

## Chemical and physical attributes of an Ultisol under sustainable agricultural production systems

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**ABSTRACT:** This study aimed to evaluate the effect of four production systems: agrosilvopastoral; pasture; agropastoral and no-tillage, all compared to a native forest area (Cerrado), on the chemical and physical attributes of an Ultisol. Physical and chemical analyzes of the soil were performed, in the layers of 0.00-0.05, 0.05-0.10, 0.10-0.20, 0.20-0.40 and 0.40-1.00 m. Regarding the physical analysis, samples of up to 0.40 m were used. We verified that the soil under the Cerrado biome displayed higher organic matter content, aggregates larger than 2 mm percentage and weighted mean diameter in the layer of 0.05-0.10 m. The pasture system showed higher pH and soil base saturation, and higher Ca and Mg contents in the 0.10-0.20 and 0.40-1.00 m layers. All systems provided an increase in soil organic matter content. The highest contents of P, K, Ca and Mg were observed in the surface layer for all systems. Agropastoral system disaggregated the soil in the 0.05-0.10 m layer. No-tillage resulted in similar soil porosity values along the soil profile. *Urochloa brizantha* cv. Marandu usage as pasture contributed to improving soil chemical and physical fertility.

**Key words:** agropastoral system; agrosilvopastoral system; no-tillage

## Atributos químicos e físicos de um Argissolo sob sistemas sustentáveis de produção agropecuária

**RESUMO:** O presente trabalho foi realizado com o objetivo de avaliar o efeito de quatro sistemas de produção: agrossilvipastoril; pastagem; agropastoril e semeadura direta, comparados a uma área de mata nativa (Cerrado), sobre os atributos químicos e físicos de um Argissolo. Foram realizadas análises químicas e físicas do solo, nas camadas de 0,00-0,05, 0,05-0,10, 0,10-0,20, 0,20-0,40, 0,40-1,00 m. Para análise física foram utilizadas amostras até 0,40 m. Constatou-se que o solo sob Cerrado apresentou maior teor de matéria orgânica, maior porcentagem de agregados maiores que 2 mm e maior diâmetro médio ponderado na camada de 0,05-0,10 m. O sistema pastagem apresentou maior pH e saturação por bases e maiores teores de Ca e Mg nas camadas de 0,10-0,20 e 0,40-1,00 m. Todos os sistemas proporcionaram aumento nos teores de matéria orgânica do solo. Os maiores teores de P, K, Ca e Mg foram observados na camada superficial em todos os sistemas. O sistema agropastoril desagregou o solo na camada de 0,05-0,10 m. O sistema de semeadura direta apresentou valores semelhantes de porosidade ao longo do perfil. A utilização de *Urochloa brizantha* cv. Marandu como pastagem contribuiu para melhoria da fertilidade química e física do solo.

**Palavras-chave:** sistema agropastoril; sistema agrossilvipastoril; sistema de semeadura direta

## Introduction

Intensive use of areas in the Cerrado biome for agricultural production, coupled with improper soil management techniques, has caused degradation of soil structure (Mendonça et al., 2013) and the pastures, limiting the competitiveness and sustainability of beef cattle as well as other agricultural activities (Bonini et al., 2016).

In face of the interest of recovering the productive capacity of pastures, the agroforestry systems, which integrate agriculture, livestock raising and silviculture, appear as a potential alternative, especially for small and medium producers, as they can increase and diversify their income while adding environmental benefits to productive activities (Freitas et al., 2013).

Implementation of agrosilvopastoral systems composes an important sustainable use strategy, mainly in areas potentially subjected to degradation (Santos et al., 2013a). This is because these systems improve the chemical, physical and biological attributes of the soil, given by the intensified soil use, inclusion of species with different root systems, as well as plant residues with different C/N ratios, which contributes to changes in decomposition and nutrient cycling rates (Costa et al., 2015). However, there is little information available on changes in soil chemical and physical attributes under agrosilvopastoral systems in Northwestern São Paulo.

This present study was carried out in order to verify the effect of different sustainable systems of agricultural production on the chemical and physical attributes of an Ultisol in the Northwestern São Paulo.

## Materials and Methods

The experiment was set up in May 2009, in Votuporanga, SP (20°20'S, 49°58'W and 510 m of altitude) in a eutrophic Red-Yellow Ultisol ("Argissolo", according to SiBCS, Santos et al., 2013b).

A completely randomized design with three replications and four production systems was employed: agrosilvopastoral system (ASS); pasture (PAST); agropastoral system (ASP); no-tillage system (NTS) and an area of native forest - Cerrado (CER). Each plot with approximately 1.0 ha.

Prior to the experiment implementation, soil samples were collected for chemical (Raij et al., 2001), physical (Danielson et al., 1986), granulometric (Day, 1965) and structural (Kemper & Chepil, 1965) soil characterization in the layers of 0.00-0.20 and 0.20-0.40 m deep, with Table 1 displaying these results.

Plant science management of all treatments is available in Borges et al. (2017a) and down below:

Treatments with the agrosilvopastoral and pasture systems were implemented in a degraded ten-year pasture area. The area was prepared conventionally by plowing and harrowing. Subsequently, in September 2009, millet (*Pennisetum glaucum*) was sown in total area under pasture and between terraces in the agrosilvopastoral system.

In the agrosilvopastoral system treatment, eucalyptus was planted in October 2009, in a single line system, with 2 m spacing between plants and 13.5 m between rows, totaling 370 plants ha<sup>-1</sup>.

In November 2009, millet was desiccated and, shortly after it, soybean was sown in the pasture system total area and between the agrosilvopastoral system terraces. The soybean harvest was performed in April 2010, and the no-tillage of *Crotalaria juncea* in June 2010.

In December 2010, after the *C. juncea* desiccation, maize and *Urochloa brizantha* cv. Marandu were sown (no-tillage) between the maize rows. Twenty days after *U. brizantha* sowing, nicosulfuron herbicide was applied at 0.1 L ha<sup>-1</sup>, aiming to delay *U. brizantha* development in order to avoid competition with the maize crop.

In the agrosilvopastoral and pasture systems treatment, in September 2011 were introduced recently weaned beef cattle, which remained in continuous grazing in the area for twenty-four months, when they were sent for slaughter. After the slaughtering of the first batch, a new one was introduced under the same conditions as the previous. The employed grazing system is the continuous one and the stocking rate depends on the forage supply.

No-tillage system treatment was implemented in an area meant for grain production, with conventional tillage system. The area was cultivated with peanut in the 2008/09 crop

**Table 1.** Chemical, granulometric, physical and structural characterizations of the soil, in the 0-0.20 and 0.20-0.40 m layers, 2009.

Depth (m)	P (Resin) (mg dm <sup>-3</sup> )	OM (g dm <sup>-3</sup> )	pH (CaCl <sub>2</sub> )	K	Ca	Mg	H+Al	Al	V (%)
				(mmol <sub>c</sub> dm <sup>-3</sup> )					
0-0.20	6	12	4.9	2.8	12	6	20	1	51
0.20-0.40	6	12	4.8	1.8	10	6	21	1	45
		Sand		Silt				Clay	
				(g kg <sup>-1</sup> )					
0-0.20		815		104				81	
0.20-0.40		783		142				75	
	M <sup>(1)</sup>	μ <sup>(2)</sup>	TP <sup>(3)</sup>	SD <sup>(4)</sup>		> 2 mm <sup>(5)</sup>		WMD <sup>(6)</sup>	
		(m <sup>3</sup> m <sup>-3</sup> )		(kg dm <sup>-3</sup> )		(%)		(mm)	
0-0.20	0.03	0.34	0.38	1.59		57.88		2.76	
0.20-0.40	0.03	0.34	0.37	1.58		52.26		2.61	

<sup>(1)</sup>macroporosity; <sup>(2)</sup>microporosity; <sup>(3)</sup> total porosity; <sup>(4)</sup>soil density; <sup>(5)</sup> percentage of aggregates larger than 2 mm; <sup>(6)</sup>weighted mean diameter.

and grain sorghum on the peanut stubble. After sorghum cultivation, all sowing was done under the no-tillage system.

Agropastoral system treatment, alternating between crops and pasture, was implemented in an area that was intended for grain production, under conventional tillage system. Animals in this area, recently weaned beef cattle, are introduced sixty days after maize harvesting and removed thirty days before soybean sowing. The employed grazing system used was continuous one and the stocking rate depended on the forage supply.

Table 2 displays the crops used in each treatment.

Table 3 displays the amount of used nutrients during the study at the different production systems.

In October 2014, new chemical analyzes and fertility determination of the soil were performed. Samples were collected in open trenches at three random points from each plot, collecting three sub-samples per depth in the central portion from each of the following layers: 0.00-0.05, 0.05-0.10, 0.10-0.20, 0.20-0.40 and 0.40-1.00 m. The three sub-samples were then homogenized and formed a composite sample of each depth. Samples were collected by using a hoe, and, subsequently, air-dried. Then, it was determined: pH in  $\text{CaCl}_2$  0.01 mol L<sup>-1</sup> (soil:solution at 1:2.5 ratio), potential acidity ( $\text{H}^+ + \text{Al}^{3+}$ ) and the soil P, K, Ca and Mg contents, extracted by the ion-exchange resin (Raij et al., 2001). Using these results, the base saturation values (V) were calculated by the relation between the exchangeable base content in the soil (Ca, Mg and K) and the cation exchange capacity (CEC), in percentage.

In October 2014, soil samples were also collected using volumetric rings (approximately 0.05 m in diameter and 0.04 m in height) for macroporosity, microporosity, total porosity and soil density analysis (Danielson et al., 1986), and from monoliths for wet-sieving aggregate stability analysis and weighted mean diameter (WMD) calculation (Kemper & Chepil, 1965), in a vertical oscillation device envisioned by Yoder (1936). Samples were collected from open trenches at three random points of each plot, with three sub-samples collected by depth in the central portion from each of the following layers: 0.00-0.05 m, 0.05-0.10 m 0.10-0.20 m and 0.20-0.40 m. After analysis, the three sub-samples composed a mean sample of each depth.

Data were submitted to the F test and the means were compared by the Tukey test ( $p = 0.05$ ) by employing the Assistat computer program (Silva & Azevedo, 2016).

## Results and Discussion

Tables 4 and 5 display the mean squares of the chemical and physical attributes of the soil as well as the significance of the F test at 1 and 5% probabilities.

Tables 6 and 7 display the values of the soil chemical and physical attributes.

Native forest (Cerrado) showed higher organic matter content; higher percentage of aggregates larger than 2 mm and higher WMD than the production systems in the 0.05-

**Table 2.** Crops used in the different production systems from October (Nov) 2009 to April (Apr) 2015.

Production system	2009/10		2010/11		2011/12	
	Nov/Apr	May/Oct	Nov/Apr	May/Oct	Nov/Apr	May/Oct
ASS <sup>(1)</sup>	Millet/Soybean	<i>C. juncea</i>	Maize + <i>U. brizantha</i>	<i>U. brizantha</i>	<i>U. brizantha</i>	<i>U. brizantha</i>
PAST <sup>(2)</sup>	Millet/Soybean	<i>C. juncea</i>	Maize + <i>U. brizantha</i>	<i>U. brizantha</i>	<i>U. brizantha</i>	<i>U. brizantha</i>
APS <sup>(3)</sup>	-	-	Peanut	Fallow	Maize + <i>U. brizantha</i>	<i>U. brizantha</i>
NTS <sup>(4)</sup>	Soybean	<i>C. juncea</i>	Maize	<i>C. juncea</i>	Soybean	Forage sorghum
2012/13		2013/14		2014/15		
ASS	<i>U. brizantha</i>	<i>U. brizantha</i>	<i>U. brizantha</i>	<i>U. brizantha</i>	<i>U. brizantha</i>	-
PAST	<i>U. brizantha</i>	<i>U. brizantha</i>	<i>U. brizantha</i>	<i>U. brizantha</i>	<i>U. brizantha</i>	-
APS	<i>U. brizantha</i>	<i>U. brizantha</i>	Soybean	<i>C. juncea</i>	Maize + <i>U. brizantha</i>	-
NTS	Soybean	Grain sorghum	Soybean	<i>C. juncea</i>	Maize	-

<sup>(1)</sup>ASS: Agrosilvopastoral system; <sup>(2)</sup>PAST: pasture; <sup>(3)</sup>APS: Agropastoral system; <sup>(4)</sup>NTS: No-tillage system; May: May; Oct: October.

**Table 3.** Amount of used nutrients at the different production systems from the 2009/10 to the 2014/15 crops.

Production system <sup>(1)</sup>	2009/10			2010/11			2011/12		
	N	P	K	N	P	K	N	P	K
kg ha <sup>-1</sup>									
ASS	15.0	124.0	60.0	116.4	91.0	86.4	45.0		
PAST	12.0	60.0	60.0	116.4	91.0	86.4	45.0		
NTS	12.0	60.0	60.0	112.2	67.2	86.4	20.0	88.0	76.0
APS	-	-	-	10.0	35.0	20.0	112.0	100.0	48.0
2012/13		2013/14		2014/15					
kg ha <sup>-1</sup>									
N P K N P K									
ASS	33.0			100.0					
PAST	33.0			100.0					
NTS	12.0	60.0	60.0	14.0	70.0	70.0			
APS	-	-	-	14.0	70.0	70.00			

<sup>(1)</sup>ASS: Agrosilvopastoral system; <sup>(2)</sup>PAST: pasture; <sup>(3)</sup>NTS: No-tillage system; <sup>(4)</sup>APS: Agropastoral system.

**Table 4.** Summary of the analysis of variance of the chemical attributes of the soil, Votuporanga, SP, 2014.

V.S.	D.F.	Mean square								
		P	OM	pH	K	Ca	Mg	H+Al	Al	V
0-0.05 m										
T	4	413.27**	12.71 <sup>ns</sup>	0.09 <sup>ns</sup>	1.97 <sup>ns</sup>	90.35 <sup>ns</sup>	75.74 <sup>ns</sup>	39.39 <sup>ns</sup>	2.29**	247.68 <sup>ns</sup>
R	10	19.33	4.77	0.12	1.02	55.84	38.48	31.76	0.01	225.52
CV		33.53	7.90	6.22	35.05	43.37	40.08	31.44	18.22	23.99
0.05-0.10 m										
T	4	253.92*	24.84*	0.09 <sup>ns</sup>	3.46*	12.03 <sup>ns</sup>	37.72**	18.03 <sup>ns</sup>	4.50**	296.43 <sup>ns</sup>
R	10	49.17	4.18	0.13	0.91	8.42	4.94	50.71	0.01	241.11
CV		79.75	8.88	7.14	41.84	40.12	30.86	28.54	13.81	37.60
0.10-0.20 m										
T	4	36.31**	3.94 <sup>ns</sup>	0.33**	0.47 <sup>ns</sup>	25.53*	5.76*	119.64**	3.69**	367.03**
R	10	5.34	6.46	0.02	0.49	5.62	1.13	19.28	0.004	54.53
CV		55.40	12.20	3.09	42.64	40.71	26.74	15.52	7.46	25.12
0.20-0.40 m										
T	4	10.88 <sup>ns</sup>	7.11*	0.36*	1.16 <sup>ns</sup>	23.98*	2.41 <sup>ns</sup>	114.87 <sup>ns</sup>	0.46**	298.05 <sup>ns</sup>
R	10	3.51	1.55	0.08	0.38	4.58	1.75	68.97	0.01	100.69
CV		78.16	6.62	5.60	49.10	36.24	32.15	32.01	20.28	32.11
0.40-1.00 m										
T	4	3.30 <sup>ns</sup>	4.70 <sup>ns</sup>	0.35**	0.24 <sup>ns</sup>	12.21**	2.30**	18.26*	0.76**	228.44**
R	10	2.62	3.62	0.03	0.26	0.64	0.22	4.35	0.01	18.63
CV		90.98	10.72	3.12	46.77	14.77	11.56	10.79	27.58	12.28

VS - Variation sources; T - Treatments; R - Residual; CV - Coefficient of variation (%); D.F. - Degrees of freedom; OM - Organic matter; H+Al - Potential acidity; V - Base saturation; ns - non-significant; \* - significant at 5% by the F test; \*\* - significant at 1% by the F test.

**Table 5.** Summary of the analysis of variance of the soil physical attributes, Votuporanga, SP, 2014.

V.S.	D.F.	Mean square					
		M	μ	TP	SD	> 2 mm	WMD
0-0.05 m							
T	4	0.001*	0.003*	0.002*	0.03**	229.01*	0.62*
R	10	0.0002	0.0005	0.0006	0.004	46.16	0.12
CV		36.60	6.25	6.32	4.10	8.22	8.72
0.05-0.10 m							
T	4	0.0002 <sup>ns</sup>	0.006*	0.005**	0.01*	795.82**	1.91**
R	10	0.0003	0.001	0.0006	0.003	10.94	0.04
CV		46.22	9.19	6.52	3.58	4.63	5.51
0.10-0.20 m							
T	4	0.001 <sup>ns</sup>	0.002 <sup>ns</sup>	0.002**	0.01*	1877.32**	3.65**
R	10	0.001	0.001	0.0002	0.001	176.82	0.44
CV		53.65	10.54	3.96	2.67	23.80	23.96
0.20-0.40 m							
T	4	0.001*	0.003**	0.002*	0.01	1679.15**	3.37*
R	10	0.0002	0.0004	0.0003	0.004	215.32	0.57
CV		34.63	6.42	5.18	3.91	33.67	33.74

VS - Variation sources; T - Treatments; R - Residual; CV - Coefficient of variation (%); D.F. - Degrees of freedom; M - macroporosity; μ - microporosity; TP - total porosity; SD - soil density; > 2 mm - diameter of aggregates larger than 2 mm; WMD - weighted mean diameter; ns - non-significant; \* - significant at 5% by the F test; \*\* - significant at 1% by the F test.

0.10 m layer; higher microporosity and lower soil density than the agropastoral and no-tillage systems in the superficial layer (0-0.05 m); higher percentage of aggregates larger than 2 mm and higher WMD than the agropastoral and no-tillage systems in the 0.10-0.20 m layer; higher microporosity than pasture, agropastoral and no-tillage systems, and higher percentage of aggregates larger than 2 mm than the agropastoral and no-tillage systems in the 0.20-0.40 m layer. These results corroborate with Diel et al. (2014), who also observed higher organic matter content in the area under native forest; also with Silva et al. (2013), who found higher WMD in the area under forest; and with Silva et al. (2015), who found lower

soil density values in forested soils used as a reference, also emphasizing that anthropic use increases soil compaction.

Although Cunha Neto et al. (2013) observed higher nutrient stock in the litter of eucalyptus stands among four forest formations, and Freitas et al. (2013) found that agrosilvopastoral systems deposit more nutrients in the soil (except for P) through litter than a pasture system with *Urochloa* in monoculture, the agrosilvopastoral system in this study did not differ from the pasture regarding organic matter, K and Ca, in relation to potential acidity and base saturation, and it also showed the highest Al contents throughout the soil profile.

**Table 6.** Chemical attributes of the soil at different layers, Votuporanga, SP, 2014.

Treatments	P		OM		pH	K Ca Mg H+Al Al V							
	(mg dm <sup>-3</sup> )		(g dm <sup>-3</sup> )			(mmolc dm <sup>-3</sup> )						(%)	
0-0.05 m													
ASS <sup>(*)</sup>	7.21	b	24.89		5.50	2.50	24.62	20.16	19.78	2.06	a	60.70	
PAST	2.08	b	26.50		5.82	2.08	17.37	18.01	11.58	0.10	b	76.10	
APS	22.82	a	29.29		5.47	2.46	12.07	15.36	19.83	0.10	b	59.25	
NTS	28.43	a	27.54		5.78	4.11	20.31	16.79	18.25	0.10	b	65.55	
Cerrado	5.02	b	29.94		5.50	3.27	11.77	7.06	20.17	0.10	b	51.45	
0.05-0.10 m													
ASS	3.12	b	21.38	b	4.81	1.27	7.32	12.06	25.21	2.84	a	40.57	
PAST	2.90	b	21.81	b	5.27	1.55	8.54	8.64	21.17	0.10	b	57.76	
APS	10.77	ab	21.42	b	5.06	4.02	4.71	2.67	24.53	0.10	b	31.53	
NTS	24.12	a	22.40	b	5.02	2.21	5.89	5.20	26.02	0.10	b	36.02	
Cerrado	3.05	b	28.12	a	5.15	2.36	9.71	7.43	27.85	0.10	b	40.60	
0.10-0.20 m													
ASS	2.48	b	20.02		4.59	1.11	5.85	3.44	28.54	2.76	a	27.17	abc
PAST	1.27	b	19.86		5.16	1.76	9.42	6.32	21.91	0.10	d	43.74	a
APS	10.01	a	20.12		5.19	1.67	7.95	3.70	22.36	0.10	d	37.59	ab
NTS	4.63	ab	21.88		4.47	2.19	2.94	2.65	36.64	0.83	b	17.63	c
Cerrado	2.47	b	22.27		4.72	1.46	2.94	3.77	32.03	0.45	c	20.84	bc
0.20-0.40 m													
ASS	1.65		17.55	ab	4.93	0.71	7.73	5.02	22.82	0.91	a	37.03	
PAST	0.66		18.88	ab	5.33	1.24	8.83	4.97	24.37	0.10	b	40.11	
APS	5.59		17.06	b	5.20	0.84	6.77	3.87	19.10	0.10	b	37.55	
NTS	2.52		19.66	ab	4.56	2.29	4.42	3.80	35.42	0.70	a	24.42	
Cerrado	1.56		20.84	a	4.60	1.16	1.77	2.89	28.00	0.10	b	17.14	
0.40-1.00 m													
ASS	1.44		16.47		5.12	0.99	6.89	3.64	18.36	1.22	a	38.26	ab
PAST	0.44		17.58		5.67	1.07	7.56	5.51	16.40	0.01	b	46.48	a
APS	2.94		17.45		5.23	1.26	5.20	3.61	18.17	0.01	b	35.42	ab
NTS	2.75		17.34		4.98	1.47	5.10	4.10	21.58	0.01	b	33.13	bc
Cerrado	1.34		19.84		4.75	0.72	2.35	3.28	22.22	0.01	b	22.40	c

(\*) ASS: Agrosilvopastoral system; PAST: pasture; NTS: No-tillage system; APS: Agropastoral system. Means followed by the same letter does not differentiate from each other by the Tukey test at 5%.

Pasture showed higher pH, base saturation, and higher Ca and Mg contents in the 0.10-0.20 and 0.40-1.00 m layers, among all treatments, and lower potential acidity in the 0-0.20 and 0.40-1.00 m layers, corroborating with Machado et al. (2017), who also found lower potential acidity content under pasture.

The agropastoral system had the lowest percentage of aggregates larger than 2 mm and the lowest WMD in the 0.05-0.10 m layer; lower total porosity compared to the agrosilvopastoral system in the 0-0.05 m and 0.10-0.40 m layers; higher soil density in the 0.10-0.20 m layer and lower percentage of aggregates larger than 2 mm and lower WMD in the 0.05-0.40 m layer compared to the native forest. These alterations were caused by animal trampling and machine traffic, which may alter the physical soil attributes, causing compaction and impairing the development of crops in succession (Costa et al., 2015).

The no-tillage system showed similar porosity values along the soil profile, due to the biopores created by the root systems of the different crops used in the rotation system, mainly soybean and maize, because according to Mendonça et al. (2013), successions of maize and soybeans

results in improvement of the soil physical attributes. The crop rotation system is indicated in the Cerrado region, no-till, in order to improve soil physical attributes.

All systems increased soil organic matter contents, corroborating with Bonini et al. (2016) and Borges et al. (2017b), who found an increase in organic matter content in agrosilvopastoral and agropastoral systems.

Ca, Mg and K contents and base saturation (V) were averagely higher in the surface layer, as a consequence of the surface liming performed in all production systems (Ca, Mg and V), and by the K-based fertilization on the soil surface at the sowing time.

On average, there was a tendency for lower P contents the greater the depth in all systems was, corroborating with Diel et al. (2014), who also observed higher remaining P content in the soil superficial layers.

In the superficial layer (0-0.05 m), no-tillage and agropastoral systems showed higher P content, due to the fertilization performed with this nutrient over the years in these systems. On the other hand, the pasture and agrosilvopastoral systems showed lower P content due to the fertilization performed only at the beginning of the experiment.

**Table 7.** Macroporosity (M), microporosity ( $\mu$ ), total porosity (TP), soil density (SD), diameter of aggregates larger than 2 mm (> 2) and weighted mean diameter (WMD), at different layers, Votuporanga, SP, 2014.

Treatments	M		$\mu$ ( $m^3 m^{-3}$ )		TP		BD ( $kg dm^{-3}$ )		> 2 mm (%)		WMD (mm)	
	0-0.05 m											
ASS(*)	0.06	a	0.35	ab	0.42	a	1.55	ab	70.34	b	3.39	b
PAST	0.04	ab	0.33	ab	0.37	ab	1.55	ab	80.77	ab	3.77	ab
APS	0.04	ab	0.31	b	0.35	b	1.63	a	89.84	a	4.38	a
NTS	0.04	ab	0.32	b	0.37	ab	1.59	a	80.12	ab	3.97	ab
Cerrado	0.02	b	0.38	a	0.41	ab	1.39	b	92.25	a	4.51	a
0.05-0.10 m												
ASS-1277	0.05		0.34	ab	0.39	ab	1.60	a	69.09	c	3.34	c
PAST	0.04		0.33	b	0.36	b	1.61	a	80.00	b	3.92	b
APS	0.04		0.31	b	0.34	b	1.59	ab	47.78	d	2.35	d
NTS	0.04		0.33	b	0.37	b	1.56	ab	68.16	c	3.40	c
Cerrado	0.03		0.42	a	0.45	a	1.45	b	91.73	a	4.50	a
0.10-0.20 m												
ASS-1277	0.05		0.34		0.39	a	1.59	ab	69.54	a	3.38	ab
PAST	0.07		0.30		0.37	ab	1.62	ab	69.62	a	3.42	ab
APS	0.04		0.29		0.32	c	1.69	a	26.07	b	1.44	c
NTS	0.03		0.32		0.35	bc	1.66	ab	32.20	b	1.72	bc
Cerrado	0.03		0.35		0.38	ab	1.54	b	81.93	a	3.86	a
0.20-0.40 m												
ASS-1277	0.05	a	0.34	ab	0.39	a	1.59		45.31	abc	2.30	ab
PAST	0.04	ab	0.30	b	0.34	ab	1.64		60.24	ab	3.03	a
APS	0.05	ab	0.29	b	0.33	b	1.68		11.84	c	0.84	b
NTS	0.04	ab	0.30	b	0.34	ab	1.66		29.49	bc	1.57	ab
Cerrado	0.01	b	0.37	a	0.38	ab	1.57		71.01	a	3.45	a

(\*)ASS: Agrosilvopastoral system; PAST: pasture; NTS: No-tillage system; APS: Agropastoral system. Means followed by the same letter does not differentiate from each other by the Tukey test at 5%.

In the 0.10-0.20 m layer, the lowest Ca and Mg contents in the no-tillage system are related to the *Urochloa* absence in this system.

In the 0-0.05 and 0.10-0.40 m layers, the agrosilvopastoral and pasture systems did not differ from the native forest in relation to total porosity and soil density. This is due the accumulation of plant residues on its soil surface and the organic matter input originated by the *Urochloa* root system, present in these systems, with the increase in organic matter content promoting a decrease in soil density (Dalchiavon et al., 2013).

In the 0.10-0.40 m layer, the agrosilvopastoral and pasture systems also did not differ from the native forest in relation to the percentage of aggregates larger than 2 mm and WMD, although in soils with low clay content, as in this study, stable aggregate formation is jeopardized by the presence of sand-sized minerals (Santos et al., 2013a).

It is noteworthy that the four sustainable systems of agricultural production (agrosilvopastoral, pasture, agropastoral and no-tillage), except for the area under native forest (Cerrado), received conventional tillage system and evaluations were carried out five years after the beginning of the experiment. As emphasized by Cruz et al. (2003), it takes a minimum time of five years for stabilization of the changes caused by non-revolving soil for chemical attributes, and a similar or longer time for improvement in physical attributes, depending on the textural class. When checking the effects on soil and crops after twenty years of conventional tillage and

no-tillage, Brown et al. (2018) found that the conventional tillage is detrimental from the structural quality aspect, since the WMD and the clay flocculation degree were lower and the soil density was higher in this management system. The authors also mention that the conventional tillage provides disaggregation of the soil and fractionation of the aggregate into smaller units by the periodic mechanical soil tillage.

It is emphasized that liming, sowing, and topdressing fertilizations were performed in the four systems, which may have contributed to the higher nutrient content in the surface layer.

## Conclusions

The soil under Cerrado showed higher soil organic matter content, higher percentage of aggregates larger than 2 mm and larger weighted mean diameter in the 0.05-0.10 m layer than the production systems.

Pasture system showed higher pH and base saturation and higher Ca and Mg contents in the 0.10-0.20 and 0.40-1.00 m layers.

All systems provided increase in the soil organic matter content, in the 0.00-0.20 and 0.20-0.40 m layers, in relation to the initial levels.

The highest contents of P, K, Ca and Mg were observed in the superficial layer for all systems.

No-tillage system showed similar porosity values along the profile.

*Urochloa brizantha* cv. Marandu usage as pasture contributed to the improvement of soil chemical and physical fertility.

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