8	8.2	16.9	23.3	33.8	34.8	40.3	19.4	1.9	9.6	Silty sand
2	5	0.8	0.0	1.4	0.1	8.1	10.2	41.7	41.0	42.8	46.1	2.3	2.7	Silty sand
	35	2.0	0.0	0.6	0.1	5.9	15.5	35.9	48.6	53.3	33.1	2.2	2.8	Sandy silt*****
3	5	9.0	0.0	2.6	0.5	12.2	12.8	38.9	42.0	36.7	42.0	0.7	2.8	Silty sand
	35	9.2	0.1	2.3	0.2	11.9	9.4	34.4	53.7	39.3	30.4	2.9	6.1	Silty sand
Average value		**6.1**	**0.8**	**2.1**	**1.6**	**11.3**	**15.2**	**37.0**	**45.0**	**41.1**	**33.4**	**1.8**	**4.0**	**Silty sand**
Standard deviation		**4.4**	**2.0**	**1.0**	**3.2**	**3.9**	**5.5**	**3.0**	**7.0**	**6.7**	**9.5**	**0.8**	**3.3**	

where *****just stop before fire; B = before fire and P = post fire.

The highest values of clay are present in deeper layers, unaffected by fire, which retain more water in the soil due to vegetation and the adjacent watercourse. The vegetal formation influences the structure of the soil mainly as reservoir and water flow in plots of clay soil, because, where the fire acts hardens and vitrifies the clay. It can be observed in Table 3 that the amount of clay present in the post fire soil withdrawn at 35 cm depth has higher values than the same level before the fire, denoting that the water performed the protection of the soil in more layers deep as the fire acted on the vegetation.

Table 4 shows the percentage difference between the values of soil granulometry, presented in Table 3, before and after fire. Negative values indicate a reduction in particle size after the fire has passed and positive values an increase in the passing percentage. It is noticed a great reduction of boulders after the fire has passed and an increase in the medium and fine grains of sand. There is also a significant increase in the clayey portion of the soil. It can be associated that after the fire had passed, there was a segregation of solid particles, reducing the size of the thicker portions of the soil (Table 4).

Table 4 - Percentage difference of the physical constituents of the before and post fire soil of the samples from the study area.

Points	Depth (cm)	Soil samples					
		Gravel (%)	Sand (%)			Silt (%)	Clay (%)
			Coarse	Medium	Fine		
1	5	-100%	-82%	57%	34%	-14%	-97%
	35	12%	194%	37%	3%	-52%	411%
2	5	-100%	-96%	26%	-2%	8%	18%
	35	-100%	-92%	162%	35%	-38%	23%
3	5	-100%	-82%	4%	8%	15%	327%
	35	-99%	-90%	-21%	56%	-23%	109%

In the coarse-grained sifting, it was observed that the largest amount of gravel present in the samples is at the surface level before fire (vegetated soil) due to the soil rotation by the water in the rainy seasons, which carry thinner constituents and due to not fire action, which can disaggregate the larger particles. After the fire, it is possible to see a reduction in the presence of coarse grains, and an increase in medium and fine grains of sand, as shown in Table 4.

The humidity of the post fire samples at the collection points (Table 5) showed a large variation among them (9.4% for depth of 5 cm and 7.3% for depth of 35 cm from point 1 to point 3), values due to the action of fire by absorbing much of the water present in the soil. In moisture analyzes for vegetated soil (before fire), the moisture variation was slightly lower for the depth of 5 cm (6.6%) and continued to be significant at depth of 35 cm, with 8.9% (Table 5). It is noticed that after the fire, the moisture of the samples was reduced to two samples of each depth.

However, for all the post fire samples (Table 5), there was a decrease in humidity, with higher variations for the samples with surface elevation (7.0% for Point 1).

Table 5 - Humidity of soil samples evaluated (post fire and post revegetation).

Depth (cm)	Point	Post revegetation (%)	Post fire (%)	Diference (%)
Until 5	1	8.26	1.28	-85%
	2	14.86	8.64	-42%
	3	9.67	10.67	10%
Average value		**10.93**	**6.86**	**-37%**
Until 35	1	13.02	10.31	-21%
	2	21.96	17.01	-23%
	3	16.06	17.64	10%
Average value		**17.01**	**14.99**	**-12%**

In Table 5, the percentage variation between moisture before and after the fire has passed through the ground is also presented. Again, negative values indicate the loss of soil moisture after the fire, and positive values indicate the increase in moisture after the fire has passed. It is noticed that samples 1 and 2, for the two depths, suffered a significant reduction in moisture. At a depth of 5 cm, closer to the surface, you can see a greater loss of water content in the soil than at the deeper layer, 35 cm. Sample 3 showed different results compared to the other two samples, but it was not a significant increase, which could be associated with experimental issues.

The verification revealed low humidity after-fire soil, however, the depth of 35 cm (where there was no contact with the flame), it keeps the clay and hygroscopic humidity reaching 17% (Table 5) and beneficial to vegetation for soil restoration, denoting a higher percentage of retained water even after fire.

The density of the grains (dry soil), determined by the pycnometer method, showed a value before fire of 2.48 g cm^{-3} and after fire of 2.82 g cm^{-3}, evidencing an increase in dry density after the consumption of organic matter (OM) by the action of fire. The determination of soil density values allows quantitative analysis of the soil volume variation comparing the state of the soil mass before and after the change, which in the case of the study is the fire.

In relation to the evaluated chemical parameters of the soil (Tables 6 and 7) before and after the fire, the presence of Ca^{+2} is highlighted, however, larger amounts were detected superficially post burned, evidencing that the fire changes this fundamental element in plant nutrition and soil balance, also found in large quantities in the 35 cm height (after being vegetated) favoring soil fertility. The same happens with the highest K^{+} in the superficial layer (5 cm) due to its loss in the form of ashes under the ground, that in the deep ones (35 cm), mainly after the action of the fire. Another important fact is the increase in OM present in the post burned samples to depth of 5 cm (Table 7) compared to the samples before fire (Table 6). It is also inferred that, due to low percolation, lower OM values are established at greater depths (35 cm), besides their consumption by the vegetation when trying to reestablish. According to Wendling et al. (2005), OM is the main agent of formation and stabilization of aggregates, and therefore, the evaluation of particle diameter and fire action is important to evaluate the aggregation model.

Table 6 - Chemical parameters of the soil after vegetation of the study area.

Date	Depth (cm)	Point	Parameters						
			K^{+} (1)	Mg^{+2} (1)	Ca^{+2} (1)	$H^{+}Al^{+3}$ (1)	Al^{+3} (1)	pH (2)	OM (3)
23/04/2018	Until 5	1	0.5	0.7	7.9	0.9	0.0	6.6	24
		2	0.5	1.2	4.7	1.6	0.0	6.0	27
		3	1.0	1.1	8.4	0.9	0.0	6.9	29
	Until 35	1	0.3	0.6	9.1	0.8	0.0	6.5	24
		2	0.1	0.9	3.9	1.5	0.0	5.8	20
		3	0.4	0.7	9.1	0.7	0.0	6.8	22

(1)$cmol_c\ dm^{-3}$(mE/100ml); (2)$CaCl_2$; (3)$g\ dm^{-3}$.

Table 7 - Chemical parameters of the post fire soil of the study area.

Date	Depth (cm)	Point	Parameters						
			K^{+} (1)	Mg^{+2} (1)	Ca^{+2} (1)	$H^{+}Al^{+3}$ (1)	Al^{+3} (1)	pH (2)	OM (3)
17/09/2017	Until 5	1	4.7	1.9	9.1	1.2	0.0	7.5	54
		2	1.1	1.4	9.0	1.2	0.0	7.0	61
		3	1.3	3.0	8.8	1.3	0.0	6.9	63
	Until 35	1	0.7	1.1	8.3	1.3	0.0	6.5	33
		2	0.2	1.0	4.8	1.7	0.0	5.8	18
		3	0.2	0.6	1.8	2.0	0.6	5.0	14

(1)$cmol_c\ dm^{-3}$(mE/100ml); (2)$CaCl_2$; (3)$g\ dm^{-3}$.

Neto et al. (2009) discuss the high concentration of aluminum in the Cerrado soil after fire, but in the analyzes performed for the soil of the study area, no aluminum contents were detected at all points affected by the fire, indicating the decrease of the soil acidity, that according to Kaminski et al. (2005) Al^{+3} is a consequence of the acidity and not the cause, for a better regeneration of the vegetation in the place.

Similarly, fire increased concentrations of Mg^{+2} and Ca^{+2} in the stratum of more contact with the fire and a decrease of increasing order (according to the sampling points) in the deepest part of the soil under study. This increase is related to the calcination of the organic compounds of the vegetation caused by the action of the fire and the consequent concentration of the inorganic compounds, since the temperature of the fire does not reach the melting temperature thereof.

The analysis of the pH of the samples with a depth of 5 cm, identified soil neutralization after fire (Table 7), due to the increase of cations (Ca^{+2}, Mg^{+2} and K^{+}), facilitating the formation of basic compounds. This increase of pH favors the non-availability of Al^{+3} ions also verified in the analyzes of the greater depths (Tables 6 and 7). At depth of 35 cm (post fire), the soil samples were more acidic, which may impair revegetation (Table 7).

The conditions of the soil samples were also evaluated by relating the sum of the bases (*BS*) with the cation exchange capacity (*CEC*) of basal saturation exposed by Ronquim (2010). Equation 1 expresses the fertility limit percentage of eutrophic (fertile) soils ($V \geq 50\%$) and dystrophic (low fertility) soils ($V < 50\%$). Table 8 shows the results for the studied soil.

$$V = \frac{100BS}{CEC} \tag{1}$$

where V is the base saturation (%); *BS* is the sum of bases and *CEC* is the cation exchange capacity.

Table 8 - Base saturation indicative.

Depth (cm)	Point	Vegeted	Post fire
5	1	100	100
	2	100	100
	3	100	100
35	1	100	100
	2	100	100
	3	100	81.25

If most of the soil *CEC* is occupied by essential cations such as Ca^{+2}, Mg^{+2} and K^{+}, it is possible to say that this soil is good for plant nutrition without the need for correction. On the other hand, if a large part of the *CEC* is occupied by cations such as H^{+} and Al^{+3}, this can be classified as poor soil for vegetation, in the results of the chemical analyzes post burned and vegetated there was total reduction of the aluminum classifying the soil in good conditions.

After calculating the base saturation (Table 8) using Equation 1, it was verified eutrophic soil in all the samples that were submitted to fire.

FINAL CONSIDERATIONS

In relation to the Cerrado soil physics evaluated (study area), it is concluded that:

- the action of the fire altered the soil physical attributes (granulometry, moisture and soil) affecting water supply, aeration, deposition and movement of nutrients, microbial activity and root penetration, evidenced by the increase of fine materials (fine sands and clay) and reduction of coarse fractions (gravel and coarse sand);
- the fire action in the studied soil of the Cerrado promotes the disorganization of the larger aggregations in minors;

• even with the fire, the soil remained sandy-silt and when vegetated showed little variation of clay in the surface and depth (detected by the particle size test without deflocculant);

• the soil moisture content was higher in the depth of 35 cm for the two analysis situations (post burned and vegetated) with a greater difference in surface moisture (37%) than in the 35 cm (12%) level before and post burned;

• small variations of soil specific mass were observed comparing the state before and after the burn. During the burning, some of the nutrients (Ca^{+2}, Mg^{+2} and K^{+}) present in the leaves and stems of the vegetation go to the surface in the form of ash, being important for soil fertilizers.

• the post burned soil usually becomes thinner, that is, it loses its aggregations and cohesive power, affecting the properties of water storage in the soil and consequently, the vegetation, which in turn can accelerate erosive processes.

In relation of the Cerrado soil chemistry (study area), it is concluded that:

• in spite of the constant fires that occur in typical regions of the Cerrado, whether for natural or provoked reasons, this work shows that the studied soil reached by this intemperity undergoes chemical changes in the deposit of these minerals in the surface removed from the deeper layers that confer nutrient increase favorable to soil fertility. The increase in the concentration of macronutrients together with the increase in pH are the most relevant factors for this observation in relation to fertility.

However, as fertility cannot be evaluated only in relation to macronutrients, this work opens perspectives for future studies correlating the results presented here with values of other fertility parameters, such as: micronutrients and nematodes.

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