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Effect of strategies for controlling spontaneous plants on the quality of soil organic matter and soil fertility[1]

Efeito das estratégias de controle de plantas espontâneas na qualidade da matéria orgânica e fertilidade do solo

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ABSTRACT - Soil organic matter (SOM) and the chemical attributes of the soil are important indicators of soil quality. The aim of this study was to evaluate the effects of strategies for controlling spontaneous plants on SOM quality and soil fertility in an area of forest under restoration. Three methods for controlling spontaneous plants were established: i) mechanical (MCH), ii) chemical (CHM), and iii) chemical-cultural (CC), and evaluated using a randomized block design. After 13 months, soil samples were collected (0-10 cm) to determine basal respiration over 21 days, total organic carbon (TOC), labile carbon (LC), chemical fractions of the SOM [humine (H), humic acid (HA) and fulvic acid (FA)], and soil fertility. On days 1, 3, and 7, higher values were seen for basal soil respiration, however, no differences were found between the control strategies. There was a small change in SOM quality and soil fertility. MCH showed higher values (up to 11%) for LC, due to the intense silvicultural management. After 13 months of application, each of the strategies for controlling spontaneous vegetation proved to be favorable in relation to SOM quality and soil fertility, especially for LC, due to its relationship with the accumulation or loss of SOM, and immediate response to changes in land use or management.

Key words: Basal respiration. Chemical fractionation of SOM. Forest restoration. Soil quality. Glyphosate.

RESUMO - A matéria orgânica do solo (MOS) e os atributos químicos do solo são importantes indicadores de qualidade de solo. Esse estudo teve como objetivo avaliar os efeitos de estratégias de controle de plantas espontâneas em uma área de restauração florestal sobre a qualidade da MOS e a fertilidade do solo. Para isso, foram estabelecidos três métodos de controle de plantas espontâneas: i) mecânico (MEC); ii) químico (QUI) e, iii) químico-cultural (QC) avaliados em um delineamento em blocos casualizados. Após 13 meses foram coletadas amostras de solo (0-10 cm) nas quais se determinaram a respiração basal por 21 dias; o carbono orgânico total (COT), o carbono lábil (CL); as frações químicas da MOS [humina (H), ácido húmico (AH) e ácido fúlvico (AF)] e a fertilidade do solo. Nos dias 1, 3 e 7 foram verificados maiores valores de respiração basal do solo, contudo, não foram encontradas diferenças entre as estratégias de controle. Foram verificadas pequenas alterações na qualidade da MOS e fertilidade do solo. O MEC apresentou valores (até 11%) mais elevados de CL, propiciado pela intensificação dos tratos silviculturais. Todas as estratégias de controle da vegetação espontânea após 13 meses de aplicação mostraram-se positivas com relação à qualidade da MOS e a fertilidade do solo, com destaque para o CL, devido a sua relação com o acumulo ou perda da MOS e a imediata resposta as alterações no uso e manejo do solo.

Palavras-chave: Respiração basal do solo. Fracionamento químico da MOS. Restauração florestal. Qualidade do solo. Glifosato.

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INTRODUCTION

The proper physiological development of tree species planted in areas of forest under restoration depends on a favorable environment during planting and establishment, when the control of spontaneous vegetation is essential to avoid competition for nutrients, water, or light. The presence of grasses can limit the success of stands that are planted with the aim of restoring the Atlantic Forest.

Control of these plants is generally carried out mechanically by cutting and weeding. However, this has proved to be costly and is ineffective in restricting grasses (GONÇALVES *et al*., 2018). An alternative method is chemical control, using herbicides that cause the death of spontaneous plants, eliminating the possibility of regrowth that is usually seen after the use of mechanical controls. Another strategy is to use cultural control, cultivating herbaceous legumes between the rows. According to Amoghein *et al*. (2013), these plants promote ground cover, reducing the available light between rows and hindering the growth of grasses, in addition to benefiting the tree species.

Most studies (GONÇALVES *et al*., 2018; SANTOS *et al*., 2019) on strategies for controlling spontaneous plants in forest restoration focus on the effectiveness of such strategies in reducing the populations of these plants to improve the growth of tree species, with the aim of reducing maintenance costs. However, to assess the effectiveness of these strategies in programs of forest restoration, it is essential to monitor environmental quality (ROCHA *et al*., 2015).

As such, the quantity and quality of soil organic matter (SOM) - quantified in the form of total organic carbon, labile carbon, and chemical fractions [fulvic acid (FA), humic acid (HA) and humine (H)] - are considered indicators for assessing soil quality as well as possible environmental impacts (LOSS *et al*., 2010). In addition, microorganisms are responsible for the decomposition of organic waste and the cycling of nutrients, explaining their importance as indicators of soil quality (MENDES; SOUSA; REIS, 2015). The C-CO_2 emitted by the soil (basal respiration) can therefore be considered an indicator of the activity of microorganisms during the decomposition and mineralization of organic compounds (SILVA *et al*., 2013).

The maintenance/addition of soil organic matter takes place through the deposition of plant residue (DICK *et al*., 2009). Land use and management practices, as well as crop residue, are responsible for the carbon balance (inputs and outputs) of the system (BALIN *et al*., 2017). Therefore, strategies for controlling spontaneous plants (grasses - with high a C/N ratio) that introduce legumes (with a low C/N ratio) into the system, can favor the dynamics of SOM cycling through the supply of plant residue containing different sources of C for the soil microorganisms, resulting in the formation of humic substances, and consequently, in an improvement in the physical, chemical, and biological properties of the soil (FORRESTER *et al*., 2013; KOUTIKA *et al*., 2014).

This study was based on the hypothesis that different strategies for controlling spontaneous vegetation alter the supply of plant residue and, as a result, change nutrient cycling and the quantity and quality of the SOM. The aim of this study therefore was to evaluate how three strategies (mechanical, chemical, and chemical-cultural) for controlling spontaneous plants interfere with the indices of SOM quality and with soil fertility in an area of forest under restoration.

MATERIAL AND METHODS

Description of the experimental area

The experiment was conducted in an area belonging to the Ecological Reserve of Guapiaçu (REGUA), in the district of Cachoeiras de Macacu, in the state of Rio de Janeiro (RJ) (22°27’32.26” S, 43°45’53.72” W). According to the Köppen classification, the local climate is type Af (tropical humid, with no dry season). The average annual rainfall is 2,050 mm, with an average annual temperature of 21.9 ºC (AZEVEDO *et al*., 2018).

The soil was classified as a cambisolic Latossolo Vermelho-Amarelo Distrófico (Oxisol), with relief varying from flat to smoothly undulating (5º to 15º) at an average altitude of 35 m. The chemical and physical characteristics of the soil are shown in table 1.

The experimental area was originally intended for the extensive grazing of beef cattle, with a predominance of species of brachiaria, especially *Urochloa brizantha* (Hochst. Ex A.Rich.) R.Webster cv. Marandu. and *U. mutica* (Forssk.) T. Q. Nguyen. One month before beginning the study (April 2017), the cattle were removed, and the area was fenced off. Three plant-control strategies (grass and spontaneous plants) were used, comprising the following treatments: i) mechanical control (MCH) – cleaning the ground and cutting, ii) chemical control (CHM) – the application of glyphosate and, iii) chemical-cultural control (CC) - the application of glyphosate and cultivation of herbaceous legumes. For the mechanical control (MCH), the area was cleaned by hoe to a radius of 30 cm around each seedling. Cutting took place between the rows whenever the brachiaria grass reached a height of more than 35 cm. For the chemical control (CHM), glyphosate (Roundup NA - glyphosate isopropylamine salt) was applied at a dose of 1.44 kg ha^{-1} a.e. (4 L ha^{-1}) before planting the tree seedlings and whenever the grass reached 35 cm. For the chemical-cultural control (CC), the same dose of herbicide was applied before planting the tree seedlings, followed by sowing the species of herbaceous legumes [jack bean (*Canavalia ensiformis* (L.) DC) and pigeon pea (*Cajanus cajan* (L.) Millsp.] between the rows of plants. The herbaceous legumes were cut with the aid of a machete: the pork beans level with the ground, and the pigeon pea 1.0 m from the ground. The dates and activities of the three treatments are briefly described in Table 2.

An experimental design of randomized blocks was used, with four replications, giving 12 sample units of 214 m^2 (15 x 14 m). In each sample unit, five seedlings chosen from eight tree species were used: *Alchornea sidifolia* Müll. Arg.; *Cordia abyssinica* R. Br.; *Cordia trichotoma* (Vell.) Arrab. Ex Steud.; *Guarea guidonia* (L.) Sleumer.; *Inga edulis* Mart.; *Peltophorum dubim* (Springer.) Taub.; *Piptadenia paniculata* Benth. and *Sparattosperma leucanthum* (Vell.) K. Schum. The seedlings were planted at a spacing of 3.0 x 1.7 m (~ 1900 seedlings ha^{-1}). When planting, 150 grams of N-P-K fertilizer (03-13-06) were applied to the planting holes for each treatment.

Collecting the soil samples

The soil samples were collected from the central part of each sample unit (working plot - 100 m^2 of the central area). Sampling took place 13 months after planting the seedlings and setting up the experiment, in June 2018. The collections were taken from mini trenches (10 x 20 x 20 cm) cut with the aid of a flat shovel to a depth of 0-10 cm between the plant rows. Six individual samples were collected per sample unit to make up one composite sample, for a total of 12 samples.

While still in the field, the composite samples were passed through a 4 mm sieve and then cleaned manually to remove any roots or litter. The samples were then packed in plastic bags, placed in a thermal box, and transported to the laboratory. In the laboratory, a part of the samples was air-dried, broken up and passed through a 2 mm sieve to obtain air-dried fine earth (ADFE).

Table 1 - Chemical and physical characteristics of the soil profile (0-90 cm) in the area of forest under restoration (March 2017)

Layer (Horizon)	pH	Ca^{+2}	Mg^{+2}	Al^{+3}	H+Al	P	K$^+$	TOC	Texture	TS
	H_2O	---------------- cmol$_c$ dm^{-3} ---------------				----- mg dm^{-3} -----		g kg^{-1}		
0-16 cm (A)	5.0	0.70	0.77	0.5	6.9	3.2	260	49	CLM	CLY
16-25 cm (BA)	4.6	0.15	0.11	1.5	6.3	1.1	24	24	SCL	MED
25-90 cm (Bw)	4.5	0.03	0.01	1.5	4.0	0.5	11	9	SCL	CLY

TOC – Total organic carbon; CLM – Clayey-loam, SCL - Sandy-clay-loam; TS – Type of soil: CLY - clayey, MED – medium texture; Ca^{+2}, Mg^{+2}, Al^{+3}: extractor 1.0 mol L^{-1} KCl; H+Al: extractor $C_4H_6O_4Ca$ at pH7; K and P – available P: extractor Merlich 1

Table 2 - Strategies for controlling spontaneous plants: dates and activities carried out in the sample units in an experiment located in the district of Cachoeiras de Macacu, RJ

Date	MCH	CHM	CC
05/04/17	Cleaning	Application of herbicide	Application of herbicide
05/25/17	Planting the seedlings	Planting the seedlings	Planting the seedlings
06/06/17	Cutting	-	-
08/07/17	-	Application of herbicide	Application of herbicide
09/15/17	Cutting and cleaning	-	-
10/06/17	-	-	Planting the legumes
11/09/17	Cutting and cleaning	Application of herbicide	-
01/05/18	-	-	Pruning the legumes
02/21/18	Cutting and cleaning	Application of herbicide	-
04/12/18	Cutting and cleaning	-	Cutting the legumes

MCH: mechanical control; CHM: Chemical control; CC: chemical-cultural control

Determining basal soil respiration

Basal respiration ($C\text{-}CO_2$ efflux) was assessed following the method described by Jenkinson and Powlson (1976). The soil samples (sieved at 4 mm and kept in a thermal box) were moistened to 60% of field capacity. They were then transferred and kept in hermetically sealed flasks. Two containers were inserted into each flask, one containing 20 mL of 0.5 mol L^{-1} NaOH to fix the CO_2 produced during incubation, and the other containing 20 mL of distilled water to maintain the humidity. The flasks were covered with black canvas to simulate conditions in the field and kept at an average temperature of 27 ºC. The $C\text{-}CO_2$ produced was quantified after 1, 3, 7, 10, 14 and 21 days, when each flask was opened for a maximum of 15 minutes, and 1 mL 50% $BaCl_2$ solution was immediately added to the containers with the NaOH. These were then removed with tweezers, and two drops of 1% phenolphthalein indicator were added for titration with HCl, previously standardized at 0.498 mol L^{-1}, until the pink color disappeared; the amount of HCl used in titration was then recorded. After quantifying the volume spent on titration, the amount of CO_2 released per gram of dry soil during the given period was calculated using equation 1.

$$\text{BSR (mg de C} - \text{CO}_2\ \text{kg}^{-1}\ \text{soil hr}^{-1}) = (\frac{(V_b - V_a).M.6.1000}{P_s})/T \qquad (1)$$

where: BSR = basal soil respiration; Vb (ml) = volume of hydrochloric acid used in titration of the control solution (white); Va (ml) = volume used in titration of the sample; M = exact molarity of the HCl; Ps (g) = weight of dry soil, and T = incubation time of the sample in hours.

Fertility and chemical fractionation of the soil organic matter

Soil fertility was analyzed in samples of ADFE, as per Teixeira *et al*. (2017). To extract the Ca^{+2}, Mg^{+2} and Al^{+3}, the 1.0 mol L^{-1} KCl extractor was used, the $C_4H_6O_4Ca$ extractor at pH7 was used to extract the H+Al, and the Merlich 1 extractor to extract the K^+, Na^+ and available P. The TOC was determined by oxidation of the organic matter with potassium dichromate ($K_2Cr_2O_7$) in sulfuric acid medium. The following were also determined: the pH in water; the levels of available phosphorus (P) by photocolorimetry; potassium (K^+) and sodium (Na^+) by flame photometry; and calcium (Ca^{+2}), magnesium (Mg^{+2}), exchangeable aluminum (Al^{+3}), extractable acidity (H+Al) and total organic carbon (TOC) by titration.

In a quantitative chemical fractionation of the humic substances, the humic-fraction carbon was quantified to give the humine (H), humic acid (HA) and fulvic acid (FA) fractions. The samples were treated with 0.1 mol L^{-1} NaOH, homogenized manually and left to stand for 24 h. They were then centrifuged at 4500 rpm for 30 minutes, and the process repeated twice. The pH of the supernatant was adjusted to 1.0 by the addition of 20% sulfuric acid (H_2SO_4) and allowed to decant for 18 h. The acidified material was then filtered, and the volume topped up to 50 mL with distilled water, isolating the FA fraction. The filter was completely washed by adding 0.1 mol L^{-1} NaOH to the precipitate, and the volumes topped up to 50 mL using distilled water, isolating the HA fraction. The residual material was considered the H fraction. The carbon in the extracts of the FA, HA and H fractions was quantified as per Yeomans and Bremner (1988). From the level of each fraction, the HA/FA ratio was calculated, together with the H content and the ratio between the fractions in the alkaline extract (AE = FA + HA), giving the AE/H ratio.

Determining labile soil carbon

The method described by Weil *et al*. (2003), was used to quantify the labile carbon (LC) via oxidation with 0.2 mol L^{-1} potassium permanganate ($KMnO_4$). To do this, 2.5 g of ADFE were placed in 50 -ml falcon tubes, and 18 ml of distilled water and 2 ml of 0.2 mol L^{-1} $KMnO_4$ solution (pH7.2) were added. The tubes were then homogenized for two minutes in a horizontal shaker at 120 rpm and left in an upright position for 10 minutes for the material to sediment. After sedimentation, a 0.5 ml aliquot was removed from the supernatant and transferred to another container containing 49.5 ml of distilled water. The solution was lightly homogenized until a purple color could be seen. The reading was taken with the aid of an absorbance spectrophotometer at 550 nm, and the labile carbon content (mg kg^{-1}) was quantified using equation 2, aided by the preparation of a standard curve with four different, previously known concentrations of $KMnO_4$ (0.005, 0.01, 0.015, and 0.2 mol L^{-1}).

$$\text{LC}=\{0{,}02\ \text{mol} - (a + b \times \text{abs})\}\times(9000\ \text{mg c/mol} \times (0.02\text{L solution/wt} \qquad (2)$$

where: 0.02 mol L^{-1} = initial concentration of the solution; a = intercept of the standard curve; b = slope of the standard curve; abs = unknown absorbance; 9000 = milligrams of oxidized carbon per 1 mole of MnO_4 changing from $Mn^{7+} \rightarrow Mn^{4+}$; 0.02 L = volume of reacted stock solution; Wt = weight of the air-dried soil sample in kg.

Statistical analysis

After checking the normality of the residuals and the homoscedasticity of the variances, the variables under study were submitted to analysis of variance (ANOVA), considering the randomized block design. The mean values were evaluated by F-test ($p<0.05$) and compared using Tukey's test ($p<0.05$). In addition, an analysis of the measurements repeated over time was carried out to assess the progressive evolution of $C\text{-}CO_2$. The analyses were carried out using the R software.

RESULT AND DISCUSSION

Eighteen months after the start of the experiment, the area of ground covered by the canopies of the seedlings was determined. Under the MCH strategy, 28% coverage was registered, with 126% under the CHM strategy, and 55% under the chemical-cultural strategy. The elimination of spontaneous species afforded by the herbicide over the whole area during the initial period of seedling growth favored the rapid growth of the tree species and, consequently, more ground being covered. In contrast, due to the little ground covered under MCH, it was necessary to intensify some silvicultural treatments such as cutting and weeding.

Basal soil respiration

Analysis of the measurements repeated over time showed no difference in the evolution of basal soil respiration between the control strategies ($p>0.05$; Figure 1A). However, when analyzing the time factor (Table 3), it can be seen that from day 1 to day 7, respiration was higher ($p<0.05$) compared to day 14 and day 21. There was no interaction between the treatments and the time factor ($p>0.05$). It can also be seen that after day 7, there was a gradual reduction in basal soil respiration (Figure 1A). Due to the high variability of the results, the accumulated values for $C\text{-}CO_2$ after 21 days showed no significant differences resulting from the control strategies ($p>0.05$; Figure 1B).

Figure 1 - Basal soil respiration (A) and cumulative basal soil respiration (B) under strategies for controlling spontaneous plants in an area of forest under restoration. Values followed by the same letter do not differ significantly ($p<0.05$) by Tukey's test. MCH: mechanical control; CHM: chemical control; CC: chemical-cultural control

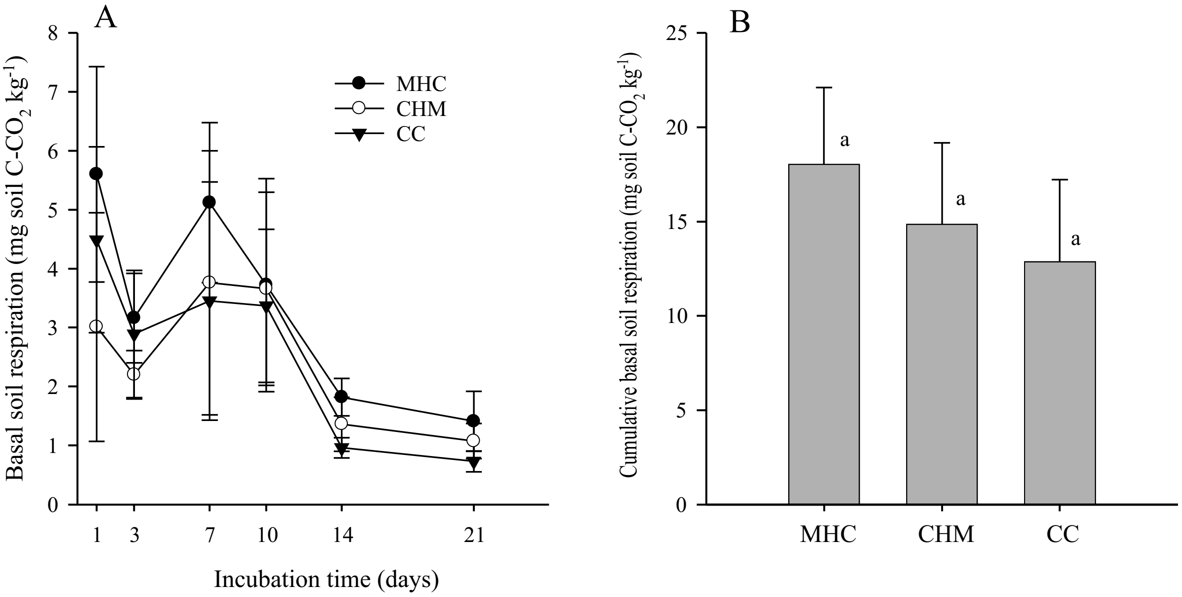

Table 3 - Significant difference (p-value) in basal soil respiration as a function of time (1, 3, 7, 10, 14 and 21 days), obtained by measuring the repetition over time. Values of $p<0.05$ differ significantly

Time (days)	1	3	7	10	14	21
1	1					
3	0.02	1				
7	0.770	0.237	1			
10	0.136	0.149	0.623	1		
14	0.010	0.049	0.040	0.067	1	
21	0.006	0.017	0.034	0.038	0.78	1

The reduction in basal respiration between day 1 and day 3, as well as the difference between the first ten days compared to the last few days (day 14 and day 21), can be explained by the priming effect, i.e., strong changes in SOM cycling (KUZYAKOV; FRIEDEL; STHAR, 2000), in which the labile fraction of the available SOM, as well as plant residue with a low C/N ratio, stimulate an increase in microbial activity (LOSS *et al*., 2013). Loss *et al*. (2013), observed a similar pattern, with higher C-CO_2 values up to day nine, followed by a gradual reduction.

Areas occupied by grasses may show high microbial activity due to the root biomass and intense mycorrhizal interactions that function as C pumps in the soil (SOUZA *et al*., 2010). Areas with less canopy cover (MCH) and a consequently higher density of spontaneous plants may therefore show higher values for basal respiration. In contrast, planting legumes (CC), and the resulting addition of N to the system, can also promote an increase in basal respiration (ALMEIDA; BAYER; ALMEIDA, 2016). Furthermore, various authors (ARAÚJO; MONTEIRO; ABARKELI, 2003; TIRONI *et al*., 2009) have also reported an increase in C-CO_2 emissions after the application of herbicides. For example, Castilho *et al*. (2016), who stated that the soil microbiota uses glyphosate as a carbon (energy) source, producing CO_2 in the short term. We therefore believe that the cumulative C-CO_2 respiration was intensified by each of the control strategies under evaluation.

Basal microbial respiration is dependent on the availability of nutrients, soil texture, and the presence of organic residue, among other attributes (TANG *et al*., 2006). As such, the higher pH values under MCH (Table 3) may be an indication that measurements taken 13 months after implementing strategies for controlling spontaneous plants may present higher values for C-CO_2, since a rise in soil pH leads to greater microbial activity, affording greater SOM mineralization, and reducing the soil carbon content (CHAN; HEENAN, 1999).

Chemical attributes and chemical fractions of the soil organic matter

Up to 13 months after planting, the soil attributes showed little variation as a result of the control strategies, where significant differences were seen only in the values for pH (Table 4).

The short length of the experiment (13 months) explains the similarity of the treatments in relation to most of the chemical attributes of the soil, since the effects of forest stands on these attributes are generally seen only several years after planting (FORRESTER *et al*., 2013).

The levels of TOC and the humic fractions also showed no significant differences ($p<0.05$) resulting from the strategies for controlling spontaneous plants, 13 months after setting up the experiment (Table 5).

The humine fraction was more abundant, varying between 77% and 82% depending on the control strategy. For the FA and HA fractions, the values were similar. On the other hand, differing from the results for TOC and the fractions of humic substances, the values for LC showed significant differences ($p <0.05$) as a result of the treatments, in which the values for MCH were higher (Table 5).

The chemical and physical attributes of the soil, together with the type of vegetation and climate conditions, directly influence the distribution of carbon fractions in the soil (DICK *et al*., 2009). Although TOC is considered an indicator of soil quality, it does not always reflect the changes caused by use and management in the short term (OLIVEIRA *et al*., 2018). The higher concentrations of the humine fraction are probably related to the history of the area (long-term pasture), since the short length of the experiment did not influence this SOM fraction.

Table 4 - Chemical attributes of the soil (0-10 cm) in an area of forest under restoration with different strategies for controlling spontaneous plants, in the district of Cachoeiras de Macacu, RJ

Treatment	pH	Ca^{+2}	Mg^{+2}	Al^{+3}	H+Al	Na^{+}	P	K^{+}
	H_2O	---------------------------- cmol$_c$ dm^3				----------------------------	-------- mg dm^{-3}	-------
Mechanical	4.5 a	1.2 a	2.3 a	0.5 a	11.1 a	0.1 a	3.2 a	131.4 a
	(0.1)	(0.5)	(0.9)	(0.3)	(1.3)	(0.0)	(0.8)	(48.4)
Chemical	4.2 b	1.0 a	2.1 a	0.8 a	10.3 a	0.1 a	3.5 a	109.9 a
	(0.3)	(0.4)	(0.6)	(0.2)	(1.8)	(0.0)	(1.4)	(45.8)
Chemical-cultural	4.3 b	0.9 a	2.0 a	0.8 a	10.7 a	0.1 a	3.3 a	87.0 a
	(0.2)	(0.3)	(0.4)	(0.2)	(2.3)	(0.0)	(1.2)	(9.3)

For each attribute, mean values followed by the same letter do not differ significantly ($p<0.05$) by Tukey's test. Numbers in parentheses refer to the standard deviation

Table 5 - Mean values for total organic carbon (TOC), the fractions of humic substances, the ratio between the humic fractions, and labile carbon (LC) in the soil (0-10 cm) of an area of forest under restoration with different strategies for controlling spontaneous plants, in the district of Cachoeiras de Macacu, RJ

Treatment	TOC	FA	HA	H	HA/FA	AE/H	LC mg kg^{-1}
	------ g kg^{-1} ------						
Mechanical	59.9 a	2.1 a	2.7 a	15.7 a	1.3 a	0.3 a	89.7 a
	(7.9)	(0.2)	(0.7)	(3.2)	(0.3)	(0.1)	(2.2)
Chemical	56.0 a	1.8 a	2.1 a	17.4 a	1.2 a	0.2 a	80.5 b
	(5.7)	(0.3)	(0.9)	(9.1)	(0.3)	(0.1)	(5.2)
Chemical-cultural	57.7 a	2.0 a	2.2 a	17.5 a	1.1 a	0.2 a	81.5 b
	(10.8)	(0.4)	(0.9)	(3.3)	(0.3)	(0.1)	(3.9)

Mean values followed by the same letter do not differ significantly ($p<0.05$) by Tukey's test. Numbers in parentheses refer to the standard deviation. TOC: total organic carbon; FA: fulvic acid; HA: humic acid; H: humine; HA/FA: humic acid to fulvic acid ratio; AE: alkaline extract = FA+HA; AE/H: alkaline extract to humine ratio; LC: labile carbon

Brachiaria, being a C_4 plant (grasses with a large amount of crop residue with a high C/N ratio), helps to maintain the C input to the soil at a high level, mainly due to the annual renovation of the root system, which results in greater C storage due to the increase in the humine fraction (BARRETO *et al*., 2008).

The fact that LC is the only variable that showed different values between control strategies demonstrates its great potential as an indicator of soil quality. Several studies have reported LC as an indicator that is sensitive to short-term impacts, in addition to being a simple, inexpensive and low-risk method (CULMAN; SNAPP; FREEMAN, 2012; LUCAS; WEIL, 2012). Culman, Snapp and Freeman (2012) related LC to soil quality, as this attribute is directly associated with microbial and enzyme activity in the soil, and as a result, stimulates nutrient cycling processes. The intensive silvicultural treatments, especially cutting under MCH, had a continuous effect on the brachiaria, constantly stimulating the root system (LOSS *et al*., 2015) As such, the continuous deposition of plant residue associated with the high production of biomass and root exudates - directly related to the input of readily decomposable C (SOUZA *et al*., 2010) - explain the higher values for LC under this control strategy.

CONCLUSIONS

1. After 13 months, the three strategies for controlling spontaneous vegetation (mechanical, chemical and chemical-cultural) proved to be favourable to maintaining the quality of soil organic matter and soil fertility;
2. Labile carbon can be recommended for assessing the short-term impact (13 months) of changes in use and/or management practices on the quality of soil organic matter. Due to its prominent role in the main ecological processes of the soil (e.g., regulating the C balance, a source of energy for microbial activity, the formation of macroaggregates, nutrient cycling, etc.), this fraction deserves special attention in studies related to the effect of changes in use and management practices that intensify the dynamics of the soil organic matter.

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