Australian Journal of Crop Science

AJCS

AJCS 12(03): 505-510 (2018) ISSN:1835-2707
doi: 10.21475/ajcs.18.12.03.pne1126

AUSTRALIAN JOURNAL OF CROP SCIENCE | SUBMITTED: 22-OCT-2017 | REVISED: 04-JAN-2018 | ACCEPTED: 08-FEB-2018

Chemical attributes of Brazilian Cerrado soil under different management systems

Tatiana Vieira Ramos[1], Leovigildo Aparecido Costa Santos[2], Wander Gomes de Souza[2], Kellen Rabello de Souza[1], Nauara Lamaro Lima[1], Luanna Elis Guimarães[1], Daniel Cardoso Brandão[1], Jaqueline Pinheiro da Silva[3], Rosana Alves Gonçalves[1], Bruno Bastos Gonçalves[1], Everton Martins Arruda[1], Francine Neves Calil[1], Carlos de Melo e Silva-Neto[4]*

[1]Agronomy School, Federal University of Goiás, GO, Brazil
[2]State University of Goiás, Anápolis, GO, Brazil
[3]State University of São Paulo, Botucatu, SP, Brazil
[4]Federal Institute of Education, Science and Technology of Goiás, Cidade de Goiás – GO, Brazil

***Corresponding author: carloskoa@gmail.com**

Abstract

Agricultural use and management systems in tropical soils of the Brazilian Cerrado may directly influence its chemical properties, in the conventional cultivation systems with pastures or grains, as well as in areas with a crop-livestock-forest integration system. Thus, the objective was to evaluate the chemical attributes of the soil under different use and management systems. The research was carried out at Boa Vereda Farm, in the state of Goiás, Brazil. The experimental design was completely randomized with a 5 x 3 factorial arrangement divided into five production systems: (1) among the rows of Eucalyptus (CLFI), (2) within the rows of Eucalyptus (CLFI), (3) in conventional agricultural monoculture, (4) pasture, and (5) – natural Cerrado (control treatment). Samples were collected in three soil depths (0-0.5; 0.5-0.1 and 0.1-0.2 m), with four replicates each. Among the chemical properties of the soil studied, the organic matter, calcium, magnesium and potassium contents, base saturation, and cation exchange capacity, are higher in the soil with natural Cerrado. The area of agricultural monoculture showed the highest levels of phosphorus and copper, but has the lower levels of organic matter in the soil. The chemical properties of the soil were similar in the CLFI system, regardless of the evaluation point (within or among rows). The chemical properties of the soil evaluated were similar between the pasture cultivated in CLFI and the conventional system. Therefore, the land use and management system do not directly influence the chemical properties of the soils evaluated.

Keywords: Agrosilvopastoral; pasture; grain production, fertility.

Introduction

The Brazilian Cerrado occupies approximately two million square kilometers or 23% of the total area of the country. Most of the soils in this region are highly weathered oxysols, with serious limitations for food production as regards the naturally low soil fertility. The soils are acidic, with low availability of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), zinc (Zn), boron (B) and copper (Cu). Cerrado soils are also peculiar in having high aluminum saturation (m%) and a high phosphorus binding capacity.

The deterioration of natural resources, especially land and water, has grown uncontrollably in the Cerrado area. Ecosystem changes take place as natural vegetation is replaced by industrial or agricultural/livestock activities, negatively impacting the environment due to the improper soil use and management. Agriculture/livestock activities are the ones that most transform the natural soil properties. These systems depend directly on the use of non-renewable resources (fuel, fertilizers and correctors), and cause direct changes in the chemical, physical and biological properties of the soil (Pereira et al., 2016).

The soil is shaped by the balance between chemical and physical properties, thus limiting food and fiber production (Araújo et al., 2007). In addition, the soil is a substrate for plant growth, providing the necessary physical support, water, nutrients and oxygen to the roots. Maintaining soil quality not only increases the productivity of crops, but also preserves the quality of the environment, thereby preserving the health of plants, animals and humans.

Soil properties in the native Cerrado area are defined by the vegetation and deposition of organic matter, while soil exploration by the roots increases its structural quality, nutrient availability and creates a microclimate in the region (Silva Júnior et al., 2012; Abreu et al., 2016; Zago et al., 2018). Roots also protect the soil against direct exposure to sunlight and the impact of rainwater, which can disaggregate the soil and carry its nutrients by runoff. Carneiro et al. (2009) and Ferreira et al. (2017) carried out studies in native Cerrado areas and observed that the chemical and microbiological properties of the soil are altered when the system is converted to an area of pasture or grain cultivation. Therefore, we need to find alternative production models that are more economically and environmentally efficient, by seeking productive agroecosystems that maintain or improve soil and conditions of the Cerrado biome.

Conventional agriculture, in which only monocultures are planted, proved to be inefficient for agricultural production and environmental conservation. Thus, there is a search for different productive forms, in which the agricultural system is rethought, tending to approach an agro-ecosystem as close to the natural environment (Altieri et al., 2017; Zago et al., 2018). The crop-livestock-forest integration system seeks to bring current productive models closer to ecosystem relationships, reducing environmental impacts and enhancing ecological processes that positively influence agricultural production, such as nutrient, hydrological and carbon cycling.

The agricultural use and management systems in tropical soils of the Brazilian Cerrado biome directly affect its chemical properties in conventional, pasture/grain-cultivated systems as well as in areas inserted within the crop-livestock-forest integration system. The study of soils in the Cerrado region, under different production management and conservation conditions contributes to defining new productive agro-ecosystems consistent with the climatic and soil characteristics of the biome. Therefore, the objective of this study was to evaluate the chemical attributes of the soil under different use and management systems in the Brazilian Cerrado.

Results

Chemical properties of the soil such as the cation exchange capacity (CEC), base saturation (V%), soil organic matter (MO) and macronutrients (Ca^{2+}, Mg^{2+}, P and K^{+}) are higher in the natural Cerrado (CN) than in other agricultural production systems, thus showing the stability of the natural system compared to the other areas evaluated (Table 1).

The highest levels of MO were recorded in the CN area and in the 0-5 cm layer of the soil (5.25%). The MO contents found in the 5-10 cm layer were similar for the CN, PAS and CLFI (within and between rows) areas. Another highlight is that MO contents in the 10-20 cm soil layer of the pasture area (PAS) was similar to the recorded for the CN area, due to the large volume of the pasture root system, which favors higher MO contents in the lower layers of the soil.

The P levels in the agricultural crop area (CA) were similar to those found in the CN area, differing from the other management systems evaluated. The CA system had the highest P content in the 5-10 cm depth, similar to the recorded for the CN and higher than those found in PAS and CLFI systems (between or within rows).

The K^{+} contents differed significantly between the agricultural use and management systems adopted. However, the 0-5 cm depth of the CLFI areas (ER) and CA system, areas statistically similar to the CN area, exhibited the highest K^{+} contents in the soil. The potential acidity (H + Al) and V% differed significantly among the depths evaluated. The PAS management exhibited the highest mean H+Al, for the three layers studied (4.16 $cmol_c.dm^{-3}$) and the lowest mean V% (31.33). This pattern was expected, as a reduction of V% values is expected with increasing H + Al.

The availability of the micronutrients Mn^{2+} and Zn^{2+} was also similar among the agricultural systems evaluated. The soils of the NC and AC presented the highest levels of Cu^{2+}, followed by the PAS. The lowest Cu^{2+} contents were recorded in the areas consorted with eucalyptus (CLFI DR and ER).

The PCA analysis of the chemical properties of the soil under different land use and management systems allowed the identification of three groups. The first with the CN area, with the highest Ca^{2+}, Mg^{2+}, P, K^{+}, and MO contents and highest CEC and V (%), indicating a balanced system., with the higher values of base saturation and cation exchange capacity favor the equilibrium between the nutrients in the soil solution (Fig. 1).

The PAS and CLFI (DR and ER) systems form a group with the highest H + Al values, reducing the V%, and consequently the availability and balance of the other nutrients. Therefore, the chemical quality of the soil is more susceptible when pastures are cultivated. The P contents recorded in the agriculture crop area (CA) stands out as the one that most approached the contents found in the NC area. This proximity was caused by the fertilization with phosphate minerals carried out annually for rotation cultivation with soybean and maize.

The chemical attributes evaluated in the different soil management systems, except CN, are influenced by soil depth (Fig. 2), either by the contribution of litter deposited in the CLFI, or by the fertilization procedures carried out in the agricultural cultivation and pasture areas. In addition, there is a greater contribution of MO in deeper layers of the PAS, favored by the grass root system.

Discussion

Organic matter (MO) levels were higher in the soil depth of 0.10-0.20 m in the pasture area than in the other depths. This was unexpected, given that higher MO contents are generally found in the more superficial layers in tropical soils due to the external effects of biotic and abiotic factors, and to the accumulation and decomposition of organic residues. The MO levels in the three systems (CA, CLFI DR and ER) are quite similar, indicating that nutrient inputs and outputs are occurring in a balanced and quantitatively equivalent manner in the system models evaluated.

The CA exhibited low MO values in the depths studied. Nunes et al. (2011) evaluated management systems and organic matter contents in Oxisol of the Cerrado biome with a soybean-corn succession, and found that the least cultivated systems had lower MO levels than the pasture production systems. Santana et al. (2016) and Zago et al. (2018) highlight that land use and management system exert a profound influence on nutrient supply, since it directly affects the soil microbiota, influencing the decomposition of MO and mineralization of nutrients to the soil. However, the systems studied differed from the natural Cerrado on several of the chemical properties studied, corroborating the findings of Carneiro et al. (2009). On the other hand, Carneiro et al. (2009) reported higher H + Al contents and

Table 1. Chemical characteristics of the Cerrado soil in different agricultural systems and depths at Cachoeira Dourada, Goiás, Brazil.

	Pro	pH	MO	V	CTC	H+Al	Ca^{2+}	Mg^{2+}	P	K^{+}	Cu^{2+}	Fe^{2+}	Mn^{2+}	Zn^{2+}
	(m)	(H_2O)	(%)		$cmol_c dm^{-3}$				$mg dm^{-3}$					
	0-0.5	5.25aA	5.25aA	85.50aA	18.75aA	2.50aA	13.00aA	3.25aA	6.75aA	194.25aA	3.5aA	12.50aA	56.75aA	0.62aA
CN	0.5-0.1	5.50aA	3.50bB	79.25aA	17.25aA	3.00aA	11.00aA	2.75aA	4.00bB	195.25aA	3.5aA	10.25aA	47.75aA	0.65aA
	0.1-0.2	5.25aA	4.50aA	83.00aA	19.75aA	3.50aA	13.25aA	3.00aA	5.00abA	209.25aA	3.5aA	10.25aA	46.5aA	0.6aA
	0-0.5	5.00aA	2.25aB	57.75aB	5.75aB	2.25aA	1.75aB	1.25aB	3.75aB	120.75aB	3.75aA	9.25aA	50.25aA	0.62aA
CA	0.5-0.1	5.00aA	1.75aBC	39.25bC	5.50aB	3.50aA	1.00aB	0.75aB	8.00bA	74.00bC	3.5aA	8.50aA	54aA	0.55aA
	0.1-0.2	5.00aA	2.00aBC	43.25abB	5.75aB	3.25aA	1.25aB	1.25aB	3.25aB	62.75bC	3.5aA	8.75aA	55.25aA	0.75aA
	0-0.5	6.00aB	3.00aB	48.50aB	7.00aB	3.75aAB	1.25aB	1.25aB	4.25aB	133.00aB	3aA	11.50aA	65.25aA	0.62aA
DR	0.5-0.1	5.75abAB	2.25aB	42.75abB	6.25aB	3.75aAB	1.25aB	1.50aB	3.50aB	96.50aAC	3aA	9.75aA	55.25aA	0.65aA
	0.1-0.2	5.50bA	3.00 aB	30.25bC	4.50bB	3.50aA	0.25bB	1.00aB	2.75abB	60.25bC	3aA	10.25aA	41.25aA	0.55aA
	0-0.5	5.50aA	2.75aB	41.25aB	7.75aB	4.50aB	1.25aB	1.75aB	2.75aB	65.50aC	3aA	11.25aA	67.75aA	0.75aA
ER	0.5-0.1	5.50aA	2.75aB	38.25aBC	6.50aB	4.00aB	1.25aB	1.25aB	2.25aB	52.25aC	3aA	10.00aA	54.25aA	0.62aA
	0.1-0.2	5.50aA	2.25aB	39.00aBC	5.25bB	3.25aA	0.75aB	1.00aB	2.25aB	47.00aC	3aA	8.75aA	44aA	0.52aA
	0-0.5	5.50aA	2.75 aB	29.00aD	6.25aB	4.50aB	1.75aB	1.00aB	2.75aB	69.25aC	3aA	11.50aA	52.25aA	0.72aA
PAS	0.5-0.1	5.00bA	2.50 aB	23.00aD	5.00aB	3.75aA	1.00aB	0.00bC	2.75aB	66.00aC	3.25aA	10.50aA	47aA	0.67aA
	0.1-0.2	5.00bA	4.00 bA	42.00bB	12.50bA	4.25aB	1.25aB	1.00aB	3.00aB	127.75bB	3.25aA	15.00aA	47aA	0.65aA

where: 1CN = Natural Cerrado; CA = Agricultural Crop; DR = Eucalyptus within rows; ER = Eucalyptus between rows; PAS = Pasture; MO = Organic matter. The same lowercase letters at the same depth (line) do not differ statistically and the same uppercase letters represent a non-significant difference between adopted management and land use (P<0.05).

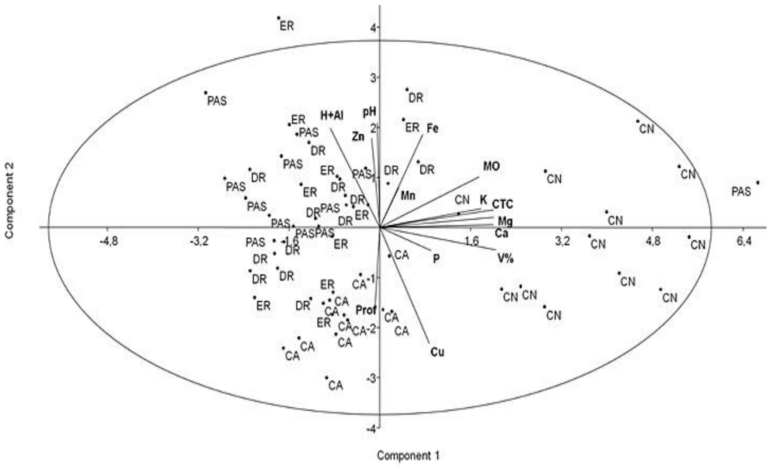

Fig 1. Principal component analysis of the chemical properties of CLFI soils (DR- within rows and ER- between rows), agricultural crop (CA), Natural Cerrado (CN) and Pasture (PAS), in different depths (0 -0.5, 0.5 – 0.10 and 0.10 – 0.20 m). The properties analyzed were Depth (37.93%*), Organic Matter (MO; 15.54%*), Hydrogen potential (pH; 11.74%*), Phosphorous (P; 8.61%*), Potassium (K; 6.41%*); Calcium (Ca; 4.78%), Magnesium (Mg; 3.98%), H+Al (3.47%), CTC or CEC (2.73%), V% (1.99%), Copper (Cu; 1.74%), Iron (Fe, 0.89%), Manganese (Mn; 0.12), Zinc (Zn; 0.004%). * Values significant at a 95% significance level.

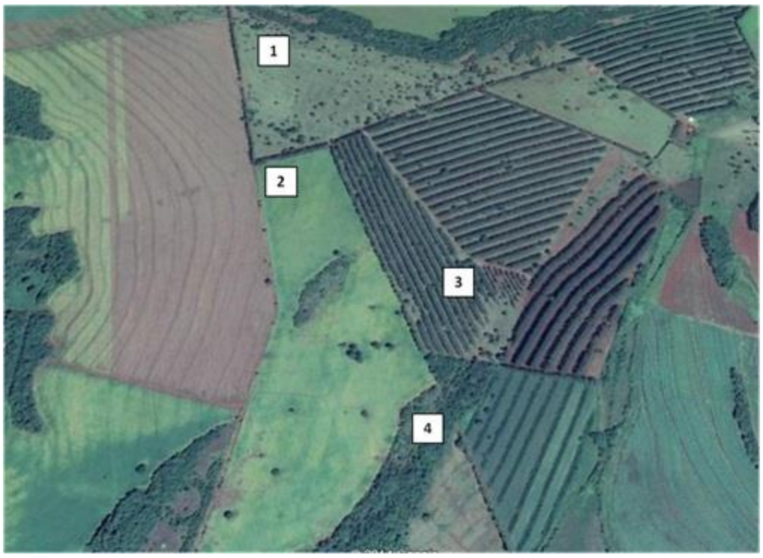

Fig 2. Areas selected to carry out the research procedures, at the Vereda Farm, municipality of Cachoeira Dourada, Goiás, Brazil, 2014. 1. Pasture (PAS); 2. Agricultural crop (CA). 3. Crop-Livestock-Forest Integration (CLFI DR and ER); 4. natural Cerrado (CN).

lower Ca^{2+}, Mg^{2+} and P contents in Cerrado areas than in areas managed with conventional agriculture, contrasting with the results obtained in this study. P contents in the CA system is an exception for presenting contents similar to the recorded for CN, despite presenting higher contents in the depth of 0.5-0.10, possibly due to soil correction and fertilization.

Barbosa et al. (2010) explains this inversion of soil P contents in grain production systems by the location of P application, since the portions applied in the planting line are usually deposited beneath the seeds, at an average depth of 0.6-0.8 m. On the other hand, the K^+, Ca^{2+}, and Mg^{2+} contents and V% values were significantly lower in all cultivated areas when compared to the CN area. However, the K^+, Ca^{2+}, and Mg^{2+} contents and V% were higher in the depths of 0-0.5 and 0.5-0.10 m in CLFI areas than in PAS areas. Lemos-Junior et al. (2016) emphasizes that CLFI produces a considerable volume of eucalyptus wood and contributes with the agroecosystem with litter deposition and organic matter, explaining the characteristics of their soils being better than in areas with only pasture. Similar to this study, Cardoso et al. (2011) reported such reductions by evaluating the chemical properties of soil from native tree vegetation and pastures of the Brazilian Pantanal. These results can be attributed to the lower nutrient cycling in pastures, consequent of the lower supply of organic material into the soil. The decomposition and mineralization of organic material is possibly an important source of nutrients in tropical low fertility and unfertilized soils (Moreira and Malavolta, 2004; Calil et al., 2016).

Forest ecosystems can be characterized as "closed systems" because their nutrient cycle is composed of small losses or relative gains, and high rates of internal cycling in the soil-plant system (Gama-Rodrigues, 2004; Martins et al., 2016; Pereira et al., 2017; Ferreira et al., 2017). The "open" systems, in turn, present high nutrient losses, and are represented mainly by agricultural systems, while the CLFI systems correspond to an intermediate situation (Gama-Rodrigues et al., 2004). CLFI systems integrated with native Cerrado trees are viable alternatives for more balanced agroecosystems. Calil et al. (2016) studied grazing systems integrated with Baru (*Dipteryx alata* Vog.), Pequi (*Caryocar brasiliense* Camb.) and Cagaita trees (*Eugenia dysenterica* DC.), and reported a productivity gain on pasture due to the differentiated deposition of litter from the native tree species, significantly improving the productivity growth of Brachiaria grass (*Urochloa decumbens* (Stapf) R.D.Webste).

The Mn^{2+} and Zn^{2+} contents in the agricultural crop area were higher in the deeper layers of the soil, which may be associated with the upturning of the soil for cultivation. It is important to highlight that the Mn^{2+}, Cu^{2+}, Zn^{2+} contents were higher in the superficial layer of the soil in the other areas. This may be related to the low mobility of these micronutrients and to losses by leaching, in addition to the greater contribution of organic material to the soil surface, which favors productivity consequent of nutrient availability. Micronutrient complexation, aggregation, water infiltration and retention, aeration and microbial activity favor the balance of agroecosystems and reinforce the importance of organic matter in nutrient cycling (Cardoso et al., 2011).

The Zn^{2+} values were higher in the PAS area, where the MO was low, contrasting with the observed for the NC area (low Zn^{2+} and high MO). Papoyan et al. (2015) stating that Zn^{2+} is potentially toxic to plants in high concentrations, reducing the production of biomass of the aerial part and of the root. Consequently, the organic matter also becomes lower. At the depth of 0.10 - 0.20 cm, the organic matter of the PAS area has MO values similar to the reported for the CN area, which may be due to the Brachiaria roots.

As demonstrated, the agricultural activity in the Cerrado directly affects the physical and chemical properties of soils, and may contribute to the improvement or degradation of its characteristics. The current production challenge, especially in countries with large agricultural production, is the search for balanced agroecosystems that can combine production with conservation.

Materials and methods

Characterization and design of the experimental area

The study was carried out at Boa Vereda Farm, municipality of Cachoeira Dourada, southern state of Goiás, Brazil (latitude 18°29’30”, longitude 49°28’30”, and mean altitude of 459 m), within the Cerrado biome. The local climate is Aw according to the Köppen classification, typical of tropical humid climates, with two well defined seasons (dry winters and humid summers), an average annual temperature of 24 °C and average annual rainfall of 1340 mm. The prevailing soil of the region has been classified as Oxisol of clayey texture (Embrapa, 2013).

The experimental area presents a crop-livestock-forest integration system (CLFI), with eucalyptus (*Eucalyptus* x *urograndis*) planted in triple lined rows (3 m x 2 m) and a 14 m spacing cultivated with pasture of *Urochloa decumbens* (Stapf) Webster, with six years of implementation. This pasture between the rows is used for grazing cattle with a stocking rate of 5 animals per hectare. In the same property, surrounding the CLFI system, are areas of agricultural monoculture with conventional tillage, cultivated pasture and natural Cerrado (Fig. 2).

The design was completely randomized with a 5x3 factorial arrangement, combining five areas for collecting soil samples: CLFI within the rows (DR), CLFI between rows (ER), cultivated pasture (PAS), agricultural crop area (CA) and natural Cerrado (CN). Samples were collected in three soil depths (0-0.5; 0.5-0.10 and 0.10-0.20 m), with four replicates each.

Data collection

Soil samples were manually collected at the depths of 0 – 0.5; 0.5 – 0.10 and 0.10 – 0.20 m using a hoe and a shoulder blade, opening trenches of approximately 10 x 50 x 25 cm. Then, the soil samples were air-dried, crushed and passed through a 2 mm mesh screen (TFSA) (Embrapa, 2011).

The phosphorus and potassium contents were extracted by Mehlich I; calcium and magnesium extracted in KCl and determined by titration of EDTA; Copper, Zinc, Iron and Manganese determined in an atomic absorption spectrophotometer; and Hydrogen, exchangeable aluminum and pH ($CaCl_2$) according to the methodology described by Embrapa (2011). The potential (CEC_{pot}) and effective cation exchange capacity (CEC_{ef}) and Base Saturation (V%) were calculated from the data. Soil organic matter content (MO) was determined by the dichromate oxidation method and spectrophotometer reading (Embrapa, 2011).

Statistical analysis

The data were analyzed using the F test, and the means were compared using Tukey's test ($p < 0.05$) in the event of significant results (Ferreira, 2011). A principal component analysis (PCA) was performed to evaluate the relationship among the variables, and was based on a correlation matrix (Johnson and Wichern, 2007; Santana et al., 2016). In this case, the average of each chemical component of the soil was considered in each system evaluated, and in the three depths.

The circle of eigenvectors of the variables and the ordination diagram of the samples, soil sample collection sites and three depths, was constructed for the first two components (x and y axes, the first and second principal components respectively). An ellipse of the confidence area (coefficient of 0.95) was drawn in the ordination diagram from the set of samples of each soil group. The probability that the values fall within the area marked by the ellipse is a function of the coefficient that controls the size of the ellipse.

Conclusion

Among the chemical properties of the soil studied, organic matter, base saturation, cation exchange capacity, calcium, magnesium and potassium are higher in the Natural Cerrado soil (CN). The agricultural crop area (CA) has the highest phosphorus and copper contents, but the lowest levels of organic matter in the soil. The chemical properties of the soil are similar in the CLFI system, regardless of the evaluation point (within or between rows). The chemical fertility of the soils evaluated for the pasture grown in CLFI and in conventional system is similar.

Acknowledgment

The authors thank the researcher Dr. Abílio Rodrigues Pacheco for the provision and assistance in the research and the Foundation of Amparo and Research of the State of Goiás (FAPEG) for funding the research. The author, the Technologist in Agroecology also thanks the support to the Federal Institute of Goiás to support the realization of the research.

References

Abreu SAH, Arruda EM, Barros LR, Almeida RF, Maranhão DDC, Silva VL, Silva Neto CM, Flores RA, Calil FN, Collier LS (2016) Chemical attributes of the soil in agroforestry systems subjected to organic fertilizations. Af J Agricul Res. 11: 2378-2388.

Altieri MA, Nicholls CI, Montalba R (2017) Technological Approaches to Sustainable Agriculture at a Crossroads: An Agroecological Perspective. Sustainability. 9(3), 349.

Araújo ASF, Monteiro RTR (2007) Indicadores Biológicos da qualidade do solo. Biosci J. 23(3) : 66-75.

Ashot P, Piñeros M, Kochian LV (2007) Plant Cd^{2+} and Zn^{2+} status effects on root and shoot heavy metal accumulation in Thlaspi caerulescens. New Phyt. 175(1): 51-58.

Barbosa FT, Bertol I, Luciano RV, Paz-Ferreiro J (2010) Sediment size and organic carbon content in runoff and soil under two crops and two seed row directions. R Bras Ciên Solo. 34: 1701-1710.

Calil FN, Brandão DC, Lima NL, Barbosa PVG, Carvalho HCS, Lima PAF, Dianese M, Silva RT, Nascimento AR, Silva-Neto CM (2016) Biomass and nutrition stock of grassland and accumulated litter in a silvopastoral system with Cerrado species. Af J Agric Res. 11: 3701-3709.

Cardoso EL, Silva MLN, Curi N, Ferreira MM, Freitas DAF (2011) Qualidade química e física do solo sob vegetação arbórea nativa e pastagens no Pantanal sul-mato-grossense. R Bras Ciên Solo. 35:613-622.

Cardoso EL, Silva MLN, Moreira FMS, Curi N (2009) Atributos biológicos indicadores da qualidade do solo em pastagem cultivada e nativa no Pantanal. Pesq Agropec Bras. 44:631-637.

Carneiro MAC, Souza ED, Reis EF, Pereira HS, Azevedo WR (2009) Atributos físicos, químicos e biológicos de solo de Cerrado sob diferentes sistemas de uso e manejo. R Bras Ciên Solo. 33(1): 147-157.

EMBRAPA (2011) Manual de Métodos de Análise de Solo. 2° Edição Revista. 225.

Ferreira FG, Machado ELM, Silva-Neto CM, Silva-Junior MC, Medeiros MM, Gonzaga APD, Solorzano A, Venturoli F, Felfili-Fagg JM (2017) Diversity and indicator species in the Cerrado Biome, Brazil. Aust J Crop Sci.11: 1042-1050.

Freiria AC, Montovani JR, Ferreira ME, Cruz CP, Yagi R (2008) Alterações em atributos químicos do solo pela aplicação de calcário na superfície ou incorporado. Ac Scient Agron. 30(2): 285-291.

Gama-Rodrigues AC (2004) Ciclagem de nutrientes em sistemas agroflorestais na região tropical: funcionalidade e sustentabilidade. In: Müller MW, Gama-Rodrigues AC, Brandão ICSFL, Seródio MHCF (Eds). Sistemas agroflorestais, tendência da agricultura ecológica nos trópicos: Sustento da vida e sustento de vida. Ilhéus. SBSAF/CEPLAC/UENF. 64-84.

Johnson RA, Wichern DW (2007) Applied multivariate statistical analysis. 6 ed. Nova Jersey: Prentice-Hall. 800.

Lemos-Junior JEM, Silva-Neto CDM, de Souza KR, Guimarães LE, Oliveira FD, Gonçalves RA, Lima N.L, Venturoli F, Calil FN (2016) Volumetric models for *Eucalyptus grandis* x *urophylla* in a crop-livestock-forest integration (CLFI) system in the Brazilian cerrado. Afr. J. Agric. Res. 11(15): 1336-1343.

Martins T, Araujo F, Siqueira K, Ribeiro A, Silva-Neto C (2016) Cerrado forests: seasonal forest and cerradão. Agrar Acad. 3: 1-14.

Moreira A, Malavolta E (2004) Dinâmica da matéria orgânica e da biomassa microbiana em solo submetido a diferentes sistemas de manejo na Amazônia Ocidental. Pesq Agrop Bras. 39: 1103-1110.

Nunes RS, Sousa DMG, Goedert WJ, Vivaldi LJ (2011) Distribuição de fósforo no solo em razão do sistema de cultivo e manejo da adubação fosfatada. R Bras Ciên Solo. 35: 877-888.

Oliveira Neto SN, Vale AB, Nacif AP, Vilar MB, Assis JB (2010) Sistema Agrossilvipastoril: Integração Lavoura, Pecuária e Floresta. Soc Inv Flors. 190.

Pereira IS, Borges E, Oliveira LH, Freitas ACX, Oliveira TM, Gonçalves BB, Silva-Neto CM, Barbosa PVG, Venturoli F, Calil FN (2016) Fire efect on the seasonal forest structure in the cerrado biome. Floresta . 46: 499.

Rheinheimer DS, Kaminski J, Lupatini GC, Santos JS (2000) Aplicação superficial de calcário no sistema plantio direto consolidado em solo arenoso. Ciên Rur. 30(2): 263-268.

Ribeiro F C (2014) Deposição e decomposição de serapilheira em áreas de integração-lavoura-pecuária-floresta em Planaltina – DF. Dissertação (Mestrado em Ciências Florestais) Brasília:UNB.

Santanta GRS, Santana CER, Silva-Neto CM, Gonçalves BB, Sant'Ana LR, Monteiro MM, Ribeiro ACC, Goncalves RA, Castro SS (2016) Microbiological features of dystroferric and dystrophic red oxisols under sugar cane crops subject to different management procedures. Af J Agric Res. 11: 941-950.

Santos HP, Fontaneli RS, Spera ST, TOMM GO (2009) Efeito de sistemas de produção integração lavoura-pecuária (ILP) sobre a fertilidade do solo em plantio direto. Acta Sci Agron. 31(4): 719-727.

Silva Júnior CA, Boechat CL, Carvalho LA (2012) Atributos químicos do solo sob conversão de floresta amazônica para diferentes sistemas na região do Norte do Pará, Brasil. Biosci. J. 28(4): 566-572.

Souza DMG, Lobato E (2014) Cerrado: correção do solo e adubação. 2 ed. Brasília: Embrapa Cerrados. 416.

Zago LM, Caramori SS, Nabout JC, Silva-Neto CM, Ferreira ME (2018) Biochemical activity in Brazilian Cerrado soils is differentially affected by perennial and annual crops. Aust J Crop Sci. 12 (2): 235-242