Floresta e Ambiente 2020; 27(3): e20180253
https://doi.org/10.1590/2179-8087.025318
ISSN 2179-8087 (online)

Floresta e Ambiente

ORIGINAL ARTICLE – Silviculture

Immediate Effects of Prescribed Burning on Chemical Properties of the *Cerrado* Soil

Sandra Ruth Saavedra Magallanes[1] 0000-0001-6462-3109
Marcos Giongo[1] 0000-0003-1613-6167
Edmar Vinícius de Carvalho[1] 0000-0002-4563-2015
Eliane Aparecida Rotili[1] 0000-0002-8466-7210
Ana Claudia Fernandes[1] 0000-0003-2602-1582
Jader Nunes Cachoeira[1] 0000-0001-9150-5431
Gil Rodrigues dos Santos[1] 0000-0002-4960-0985

Abstract

The *Cerrado* biome increasingly suffers from the environmental impacts of human action. Burning is known as an action used to destroy native vegetation and to clean areas mainly with the purpose of growing soybeans, corn, or raising cattle. In this study we aimed to investigate the influence of low-intensity burning on the chemical composition of a Red-Yellow Latosol in a region characterized as *Cerrado sensu stricto*. A total of 14 parcels of land were demarcated. In order to analyze the effects of fire on the soil chemical properties, soil samples were collected before and within 24 hours of the burning by means of the same methodology. An increase in organic matter and in the levels of Ca^{2+}, Mg^{2+}, K^{+}, Mn^{2+}, Zn^{2+}, B^{+}, S, as well in the ratios characterizing the soil (CECt, SB, Ca^{+}/T, Ca^{+}/Mg^{+}, V, and Ca^{+}/K^{+}), was observed. Variables that determine the acidity of the soil, such as pH and H + Al, presented changes, although not significant ($p > 0.05$).

Keywords: fire, micronutrients, soil acidity.

1. INTRODUCTION AND OBJECTIVES

The Brazilian *Cerrado* represents the largest area of savanna in America, spanning approximately 2 million km^2 in Central Brazil (Castro et al., 2017). *Cerrado* is characterized by different types of vegetation – pastures, open tree canopies, and dense forests – where spatial distribution is determined by many factors such as soil type and topography, and fire frequency and intensity (Batista et al., 2018; Meira et al., 2017).

Soil is a basic component of the forest ecosystem and it is subject to changes by fire. However, its effects – which may alter edaphic factors – are still scarcely studied. According to Resende et al. (2017), although the *Cerrado* ecosystem is adapted to fire, it can lead to loss of nutrients, compaction, and erosion – a problem that affects vast areas of land. Conversely, when correctly used, controlled burning is known to be a useful tool in preventing high-magnitude fire events, since dry biomass accumulation contributes to increase the occurrence of fire (Batista et al., 2013; Camargos et al., 2015).

Effects on the chemical composition of the soil chiefly results from burn severity, which consists of peak temperatures and duration of the fire (Abraham et al., 2018; Certini, 2005). Thus, soil transformation is directly proportional to the intensity of the fires in the area (Lorenzon et al., 2014).

Following the fire, essential nutrients, such as phosphorus, magnesium, calcium, and potassium, can be released by the ashes (Alcañiz et al., 2018). Therefore, burning may favor an increase in fertility – although ephemeral, it is crucial for plant regeneration. However, according to Knicker (2007), the benefits of nutrient mineralization catalyzed by burning can be depleted in the medium term when burning is carried out during the dry season. This is because rain may cause the leaching of nutrients, which results in lower concentrations that may even be inferior to the ones observed in unburned soils.

[1] Universidade Federal do Tocantins (UFT), Gurupi, TO, Brasil

Although it is a common practice in Brazil, the need for studies whose authors investigate the effects of burning on soil properties is evident, in such a way to improve the management of areas reserved for livestock activities aiming at reducing potential soil damages and contributing to its conservation.

The state of Tocantins represents an important agricultural border area in the country. Few studies have been carried out in *Cerrado* areas of municipalities in Tocantins measuring the impacts of burning on the chemical properties of the soil. This practice has also been widely used by most producers and pastoralists in the region.

Taking this into consideration, we aimed to determine the immediate effects of fire intensity on the superficial layer of the soil in a *Cerrado sensu stricto* area in the state of Tocantins, Brazil.

2. MATERIALS AND METHODS

The study was conducted in Fazenda Verdes Mares, in the municipality of Sucupira – state of Tocantins – located at a latitude of 11° 59' 36" South and longitude of 48° 58' 15" West, at 257 meters above sea level. According to the Köppen's classification, it is characterized by a tropical wet-dry climate (Aw) (tropical with wet summer and dry winter), and the average annual precipitation is 1,500 mm. The soil is heterogeneous, with variations among Red-Yellow Latosol, Plinthosol, and Cambisol. Nevertheless, the soil of the experimental area has been described as Red-Yellow Latosol. It is worth noting that the study farm holds soy crops and pastures for cattle; however, the parcels of land composing the experimental area were unchanged, i.e., composed of natural vegetation. The study area is classified according to Ribeiro & Walter's (1998) category of *Cerrado sensu stricto*. This savanna-like formation is chiefly characterized by an herb layer, predominantly covered by grasses, and a layer of trees and bushes, with irregular and twisted branches and coverage between 10 and 60% (Eiten, 1994).

Prescribed burning was carried out by the team of Centro de Monitoramento Ambiental e Manejo do Fogo (CeMAF) in October 2015 between 11:05 a.m. and 6:05 p.m. A total of 14 parcels of land with 200 m^2 in area – 10-m wide and 20-m long – was delimited. The area was marked at its length in 2-meter intervals for measurements of the fire propagation speed ($m.s^{-1}$) and height. Before and after burning, the combustible material was randomly collected from each parcel in order to determine the available amount of fuel, humidity, and combustible material consumed by the fire.

Prior to burning, the average air temperature (°C), relative humidity (%), and average wind speed ($m.s^{-1}$) were measured by a portable meteorological station (Kestrel® 4000) located near the experimental area.

Fire behavior parameters, expressed by the fire line propagation speed ($m.s^{-1}$), flame height (m), and fire intensity ($kcal.m^{-1}s^{-1}$), have also been determined. Intensity was obtained from the Byram's equation (1959), considering the calorific value of 3,705 $kcal.kg^{-1}$ determined by Pivello et al. (2010) for savanna areas.

Soil chemical properties were determined before and after burning (24 hours). For this purpose, three sampling points were used in each one of the 14 parcels of land for collecting samples composed of the first 5 cm of the superficial layer. Samples were sent to a private laboratory, where the following chemical properties of the soil would be determined: pH ($CaCl_2$): potential of hydrogen; H + Al: potential acidity ($cmol_c.kg^{-1}$); P: available phosphorus ($mg.kg^{-1}$); S SO_4^{-2}: sulfur (sulphates) ($mg.kg^{-1}$); K^+: available potassium ($mg.kg^{-1}$); Ca^{2+}: exchangeable calcium ($cmol_c.kg^{-1}$); Mg^{2+}: exchangeable magnesium ($cmol_c.kg^{-1}$); Al^{3+}: exchangeable aluminum or acidity ($cmol_c.kg^{-1}$); OM: organic matter ($g.kg^{-1}$); OC: organic carbon ($g.kg^{-1}$); B^+: boron ($mg.kg^{-1}$); Cu^{2+}: copper ($mg.kg^{-1}$); Fe^{2+}: iron ($mg.kg^{-1}$); Mn^{2+}: manganese ($mg.kg^{-1}$); and Zn^{2+}: zinc ($mg.kg^{-1}$).

Afterwards, we estimated the SB: sum of bases ($cmol_c.kg^{-1}$); CECt: effective cation exchange capacity ($cmol_c.kg^{-1}$); V: percent base saturation (%); m: percent aluminum saturation (%); Ca^+/T: calcium saturation in cation exchange capacity (CEC) (%); Mg^+/T: magnesium saturation in CEC (%); K^+/T: Potassium saturation in CEC (%); Ca^+/Mg^+: calcium magnesium ratios; Ca^+/K^+: calcium potassium ratios; Mg^+/K^+: magnesium potassium ratios. Lastly, values were classified as very low, low, medium, and high, according to the methodology described by Sousa & Lobato (2004).

All variables were processed in Microsoft Excel (2010) spreadsheets and analyzed by the XLSTAT software, version 19.01 (2017). T-tests ($p > 0.05$) and the Pearson's correlation were used for data analysis and comparison.

3. RESULTS AND DISCUSSION

On the day of the burning, the average air temperature was 41.82 °C; relative humidity, 15.74%; and wind speed, 0.40 $m.s^{-1}$ (Table 1). These meteorological variables changed throughout the day, which impacted variables of the fire behavior. According to Soares & Batista (2007), air temperature varies both in time and in space, whereas the maximum temperature is observed after midday.

According to our results, and based on McArthur & Cheney's (1966) classification, the burning intensity was very low, accounting for a mean of 84.42 $kcal.m^{-1}s^{-1}$ with a standard deviation of 72.429 (Table 2). Nevertheless, it was not significantly related to the chemical variables.

Table 1. Description of environmental variables during prescribed burning.

Temperature (°C)	Humidity (%)	Wind ($m.s^{-1}$)
41.82 ± 3.36*	15.74 ± 6.14*	0.40 ± 0.33*

* We found a difference of 5% among the means ± standard deviations by the t-test.

Table 2. Variables of the fire behavior.

Parcel of land	Height (cm)	Propagation speed ($m.s^{-1}$)	Intensity ($kcal.m^{-1}.s^{-1}$)
Mean	50.72 ± 18.93*	0.03 ± 0.03*	84.42 ± 72.43*

* We found a difference of 5% among the means ± standard deviations by the t-test.

However, the percentage of combustible material consumed by the fire (CMC) (Table 3), 55.70%, was the only burning-related variable presenting a significant correlation ($p < 0.05$) with soil chemical properties. These variables consist in the content of Ca^{2+}, Fe^{2+}, CO, SB, and the Ca^{+}/T ratio (Table 4).

Table 3. Description of the quantity of combustible material in the study area.

Variables	Mean
CMA	7.48 ± 2.184
HCM	5.24 ± 1.816
CMC	55.74 ± 14.131*

* We found a difference of 5% among the means ± standard deviations by the t-test. CMA: combustible material available ($t.ha^{-1}$); HCM: humidity of combustible material (%); CMC: combustible material consumed (%).

Oliveira et al. (2005) reported that the action of fire with temperatures above 400 °C may cause the loss of P and N in the *Cerrado* environment, which affects the quality of the soil. Some authors have pointed out that when the fire consumes the initial biomass, its ashes return a significant amount of nutrients to the soil when compared with burned areas without biomass. This indicates to which extent the vegetation cover is important for the soil (Sampaio et al., 2003; Simon et al. 2016).

Before burning, the chemical variables (Table 5) found in the soil of the experimental parcels of land presented very high acidity, with pH below 4.5, and potential acidity (H + Al) and exchangeable acidity (Al^{3+}) on the medium scale. However, aluminum saturation (m) was high, whereas CECt and base saturation (V) presented low levels.

The soil presented an average of 13.5 $g.kg^{-1}$ of organic matter and 11.14 $g.kg^{-1}$ of organic content. Considering the macronutrient parameters presented by Sousa & Lobato (2004), contents of S, P, Ca^{2+}, and Mg^{2+} were very low, although K^{+} was at a medium level. The micronutrient variables were found between the very low (Zn^{2+}), low (B^{+} and Cu^{2+}), medium (Mn^{2+}), and high levels (Fe^{2+}). Pivello et al. (2010) observed that, during the dry season, after burning in a *Cerrado campo sujo* area, the pH was below 4.5 and the potential acidity, above 70%. On the other hand, during the rainy season, the availability of nutrients was higher, including the organic matter content.

In our study, after burning, the organic matter (OM) content increased by 45.7%, followed by the organic carbon (OC), which increased by 20%. Pomianoski et al. (2006) observed the effects of fire on the soil OM in an agroforestry system, and concluded that, after prescribed burning, the availability of organic matter increased by 37% on the first layer (0-5 cm). According to Oyedeji et al. (2016), fire quickly accelerates the mineralization of soil organic matter.

Variables that determine soil acidity, such as pH and H + Al, changed, although not significantly. However, aluminum saturation (m) significantly decreased; nevertheless, Al^{3+} reduced by 26% (Table 5). Faria et al. (2011) found a slight increase in the pH and exchangeable acidity variables (Al^{3+}) after burning, whereas the potential soil acidity (H + Al) presented significantly lower values. Conversely, Batista & Soares (1995) did not find a significant difference in characteristics related to soil acidity in a *Pinus taeda* plantation after burning.

Table 4. Significant correlations ($p < 0.05$) between chemical variables and the combustible material consumed.

Variable[1]	CMC	OC	Ca^{+}/T	Fe^{2+}	V	Ca^{2+}
CMC	–	0.0490**	0.0452**	0.0083**	0.0496**	0.0221**
OC	– 0.5344	–	0.0440**	0.0002**	0.0142**	0.0084**
Ca^{+}/T	– 0.5421	0.5447*	–	0.0162**	0.0002**	< 0.0001**
Fe^{2+}	– 0.6730	0.8400*	0.6279*	–	0.0002**	0.0004**
V	– 0.5332*	0.6376*	0.8328*	0.8345*	–	< 0.0001**
Ca^{2+}	– 0.6043*	0.6728*	0.8842*	0.8176*	0.9742*	–

[1] Below the diagonal: Pearson's coefficient; above the diagonal: T-test value for Pearson's coefficient. *Correlation is significant at the 0.05 level. **Correlation is significant at the 0.01 level. CMC: combustible material consumed; OC: organic content; Ca^{+}/T: calcium saturation in cation exchange capacity (CEC); Fe^{2+}: iron; V: bases of saturation; Ca^{2+}: calcium.

We observed an increase in the saturation of micronutrients K^+, Ca^{2+}, Mg^{2+}, S, and P (Table 5), although only the available phosphorus had no significant difference in the analysis. According to Lorenzon et al. (2014), who aimed to determine the consequent effects of fire on Red-Yellow Latosol, there was an increase in the content of P, from 1.61 to 4.19 mg.dm^{-3}; Ca^{2+}, from 3.08 to 6.23 cmol$_c$.dm^{-3}; K, from 42.40 to 44.40 mg.dm^{-3}; and Mg^{2+}, from 0.65 to 1.24 cmol$_c$.dm^{-3}. Rheinheimer et al. (2003) also observed an increase in the content of P after burning. However, they have also observed a sharp decrease of this nutrient on the superficial layer up to 60 days after burning. Yet, the soil presented higher K^+ values in the burned parcels of land than in the unburned ones. Simon et al. (2016), upon studying the effects of burning in the *Cerrado* soil, verified that, in the 0.0-0.5 m depth layer, the Ca^+/Mg^+ ratio presented higher availability of these nutrients after burning.

Regarding changes in the content of micronutrients, we observed a significant increase in availability of Zn^{2+}, Mn^{2+}, and B^+ contents (Table 5). Couto et al. (2006) studied the impact of fire on the availability of soil nutrients in the Pantanal region, and according to their results, there were no changes in Mg^{2+}, B^+, and Fe^{2+} values. Additionally, they found a slight increase in Cu^{2+} values.

According to the statistical analyses, we found a significant increase in the CECt, SB, and Ca^+/T ratios (Table 5). However, the K^+/T and Mg^+/T ratios significantly decreased (Table 5). Simon et al. (2016) verified that, after burning, the superficial layer (0-5 cm) presented higher CEC values. This result was justified by the increase in availability of bases in the soil, besides the organic matter mineralization after burning. Thus, CEC increased due to the increase in bases and negative loads in the soil, which allowed these elements to be retained. Similar results have also been observed by other authors (e.g., Dick et al., 2008; Rheinheimer et al., 2003). According to these authors, the increase in cation concentration (Ca^{2+} and Mg^{2+}) may be related to the release of oxides from the ashes.

Table 5. Mean chemical variables before and after prescribed burning.

Chemical variables	*A priori*	*A posteriori*
pH ($CaCl_2$)	4.01	4.06
P (mg.kg^{-1})	2.73	3.11
S SO_4^{-2} (mg.kg^{-1})	2.00	3.07*
K^+ (mg.kg^{-1})	34.43	46.36*
Ca^{2+} (cmol$_c$.kg^{-1})	0.19	0.31*
Mg^{2+} (cmol$_c$.kg^{-1})	0.14	0.23*
Al^{3+} (cmol$_c$.kg^{-1})	0.51	0.38**
H + Al (cmol$_c$.kg^{-1})	3.90	4.35
OM (g.kg^{-1})	13.05	24.07*
OC (g.kg^{-1})	11.14	13.93*
B^+ (mg.kg^{-1})	0.11	0.16*
Cu^{2+} (mg.kg^{-1})	0.41	0.39
Fe^{2+} (mg.kg^{-1})	53.50	63.64
Mn^{2+} (mg.kg^{-1})	4.98	8.45*
Zn^{2+} (mg.kg^{-1})	0.14	0.26*
SB (cmol$_c$.kg^{-1})	0.42	0.65*
CECt (cmol$_c$.kg^{-1})	4.32	5.00*
V (%)	9.50	12.93*
m (%)	56.07	38.71**
Ca^+/T (%)	4.29	6.14*
Mg^+/T (%)	3.14	4.50
K^+/T (%)	2.00	2.29
Ca^+/Mg^+	0.43	1.06*
Ca^+/K^+	1.61	3.05*
Mg^+/K^+	3.34	2.78

* Increase. ** Decrease. Pairs of means followed by * and ** differ by 5% as per the t-test. pH ($CaCl_2$): potential of hydrogen; P: available phosphorus (mg.kg^{-1}); S SO_4^{-2}: sulfur (sulphates) (mg.kg^{-1}); K^+: available potassium (mg.kg^{-1}); Ca^{2+}: exchangeable calcium (cmol$_c$.kg^{-1}); Mg^{2+}: exchangeable magnesium (cmol$_c$.kg^{-1}); Al^{3+}: exchangeable aluminum or acidity (cmol$_c$.kg^{-1}); H + Al: potential acidity (cmol$_c$.kg^{-1}); OM: organic matter (g.kg^{-1}); OC: organic carbon (g.kg^{-1}); B^+: boron (mg.kg^{-1}); Cu^{2+}: copper (mg.kg^{-1}); Fe^{2+}: iron (mg.kg^{-1}); Mn^{2+}: manganese (mg.kg^{-1}); Zn^{2+}: zinc (mg.kg^{-1}); SB: sum of bases (cmol$_c$.kg^{-1}); CECt: effective cation exchange capacity (cmol$_c$.kg^{-1}); V: percent base saturation (%); m: percent aluminum saturation (%); Ca^+/T: calcium saturation in cation exchange capacity (CEC) (%); Mg^+/T: magnesium saturation in CEC (%); K^+/T: potassium saturation in CEC (%); Ca^+/Mg^+: calcium magnesium ratios; Ca^+/K^+: calcium potassium ratios; Mg^+/K^+: magnesium potassium ratios.

4. CONCLUSIONS

Burning releases nutrients over a period of 24 hours and causes a number of chemical changes to the soil. These changes may be beneficial or harmful to chemical properties, and the degree of variation of their benefit or harm depends on several factors such as the use and type of burned soil, combustible material, time of day, duration, intensity, and frequency.

Low-to-moderate fire intensity may promote an increase in the availability of organic matter and other nutrients, such as Ca^{2+}, Mg^{2+}, K^{+}, Mn^{2+}, Zn^{2+}, B^{+}, and S, as well as in the ratios characterizing the soil, CECt, SB, Ca^{+}/T, Ca^{+}/Mg^{+}, V, and Ca^{+}/K^{+}.

ACKNOWLEDGEMENTS

The authors thank Universidade Federal do Tocantins (UFT), Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), and Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (Capes).

SUBMISSION STATUS

Received: June 5, 2018

Accepted: Nov. 24, 2018

Associate editor: Marcos Gervásio Pereira

0000-0002-1402-3612

CORRESPONDENCE TO

Gil Rodrigues dos Santos

Universidade Federal do Tocantins (UFT), Rua Badejós, lote 7, chácaras 69/72, CEP 77400-000, Gurupi, TO, Brasil

e-mail: gilrsan@mail.uft.edu.br

FINANCIAL SUPPORT

Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq)

REFERENCES

Abraham J, Dowling K, Florentine S. Controlled burn and immediate mobilization of potentially toxic elements in soil, from a legacy mine site in Central Victoria, Australia. *Science of the Total Environment* 2018; 616-617: 1022-1034. 10.1016/j.scitotenv.2017.10.216

Alcañiz M, Outeiro L, Francos M, Úbeda X. Effects of prescribed fires on soil properties: a review. *Science of the Total Environment* 2018; 613-614(1): 944-957. 10.1016/j.scitotenv.2017.09.144

Batista AC, Beutling A, Pereira JF. Estimativa do comportamento do fogo em queimas experimentais sob povoamentos de *Pinus elliottii*. *Revista Árvore* 2013; 37(5): 779-787. 10.1590/S0100-67622013000500001

Batista AC, Soares RV. Avaliação do comportamento do fogo em queimas controladas sob povoamentos de *Pinus taeda* no norte do Paraná. *Floresta* 1995; 25(1-2): 31-42. 10.5380/rf.v25i12.6443

Batista EKL, Russell-Smith J, França H, Figueira JEC. An evaluation of contemporary savanna fire regimes in the Canastra National Park, Brazil: outcomes of fire suppression policies. *Journal of Environmental Management* 2018; 205: 40-49. 10.1016/j.jenvman.2017.09.053

Byram GM. Combustion of forest fuels. In: Davis KP, editor. *Forest fire: control and use.* New York: McGraw Hill; 1959. p.61-89.

Camargos VL, Ribeiro GA, Silva AF, Martins SV, Carmo FMS. Estudo do comportamento do fogo em um trecho de floresta estacional semidecídua no município de Viçosa, Minas Gerais. *Ciência Florestal* 2015; 25(3): 537-545. 10.5902/1980509819605

Castro AHF, Alvarenga AA, Barbosa JPRAD, Mansur TOF, Paula ACCFF. Avaliação sazonal da atividade da fenilalanina amônia-liase e dos teores de fenóis e taninos totais em *Stryphnodendron adstringens* (Mart.) Coville. *Ciência Florestal* 2017; 27(3): 1037-1048. 10.5902/1980509828679

Certini G. Effects of fire on properties of forest soils: a review. *Oecologia* 2005; 143(1): 1-10. 10.1007/s00442-004-1788-8

Couto EG, Cunha LACCN, Loureiro MF. *Estudo sobre o impacto do fogo na disponibilidade de nutrientes, no banco de sementes e na biota de solos da RPPN Sesc Pantanal*. Rio de Janeiro: Sesc; 2006. (Conhecendo o Pantanal; vol. 2).

Dick DP, Martinazzo R, Dalmolin RSD, Jacques AVA, Mielniczuk J, Rosa AS. Impacto da queima nos atributos químicos do solo, na composição da matéria orgânica e na vegetação. *Pesquisa Agropecuária Brasileira* 2008; 43(5): 633-640.

Eiten G. Vegetação do cerrado. In: Pinto MN, editor. *Cerrado: caracterização, ocupação e perspectivas*. Brasília, DF: Editora UnB; 1994. p. 17-73.

Faria ABC, Blum TC, Chitsondzo C, Lombardi KC, Batista AC. Efeitos da intensidade da queima controlada sobre o solo e diversidade da vegetação de campo em Irati – PR, Brasil. *Revista Brasileira de Ciências Agrárias* 2011; 6(3): 489-494. 10.5039/agraria.v6i3a932

Knicker H. How does fire affect the nature and stability of soil organic nitrogen and carbon? A review. *Biogeochemistry* 2007; 85(1): 91-118. 10.1007/s10533-007-9104-4

Lorenzon SA, Brianezi D, Valdetaro EB, Souza CM, Martins SV, Ribeiro CAAS et al. Análise química de um solo florestal após ocorrência de fogo. *Revista Brasileira de Agropecuária Sustentável* 2014; 4(2): 142-147. 10.21206/rbas.v4i2.269

McArthur AG, Cheney NP. The characterization of fire in relation to ecological studies. *Australian Forest Research* 1966; 2(3): 36-45.

Meira MS Jr, Pereira IM, Machado ELM, Mota SLL, Ribeiro PSSP, Otoni TJO. Impacto do fogo em campo sujo no Parque Estadual do Biribiri, Minas Gerais, Brasil. *Floresta e Ambiente* 2017; 24: e00110814. 10.1590/2179-8087.110814

Oliveira IP, Santos KJG, Araujo AA, Oliveira LC. Queimadas e suas consequências na região Centro-Oeste. *Revista Eletrônica Faculdade Montes Belos* 2005; 1(2): 88-103.

Oyedeji S, Onuche FJ, Animasaun DA, Ogunkunle CO, Agboola OO, Isichei AO. Short-term effects of early-season fire on herbaceous composition, dry matter production and soil fertility in Guinea savanna, Nigeria. *Archives of Biological Sciences* 2016; 68(1): 7-16. 10.2298/ABS150526002O

Pivello VR, Oliveras I, Miranda HS, Haridasan M, Sato MN, Meirelles ST. Effect of fires on soil nutrient availability in an open savanna in Central Brazil. *Plant and Soil* 2010; 337(1-2): 111-123. 10.1007/s11104-010-0508-x

Pomianoski DJW, Dedecek RA, Vilcahuaman LJM. Efeito do fogo nas características químicas e biológicas do solo no sistema agroflorestal da Bracatinga. *Boletim de Pesquisa Florestal* 2006; (52): 93-118. 10.4336/2012.pfb.52.93

Resende FC, Cardozo FS, Pereira G. Análise ambiental da ocorrência das queimadas na porção nordeste do Cerrado. *Revista do Departamento de Geografia* 2017; 34: 31-42. 10.11606/rdg.v34i0.131917

Rheinheimer DS, Santos JCP, Fernandes VBB, Mafra AL, Almeida JA. Modificações nos atributos químicos de solo sob campo nativo submetido à queima. *Ciência Rural* 2003; 33(1): 49-55. 10.1590/S0103-84782003000100008

Ribeiro JF, Walter BMT. Fitofisionomias do bioma Cerrado. In: Sano SM, Almeida SP, editores. *Cerrado: ambiente e flora.* Planaltina: Embrapa-CPAC; 1998. p. 89-166.

Sampaio FAR, Fontes LEF, Costa LM, Jucksch I. Balanço de nutrientes e da fitomassa em um argissolo amarelo sob floresta tropical amazônica após a queima e cultivo com arroz. *Revista Brasileira de Ciência do Solo* 2003; 27(6): 1161-1170. 10.1590/S0100-06832003000600020.

Simon CA, Ronqui MB, Roque CG, Desenso PAZ, Souza MAV, Kühn IE et al. Efeitos da queima de resíduos do solo sob atributos químicos de um latossolo vermelho distrófico do cerrado. *Nativa* 2016; 4(4): 217-221. 10.14583/2318-7670.v04n04a06

Soares RV, Batista AC. *Incêndios florestais: controle, efeitos e uso do fogo*. Curitiba: Independentes; 2007.

Sousa DMG, Lobato E, editores. *Cerrado: correção do solo e adubação*. 2nd ed. Planaltina: Embrapa Cerrados; 2004.