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Chemical and physical changes in an Argisol under agrosilvopastoral system in Votuporanga, São Paulo State, Brazil

Alterações químicas e físicas em um argissolo sob sistema agrossilvipastoril em Votuporanga, SP, Brasil

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Abstract

Conservation management systems that have intended to prevent wear or soil degradation have been widespread in agriculture. The study was conducted in Site São Luiz at Simonsen district, Votuporanga, São Paulo State, in order to evaluate the chemical and physical changes in an area with agrosilvopastoral system and deployed with three soil management (treatments): Full (conventional tillage, liming and application of gypsum, phosphate and potassium); intermediate (no tillage, liming and application of gypsum at surface) and basic (no tillage and surface liming). The soil was managed in July 2009 and the planting of eucalyptus was realized in January 2010, on the terraces. Between the terraces it was cropped maize intercropped with *Urochloa brizantha* cv. Marandu. In April 2014 it was held the disturbed and undisturbed soil sampling soil at depths of 0-0.05 and 0.05-0.20 m, collecting three sub samples per plot. A randomized complete block experimental design was used with three replications, with plots of approximately 1.0 ha. It was concluded that in the layer of 0-0.05m, the intermediate management provided increase in the levels of organic matter, Ca, P and K and the basic management provided lower levels of Ca and lower pH and basis saturation values and higher potential acidity; the complete and intermediate managements provided raising the pH in the two layers evaluated; the use of liming associated with gypsum application improves the chemical characteristics of Argisols under agrosilvopastoral systems; in the layer of 0.05-0.20 m the basic management provided lower bulk density and the complete management the largest; the different managements did not differ with respect to porosity and aggregate stability.

Keywords: *Corymbia citriodora*, *Eucalyptus urograndis*, integrated systems, soil management, *Urochloa brizantha*

Resumo

Sistemas de manejo conservacionistas que têm o intuito de evitar o desgaste ou a degradação do solo vêm sendo difundidos na agricultura. O trabalho foi desenvolvido no sítio São Luiz, no distrito de Simonsen, município de Votuporanga, SP, com o objetivo de avaliar as alterações químicas e físicas em uma área com sistema agrossilvipastoril e implantada com três manejos de solo (tratamentos): completo (preparo convencional do solo, calagem, gessagem, fosfatagem, potassagem); intermediário (sem preparo, calagem e gessagem superficial) e básico (sem preparo e calagem superficial). O solo foi manejado em julho de 2009 e em janeiro de 2010, foi realizado o plantio de eucalipto sobre os terraços e milho em consórcio com *Urochloa brizantha* cv. Marandu, entre os terraços. Em abril de 2014 foram realizadas as amostragens deformada e indeformada do solo nas profundidades de 0-0.05 e 0.05-0.20 m, coletando-se três sub amostras por parcela. O delineamento experimental utilizado foi o de blocos casualizados com três repetições, com parcelas de aproximadamente 1.0 ha. Constatou-se que na camada de 0-0,05 m, o manejo intermediário proporcionou aumento nos teores de matéria orgânica, Ca, P e K e o manejo básico propiciou menores teores de Ca e menores valores de pH e saturação por bases e maiores valores de acidez

potencial; os manejos completo e intermediário proporcionaram elevação do pH nas duas camadas avaliadas; a utilização da calagem associada à gessagem melhora as características químicas de Argissolos sob sistemas agrossilvipastoris; na camada de 0,05-0,20 m o manejo básico proporcionou menores valores de densidade do solo e o completo maiores; os diferentes manejos não diferiram em relação à porosidade e à estabilidade de agregados.

Palavras-chave: *Corymbia citriodora*, *Eucalyptus urograndis*, manejo do solo, sistemas integrados, *Urochloa brizantha.*

Introduction

Conservation management systems, intending to prevent soil wear or degradation, have been widespread in agriculture.

Thus, the integrated crop-lifestock (ICL) has become an advantageous option and benefited two activities of economic importance, providing mutual benefits to the producer (Mateus *et al.* 2011). In order to promote technological innovation of agricultural activities, this system has been studied in several regions of the world (Allen *et al.* 2007; Tracy & Zhang, 2008; Balbinot Júnior *et al.* 2009; (de Faccio Carvalho *et al.*, 2010)

The adoption of ICL, contributes to facilitate the NTS with the straw produced by well managed tropical pasture. Moreover, the pasture provides a better structured soil to the crop, due to the extensive root system and the organic material residue left on the surface and subsurface soils (Loss *et al.* 2011; Silva *et al.* 2011).

The production systems with ICL managed under NTS have shown increased profitability per area, increased diversification of activities, less economic risk and lower production costs (Balbinot Júnior *et al.* 2009; Macedo, 2009). However, to be feasible, it is necessary to identified at regional scale, production systems with medium and long term, integrating the production of grain with perennial pastures that dominate the site (Santos *et al.* 2011).

The traffic of agricultural machines induce compaction, while the animal trampling may compromise the physic quality of the superficial layer of soil, which may present an increase in the density and a reduction in porosity (Giarola *et al.* 2007).

The study of soil properties through time allows the quantification, the magnitude and the duration of changes caused by different management systems (Silveira *et al.* 2011).

The aim of this research was to evaluate the chemical and physical alterations in an Argisol under three soil managements and cultivated under agrosilvopasture system, in the municipality of Votuporanga, SP, Brazil.

Material and methods

The research was performed with an Red Yellow Argisol (100 g kg^{-1} clay on the horizon A), in the Farm São Luiz, located in the district of Simonsen, Votuporanga, SP, Brazil, with geographic coordination of: latitude 20°26'78" S, longitude 49°52'58" W and mean altitude of 488 m, in an area of 10 ha on degraded pasture, which was part of the "Projeto de Produção Integrada de Sistemas Agropecuários em Microbacias Hidrográficas no Subtrópico Brasileiro e no Cerrado Sul Matogrossense - MAPA" (Project of Integrated Agricultural and Livestock Production Systems in the Brazilian subtropics and Cerrado vegetation from Mato Grosso do Sul State, Brazil).

Soil sampling was performed to evaluate the soil fertility in the layer 0-0.20 m in march 2009 and the analysis presented the following mean values: Organic matter: 17.0 g kg^{-1}; pH ($CaCl_2$): 4.5; P (resin): 5 mg dm^{-3}; K: 1.9 mmolc dm^{-3}; Ca: 9 mmolc dm^{-3}; Mg: 4 mmolc dm^{-3}; V: 37 %.

A penetrometry was performed in the area, till 0.60 m, in 2009, sampling ten random points of the area, and a resistance to soil penetration superior to 2.0 MPa in the layer 0.16-0.20 m was registered (Figure 1).

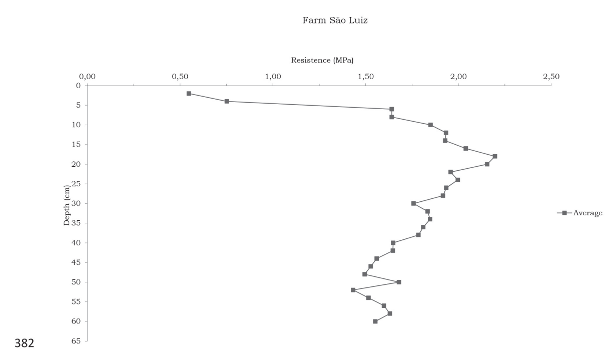

Figure 1. Soil penetration resistance in the layer of 0-0.60 m, Votuporanga, SP, Brazil, 2009.

The randomized block with three replications was used as experimental design, with parcels of approximately 1.0 ha, using three different soil management (treatments):

- Complete: conventional soil preparation, by means of plowing, harrowing and subsoiling; application of 3000 kg ha^{-1} limestone, with 34 %

of Ca and 9 % of Mg with surface with subsequent incorporation; application of 1200 kg ha^{-1} of natural reactive phosphate with subsequent incorporation; application of 1000 kg ha^{-1} of agriculture plaster in the surface; application of 100 kg ha^{-1} of potassium chloride in the surface;

- Intermediary: without soil preparation; desiccation of the original grassland with 6 L ha^{-1} of glyphosate (commercial product); application of 1000 kg ha^{-1} of limestone, in surface, with 34 % of Ca and 9 % of Mg and 1000 kg ha^{-1} of plaster;

- Basic: without soil preparation; desiccation of the original pasture with 6 L ha^{-1} of glyphosate (commercial product); application of 1000 kg ha^{-1} of limestone, in surface, with 34 % of Ca and 9 % of Mg.

The soil management was performed in July 2009, with the support of the Agricultural Patrol of Votuporanga.

Eucalyptus plantation was conducted on 01/08/2010, on the terraces with a population of 287 plants ha^{-1}, with a spacing of 2.5 m between plants. Two species were used: *C. citriodora* and *E. urograndis*, planting, alternately, a line of each species on each terrain.

On 01/19/2010, the corn culture was seeded among terrains, with a space of 0.8 m between rows. On the following day, a line of *U. brizantha* cv. Marandu was seeded, in the corn interline, using 10 kg ha^{-1} of seeds with 10 % weight of triple superphosphate, to facilitate the distribution in the planting furrows.

The amount of nutrients used in the several managements, at the seeding moment and in the first and second corn covers, are demonstrated in Table 1. The fertilizing used in the basic management was based on the standard seeding fertilization used for most of the regional producers.

Table 1. Amounts of nutrients used at the moment of seeding and corn coverage in different management systems (kg. ha^{-1}).

Management	N	P	K	Ca	S	Mg	B	Cu	Mn	Zn
					Corn seeding					
Complete and intermediary	27.0	85.5	45.0	28.4	29.7	9.9	0.5	0.5	0.7	1.4
Basic	28.0	98.0	56.0	-	-	-	-	-	-	1.1
					First coverage (3 - 4 leaves)					
Complete	69.0	17.3	69.0	-	15.5	-	0.3	0.2	-	1.0
Intermediary and basic	64.5	-	43.0	-	-	-	-	-	-	-
					Second coverage (5 - 6 leaves)					
Complete, intermediary and basic	42.0	-	-	-	46.0	-	-	-	-	-

After the corn harvest, the area remained in fallow, and, in January 2011, the beef cattle breed started, and the animals remained in continuous grazing system till slaughter. The animal stocking rate varies according to the availability of forage. In the pasture, no fertilization and application of corrective surface was performed.

In April 2014, a deforming soil sampling was performed, in order to evaluate the fertility in depths of 0-0.05 and 0.05-0.20 m, collecting three sub samples per parcel. Those three sub-samples (single samples) were homogenized in a composed sample. The samples were chemically analyzed for the determination of pH, exchangeable bases, aluminum, extractable hydrogen and assimilable phosphorus.

The undeformed soil sampling was also performed, in April 2014, in three points per parcel, in depths of 0-0.05 and 0.05-0.20 m, using rings of approximately 100 cm^3. The soil density (SD) was determined in the laboratory of soil physics of the “Centro Avançado de Pesquisa Tecnológica do Agronegócio de Seringueira e Sistemas Agroflorestais (IAC)” (Advanced Technological Research Center of Agricultural business of Rubber tree and Agroforestry), by the volumetric method of total porosity (TP), the percentage of soil water saturation the microporosity and macroporosity soil and the “tension table”.

To determinate the water stability of aggregates, three sub-samples (single samples) per parcel were collected, in layers of 0-0.05 and 0.05-0.20 m, and homogenized in a compost sample. The sampling was done with a mattock, without destroying the clods, which were placed in plastic bags and subsequently air dried.

For the determination of distribution of aggregate classes, the wet sieving was calibrated to run for 10 min with 30 oscillations per minute.

For the separation of the aggregate classes, the following classes were determined: > 4.0 mm; among 4.0-2.0 mm; among 1.0-0.50 mm; among 0.50-0.25 mm; < 0.125 mm. After the separation of the aggregated classes, the mean weighted diameter (MWD) was calculated, in mm.

Data were submitted to the tests F and Tuckey ($P < 0.05$), for comparison of the averages, using the software Assistat ™.

Results and discussion

Regarding the organic matter (OM), the intermediate soil management provided higher contents in the layers 0-0.05 m depth (Table 2). According to Potes *et al.* (2010), the increasing in soil organic matter (SOM) in not revolved soils, is caused by the decrease of microbial OM decomposition rate in soil by lowering the temperature and aeration, increasing soil coverage and no fractionation and incorporation of plant residues.

Table 2. Chemical attributes evaluated in soil layers of 0-0.05 and 0.05-0.20 m, Votuporanga, SP, Brazil, 2014.

Management	P (Resine)	OM(1)	pH ($CaCl_2$)	K	Ca	Mg	H+Al	V(2)
	mg. dm-3	g. dm-3		-------------mmol$_c$ dm-3-------------				(%)
				Layer of 0-0.05 m				
Complete	4.19	16.18 b	5.32 a	1.14	15.25 ab	6.39 a	16.18 b	58.51 a
Intermediary	6.52	19.59 a	5.49 a	2.38	18.30 a	6.95 a	14.99 b	64.53 a
Basic	4.07	15.30 b	4.40 b	2.00	9.91 b	2.78 b	23.91 a	38.45 b
CV(3) (%)	40.26	5.88	0.04	32.10	16.12	4.72	13.05	8.26
				Layer of 0.05-0.20 m				
Complete	11.77	13.79 a	5.49 a	1.16	17.92	4.26	14,63 b	61,60 a
Intermediary	22.10	14.75 a	4.83 ab	2.89	12.20	4.54	24,39 a	42,57 ab
Basic	10.24	11.53 b	4.27 b	1.27	9.15	2.87	26,78 a	33,30 b
CV (%)	122.77	4.70	5.47	85.41	27.78	35.23	13.46	18.06

Means followed by the same letter in the column do not differ accordingly to Tuckey test (P < 0.05).

(1)organic matter; (2)base saturation; (3)coefficient of variation.

Regarding the initial values, the complete and intermediary management provided increases in the pH values, in both layers (Table 2). On the other hand, Santos *et al.* (2009), noticed a reduction in pH values in treatments with ICL and mentioned that soil acidification was due to the long period in which the area was free of liming, which was not observed in this study, in the basic management.

The basic management provided low values of pH, higher acid potential and lower base saturation, in both evaluated layers, differing from the complete management, and also providing the lower levels of Ca in the superficial layer (0-0.05 m), differing from the intermediate treatment (Table 2). These results pointed out to the importance of the use of liming, associated to the plastering in Argisols, such as those from the study region, including agroforestry systems.

In the surface layer, the intermediate management provided increasing in the values of OM and pH and in the levels of Ca, P and K, comparing to the initial levels (Table 2), corroborating with Santos *et al.* (2011), who cite the levels of Ca, MO, P and K of soil are positively affected by the production systems with ICL. According to Bayer *et al.* (2006), the adoption of conservationist practices based on the minimal revolving, in the correct management of residues and in the inclusion of perennial grasses in crop rotation, may prevent the degradation of OM, and even increase the level of SOM (Volpe *et al.* 2008).

There was no difference related to the levels of P and K among the managements, in both evaluated layers, and that the NTS and minimal cultivation system tend to equalize over the years.

Although the managements did not provide differences among themselves (P < 0.05) regarding the levels of P, the intermediated management, that presented the higher levels of OM, provided level of P 55 % superior to the others, in layers of 0-0.05 m, and of 87 % superior, in level of 0.05-0.20 m. According to Brady and Weil (2002), cited by Rocha *et al.* (2015), this is due to the fact that some fractions of OM, especially fulvic acids, occupy the P absorption sites in the soil, increasing its availability. This statement was corroborated by Rocha *et al.* (2015), which observed a higher availability of P in the areas presenting higher levels of C_{org} in the soil.

The several adopted managements did not differ (P < 0,05) considering the TP of the soil (Table 3), corroborating studies conducted by Silveira *et al.* (2011), and all TP values were below 0.50 $m^3\ m^{-3}$, and only the intermediary soil management, in the layer of 0.05-0.20 m, provided values of top microporosity of 0.33 $m^3\ m^{-3}$.

Table 3. Physic soil attributes evaluated in the layers 0-0.05 and 0.05-0.20 m, Votuporanga, SP, Brazil, 2014.

Management	Macroporosity	Microporosity	Total porosity	Soil density
	---------------- m3 m-3 ----------------			k. dm-3
		Layer of 0-0.05 m		
Complete	0.0361	0.2762	0.3123	1.61
Intermediary	0.0538	0.2713	0.3251	1.54
Basic	0.0552	0.2862	0.3414	1.57
CV (%)	22.30	6.64	8.44	4.42
		Layer of 0.05-0.20 m		
Complete	0.0575	0.2930	0.3505	1.62 a
Intermediary	0.0375	0.3323	0.3697	1.58 ab
Basic	0.0448	0.3264	0.3712	1.52 b
CV (%)	22.48	3.20	5.01	2.01

Means followed by the same letter in the column do not differ accordingly to Tuckey test (P < 0.05).

In the superficial layer (0-0.05 m), there was no difference (P < 0,05) among the management adopted in relation to the SD (Table 3), in accordance to Spera *et al.* (2009). On the other hand, in the layer of 0.05-0.20 m, the basic soil management provided a lower SD and differed from the complete management, who performed the higher SD (Table 3), despite the initial soil tillage.

These results differed from those found from Silveira Neto *et al.* (2006), and Silveira *et al.* (2008), who verified that the continuous DP provided higher SD and lower values of macroporosity and TP in the layers of 0-0.3 m. According to Reeves (1995); Stone & Silveira (2001) cited by Silveira *et al.* (2008), the SD under TS may decrease with time, due, in part, to the increase in the OM level in the superficial layer, once it favors a bigger aggregation of soil, improving the structure quality and then, increasing the porosity value and decreasing the SD value.

There was no significant effect of different soil management on all soil aggregates classes and on their AWD (Table 4).

Table 4. Distribution of size of stable aggregates in water, in the layers of 0-0.05 and 0.05-0.20 m, Votuporanga, SP, Brazil, 2014.

Management	4	2	1	0.5	0.25	<0.25	MWD[1]
	---------			%		---------	mm
				Layer of 0-0.05 m			
Complete	66.60	10.88	2.11	1.24	1.83	17.32	3.73
Intermediary	83.05	7.66	0.76	0.46	0.63	7.46	4.41
Basic	60.54	12.72	3.55	2.12	3.31	17.76	3.51
CV (%)	30.09	56.18	104.62	91.48	109.70	74.02	21.28
				Layer of 0.05-0.20 m			
Complete	80.86	5.73	0.80	0.64	1.60	10.37	4.25
Intermediary	48.53	9.82	2.15	1.66	4.27	33.58	2.82
Basic	68.53	10.40	2.70	1.94	2.38	14.04	3.82
CV (%)	19.90	33.43	51.35	59.54	58.61	63.05	16.69

Means followed by the same letter in the column do not differ accordingly to Tuckey test (P < 0.05).

[1] mean weighted diameter.

Silveira *et al.* (2011), identify differences between treatments in the layer 0-0.20 m of soil, and state that all treatments containing *Urochloa ruziziensis* presented higher percentages of aggregates larger than 2 mm that the treatment without *U. ruziziensis*, probably being this, the fact of different managements of soil do not present differences, once all presented *U. brizantha*.

It is noteworthy that the used management strategies provided a percentage of aggregates larger than 4 mm top to 60 % in the superficial layer (0-0.05 m), superior to 48 % in the layer of 0.05-0.20 m, highlighting the importance of forage in soil aggregation. Salton *et al.* (2008) also observed the apparent grazing contribution in increasing the average size of stable aggregates.

The high percentage of aggregates larger than 4 mm in the intermediate handling, in the surface layer (0-0.05 m), superior to 80 %, is related to the accumulation of OM in this layer.

Conclusions

In the layer of 0-0.05 m, the intermediary management provided an increasing in organic matter content, Ca, P and K, while the basic management provided lower levels of Ca and lower levels of pH and base saturation and higher values of potential acidity.

The complete and intermediary management provided pH elevation in both evaluated levels. The use of liming associated with plastering improves the chemical characteristics of Argisols under agroforestry systems.

In the layer of 0.05-0.20 m, the basic management provided lower values of soil density, while the complete management provided higher values. The several managements did not differ related to porosity or to aggregates stability.

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