INFLUENCE OF SOIL COVER ON ORGANIC MATTER AND EDAPHIC VARIABLES IN ITATIAIA-RJ NATIONAL PARK

Alexandre dos Santos Medeiros[1], Lúcia Helena Cunha Anjos[2], Marcos Gervasio Pereira[3], Vanessa Fréo Medeiros[4]

[1*]Federal Rural University of Rio de Janeiro, Department of Soils, Graduate Program in Agronomy (Soil Science), Seropédica, Rio de Janeiro, Brazil - alexandremedeiros85@gmail.com
[2] Federal Rural University of Rio de Janeiro, Institute of Agronomy, Department of Soils, Seropédica, Rio de Janeiro, Brazil – lanjosrural@gmail.com
[3] Federal Rural University of Rio de Janeiro, Institute of Agronomy, Department of Soils, Seropédica, Rio de Janeiro, Brazil –mgervasiopereira01@gmail.com
[4] Federal Rural University of Rio de Janeiro, Agronomy Course, Seropédica, Rio de Janeiro, Brazil – vafreo@gmail.com

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Resumo

Influência da cobertura do solo sobre a matéria orgânica e variáveis edáficas no Parque Nacional do Itatiaia-RJ. Os ecossistemas florestais da região do Médio Vale do Paraíba do Sul foram submetidos a profundas modificações ao longo da história. Atualmente, predominam nessa região pastagens degradadas e fragmentos florestais secundários em diferentes estágios sucessionais, responsáveis por inúmeros serviços ambientais, dentre eles o sequestro e estabilização do CO_2. Para entendermos processos sucessionais, sua influência sobre variáveis do solo e a matéria orgânica do solo (MOS), devem ser considerados os diferentes usos da terra e a diversidade geomorfológica, já que a variabilidade ambiental pode influenciar essa dinâmica. Os objetivos do estudo foram avaliar variáveis físicas e químicas e a matéria orgânica de solos localizados na vertente sul do Parque Nacional do Itatiaia (RJ); bem como caracterizar possíveis padrões sob coberturas de Floresta Ombrófila Densa e pastagens e indicar qual cobertura acumularia os maiores teores de carbono (C) e em suas formas mais estáveis. As áreas de pastagens apresentaram as maiores médias de C, porém frações mais estáveis da MOS foram verificadas nos diferentes estágios de sucessão florestal. Também foi observado aumento da estabilidade da MOS em função do avanço dos estágios sucessionais.
Palavras chave: sucessão ecológica; unidades de conservação; preservação de recursos naturais.

Abstract

Forest ecosystems in the Middle Valley region of Paraíba do Sul have undergone profound changes throughout history. Currently, degraded pastures and secondary forest fragments predominate in different successional stages, responsible for numerous environmental services, among them the sequestration and stabilization of CO_2. In order to understand successional processes, their influence on soil variables and soil organic matter (SOM), different land uses and geomorphological diversity must be considered, since environmental variability can influence this dynamic. The objectives of the study were to evaluate physical and chemical variables and the organic matter of soils located in the southern slope of the Itatiaia National Park (RJ); as well as to characterize possible patterns under coverings of Dense Ombrophilous Forest and pastures and indicate which cover would accumulate the highest levels of carbon (C) and in its most stable forms. The pasture areas had the highest C averages, but more stable fractions of SOM were found in the different stages of forest succession. An increase in SOM stability was also observed due to the progression of successional stages.
Keywords: Ecological Succession; Conservation Units; Preservation of Natural Resources.

INTRODUCTION

The occupation of lands in the Middle Paraíba do Sul Valley promoted profound changes in the regional landscape, mainly during the coffee cycle in the 19th century, despite the importance of the Atlantic Forest ecosystems. Currently, secondary forest fragments predominated in the region separated by degraded pastures, these ecosystems being responsible for maintaining environmental services. In fact, such ecosystems are recognized as carbon mitigators (C), being able to store 283 Gt of C annually in biomass alone, in addition to preserving numerous species of fauna and flora, producing water and conserving soils (LIMA *et al*., 2012). Thus, preserving and expanding secondary forest communities can promote the mitigation of atmospheric CO_2, in addition to restoring other environmental services.

Among the processes responsible for the successive advance and the consequent resumption of environmental services in secondary forests, the cycling of nutrients, the supply and chemical quality of the litter, the activity of the soil fauna and all other processes related to the dynamics of soil organic matter (SOM) (MACHADO *et al*., 2015). Thus, in order to understand the influence of succession processes on the levels and forms of C, it is necessary to identify the variables that indicate the degree of conservation and the quality of environmental services in these forests.

The Itatiaia National Park (INP), which is located in the aforementioned region, preserves an important remaining area of Atlantic Forest in the Mantiqueira Range, which includes from forest formations in primary and secondary successional stages to Altitude Fields (BARRETO, 2013). The existence of numerous ecosystems in that park is due to the high altitudinal variation. As in the entire Paraíba do Sul Valley, INP areas have undergone profound modifications in the past, which currently constitute an important laboratory for investigating the resilience of native ecosystems and restoring environmental services.

In this scenario, the hypothesis is presented that the edaphic variables and the fractions of the soil organic matter are influenced by the different soil coverings. The objectives of this study were to evaluate the physical and chemical variables and the organic matter of the soil in the southern slope of the Itatiaia National Park (RJ) as well as to characterize possible patterns for such variables under different successional stages of Ombrophilous Forest and unmanaged pastures, in addition to indicating under which soil cover the highest C levels accumulate and their most stable forms.

MATERIAL AND METHODS

The areas selected for the study are located in the Municipality of Itatiaia, on the south side of the Park (22°30' and 22°33'S; 42°15' and 42º19'W), being subject to the direct influence of humid winds from the ocean, which allowed the establishment of the Dense Ombrophilous Forest, an ecosystem that corresponds to 12.09% of the total area of the INP (BARRETO, 2013). The sampling points were distributed along the slope under different types of vegetation cover, these being: a stretch of unmanaged pasture (P) (690 meters of altitude) and three stretches of Montane Ombrophilous Dense Forest (IBGE, 2013) in different successional stages: initial (ISF) (640m), medium (MSF) (710m) and advanced (ASF) (880m).

Prior to the creation of the INP, in the region of the municipalities of Resende and Itatiaia, the forests present on the slopes of the Mantiqueira Range were replaced by arable areas up to approximately 1,000 meters, which included coffee plantations, even in the 19th century, which were succeeded by extensive pastures and subsistence agriculture. After the creation of the INP, in 1936, natural regeneration processes began that originated areas of secondary forest in the advanced and medium successional stages. The areas in the initial stage and pastures were later incorporated into the INP, approximately 30 years ago (BARRETO, 2013).

The relief of the INP is characterized by the presence of mountains and rocky elevations, with altitudes ranging from 390 to 2,791.6 meters, with steep slopes typical of the Mantiqueira Range (BARRETO, 2013). The local geology stands out for the deposition of colluvial sediments, which form talus bodies (fragments of various sizes of rock material that are deposited at the foot of the slopes) of large dimensions, consisting predominantly of blocks and boulders of alkaline rocks, especially those of syenites, the gneiss blocks are smaller and less frequent (BARRETO, 2013). Under these conditions, soils with a clay texture or with the presence of conglomerates are originated, such as Argissolo Vermelho-Amarelo Distrófico (Ultisol) and Cambissolo Háplicos (Inceptisol), mainly in the southern slope of the INP, in the Campo Belo River watershed (BARRETO, 2013), where samples were collected.

According to Alvares *et al*. (2013), the climate in the municipality of Itatiaia can be classified as Cwa and Cfb, with cold periods associated with low rainfall, and warmer periods coinciding with the rainy season. Temperatures vary from 12.1ºC to 24.7ºC, in winter, and 24.7ºC to 30.9ºC, in summer.

For the assessment of soil variables, composite soil samples were collected up to the depth of 0-40 cm, with fixed intervals of 10 cm. Each of the 10 composite samples by depth was made of five individual samples, totaling 40 composite samples by type of cover, or 160 samples in the sum of the areas.

After preparing the soil samples, granulometric and sorptive complex analyzes were performed. The quantification of total organic soil carbon (TOC) followed the method described by Embrapa (2011). For the determination of soil density (Sd), eight undisturbed samples were collected at depths of 0-60 cm (with intervals of 10 cm) and two samples at depths of 60-100 cm, every 20 cm in depth, totaling 96 samples.

For the analysis of the chemical and granulometric fractionation of the SOM, six composite samples were collected, formed from five simple samples, at a depth of 0-10 cm, in each soil cover, totaling 24 composite samples. For the quantification of humic fractions, the differential solubility technique adapted by Benites *et al* was applied. (2003). As for obtaining the particle size fractions, the method described by Cambardella and Elliot (1992) was used. The levels of C (g kg^{-1}) of the fractions of fulvic acid, humic acid and humin, particulate organic carbon and organic carbon associated with minerals were calculated.

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In the definition of the plots and analysis of the data of the experiment, the randomized block design was assumed. All data were subjected to analysis of normality of error distribution (ShappiroWillk test) and homogeneity of variance of errors (Cochran and Bartlett), requiring the transformation of data on the variables of soil and soil density by the function $\sqrt{yi}$in an electronic spreadsheet.

For all the analyzed variables, the influence of multiple environmental variables associated with the different successional stages and the altitudinal variation was considered, these being treated as factorial experiments. The collections were carried out in November 2015, during the spring, the beginning of the period of greatest precipitation in the region. The means of the variables of the sorptive complex, TOC and Sd were compared by Tukey's T test at 5% significance. On the other hand, the means of chemical and granulometric fractionation were compared by Duncan's test at 5% significance. All analyses were performed with the aid of the R x 64 2.15.3 program.

RESULTS

In all areas evaluated, high clay contents were observed, and the corresponding texture class of soils in the southern slope of the INP was very clayey (Table 1). Regarding the sand contents, significant differences were observed in the surface horizon, in which the areas of MSF and ASF presented twice the values of this variable, compared to the pasture. In the comparison between depths, a significant difference was observed only for the silt fraction in MSF and ISF.

Tabela 1. Textura do solo na vertente sul do Parque Nacional do Itatiaia, RJ, sob diferentes coberturas e usos do solo, em diferentes profundidades (cm).

Table 1. Soil texture in the southern slope of Itatiaia National Park, RJ, under different coverages and soil uses, at different depths (cm).

VARIABLE	**Area**	**0 - 10**	**10 - 20**	**20 - 30**	**30 - 40**
Clay (g kg^{-1})	P	731.09 Aa	691.49 Aa	739.09 Aa	665.89 Aa
	ISF	693.30 Aa	632.79 Aa	683.10 Aa	626.30 Aa
	MSF	684.30 Aa	686.79 Aa	660.70 Aa	687.10 Aa
	ASF	683.80 Aa	660.90 Aa	744.89 Aa	746.19 Aa
	CV = 16.01%				
VARIABLE	**Area**	**0 - 10**	**10 - 20**	**20 - 30**	**30 - 40**
Sand (g kg^{-1})	P	84.38 Ba	95.90 Aa	91.80 Aa	110.10 Aa
	ISF	116.31 ABa	131.80 Aa	124,31 Aa	116.62 Aa
	MSF	154,90 Aa	138,71 Aa	141,00 Aa	168,61 Aa
	ASF	167,30 Aa	134,70 Aa	130.01 Aa	166,00 Aa
	CV = 35.91%				
VARIABLE	**Area**	**0 - 10**	**10 - 20**	**20 - 30**	**30 - 40**
Silte (g kg^{-1})	P	184,50 Aa	165,00 Aa	254,00 Aa	198,41 Aa
	ISF	190.40 Aab	185.12 Ab	164.31Ab	227.72 Aa
	MSF	160,81 Aab	200,61 Aa	171.92 Aab	144.63 Ab
	ASF	178,90 Aa	132,62 Aa	123.80 Ba	166,12 Aa
	CV = 41.65%				

Different uppercase letters in the column indicate significant difference in comparisons between areas, for each depth, and different lowercase letters in the row indicate significant difference in comparisons between depths, for each area, by Ttukey's T test at 5% significance. Key: CV: Coefficient of variation (%); P: Pasture; ISF: Dense Ombrophilous Forest in initial successional stage; ISF: Dense Ombrophilous Forest in medium successional stage; MSF: Dense Ombrophilous Forest in advanced successional stage; ASF:

The results of the analysis of the assortment complex indicated that the C levels in the soil were higher in the pasture area and decreased significantly with increasing depth (Table 2). Similar results were observed for P. As for N contents, significant differences were observed between forest and pasture areas at a depth of 0-10 cm, while there were no significant differences in the comparison of forest cover between them. Similar results were observed for Na^+, K^+, Mg^{+2}, S and V (%), with their respective means differing significantly between evaluated and deep roofs, and generally higher levels were verified in ISF and MSF, areas that are located in the lower parts of the slope. Despite the high levels of Al in ISF and MSF in relation to ASF, and also high levels of H+Al in ASF, no significant differences were observed between forest coverages for the pH variable. These same variables, however, presented significant differences between depths, whose values, in general, decreased with increasing soil depth.

Tabela 2. Variáveis químicas e carbono do solo na vertente sul do Parque Nacional do Itatiaia, RJ, sob diferentes coberturas e usos do solo, em diferentes profundidades (cm).

Table 2. Chemical and carbon soil variables in the southern slope of Itatiaia National Park, RJ, under different coverages and land uses, at different depths (cm).

VARIABLE	Area	0 - 10	10 - 20	20 - 30	30 - 40
	P	37.25 Aa	28.18 Aab	21.35 Ab	17.36 Ab
	ISF	31,02 Aa	23.73 Aab	16.44 Aab	14.22 Ab
C (g kg^{-1})	MSF	34,03 Aa	26.50 Aab	17.78 Ab	15.52 Ab
	ASF	32,11 Aa	26.14 Aab	18.26 Aab	11.95 Ab
	CV = 33.38%				
VARIABLE	**Area**	**0 - 10**	**10 - 20**	**20 - 30**	**30 - 40**
	P	2.18 Ba	1.87 Aa	1.46 Aa	0.83 Aa
	ISF	3.09 ABa	2.36 Aab	1.64 Aab	1.14 Ab
N (g kg^{-1})	MSF	3.47 ABa	2.14 Aa	1.53 Aa	1.79 Aa
	ASF	3.84 Aa	2.25 Aab	1.36 Ab	1.25 Ab
	CV = 42.08%				
VARIABLE	**Area**	**0 - 10**	**10 - 20**	**20 - 30**	**30 – 40**
	P	1.97 Aa	1.73 Aa	1.06 Aa	0.87 Aa
	ISF	2.70 Aa	1.68 Aab	1.36 Ab	0.97 Ab
P (mg kg^{-1})	MSF	2.36 Aa	0.79 Ab	0.48 Ab	0.53 Ab
	ASF	2.66 Aa	1.68 Aab	0.96 Ab	0.82 Ab
	CV = 51.08%				
VARIABLE	**Area**	**0 - 10**	**10 - 20**	**20 - 30**	**30 – 40**
	P	0.02 Aa	0.02 Aa	0.01 Aa	0.01 Aa
	ISF	0.02 Aab	0.03 Aa	0.01 Ab	0.01 Ab
$\mathbf{Na^+}$ (cmol dm^3)	MSF	0.02 Aa	0.03 Aa	0.02 Aa	0.02 Aa
	ASF	0.00 Bb	0.00 Bb	0.02 Aa	0.01 Aa
	CV = 46.76%				
VARIABLE	**Area**	**0 - 10**	**10 - 20**	**20 - 30**	**30 – 40**
	P	0.15 Ba	0.01 Bab	0.06 Bb	0.04 Bb
	ISF	0.25 Aa	0.19 Aa	0.18 Aa	0.19 Aa
$\mathbf{K^+}$ ($cmol_c dm^{-3}$)	MSF	0.21 Aa	0.12 ABb	0.09 Bb	0.09 Bb
	ASF	0.14 Ba	0.09 Bab	0.06 Bb	0.05 Bb
	CV = 50.34%				
VARIABLE	**Area**	**0 - 10**	**10 - 20**	**20 - 30**	**30 – 40**
	P	4.76 Aa	4.64 Ab	4.66 Aab	4.62 Ab
	ISF	4.04 Bb	4.07 Bb	4.15 Bab	4.19 Ba
pH (H_2O)	MSF	4.14 Ba	4.14 Ba	4.20 Ba	4.25 Ba
	ASF	4.11 Bc	4.15 Bbc	4.23 Bab	4.28 Ba
	CV = 5.51%				
VARIABLE	**Area**	**0 - 10**	**10 - 20**	**20 - 30**	**30 – 40**
	P	1.47 Ca	1.67 Da	1.47 Ca	1.45 Ba
	ISF	2.99 Aa	2.80 Bab	2.63 Bb	2.64 Bb
$\mathbf{Al^{+3}}$ ($cmol_c\ dm^{-3}$)	MSF	3.07 Aa	3.28 Aa	3.16 Aa	3.00 Aa
	ASF	2.65 Ba	2.40 Cab	2.33 Bb	1.94 Cc
	CV = 26.35%				
VARIABLE	**Area**	**0 - 10**	**10 - 20**	**20 - 30**	**30 – 40**
	P	13.12 Ba	11,90 Aa	8.50 Aa	7.59 Aa
	ISF	17,61 Aa	13.59 Aab	11.63 Ab	10.15 Ab
H+Al ($cmol_c\ dm^{-3}$)	MSF	18,45 Aa	13.52 Aab	11.60 Ab	11.25 Ab

VARIABLE	Area	0 - 10	10 - 20	20 - 30	30 – 40
	ASF	18,84 Aa	15.35 Aab	11.39 Ab	10.19 Ab
	CV = 29.66%				
VARIABLE	**Area**	**0 - 10**	**10 - 20**	**20 - 30**	**30 – 40**
Mg^{+2} ($cmol_c\ dm^{-3}$)	P	0.98 Aa	0.61 Aa	0.42 Ab	0.54 Ab
	ISF	0.83 ABa	0.50 Aab	0.44 Ab	0.36 Ab
	MSF	0.88 ABa	0.40 Ab	0.43 Ab	0.39 Ab
	ASF	0.55 Ba	0.30 Aa	0.28 Aa	0.30 Aa
	CV = 41.10%				
VARIABLE	**Area**	**0 - 10**	**10 - 20**	**20 - 30**	**30 – 40**
S ($cmol_c\ dm^{-3}$)	P	1.18 Ba	0.73 Ab	0.51 Ab	0.58 Ab
	ISF	1.10 Ba	0.73 Aab	0.63 Ab	0.56 Ab
	MSF	1.61 Aa	0.64 Ab	0.55 Ab	0.51 Ab
	ASF	0.83 Ba	0.40 Ab	0.40 Ab	0.37 Ab
	CV = 47.01%				
VARIABLE	**Area**	**0 - 10**	**10 - 20**	**20 - 30**	**30 – 40**
T ($cmol_c\ dm^{-3}$)	P	14,31 Aa	12,65 Aa	9.06 Aa	8.18 Aa
	ISF	18,72 Aa	14.31 Aab	12.27 Ab	10.52 Ab
	MSF	20.05 Aa	14.16 Aab	12.16 Ab	11.76 Ab
	ASF	19.70 Aa	15,81 Aa	11,80 Ab	10.57 Ab
	CV = 29.44%				
VARIABLE	**Area**	**0 - 10**	**10 - 20**	**20 - 30**	**30 – 40**
V (%)	P	8.3 Aa	5.8 Ab	5.6 Ab	8.6 Aa
	ISF	6.0 Aba	5.2 Aa	5.5 Aa	5.4 Ba
	MSF	8.1 Aa	4.5 ABb	4.3 Ab	4.6 Bb
	ASF	4.3 Ba	2.8 Ba	3.3 Aa	3.5 Ba
	CV = 33.6%				

Different uppercase letters in the column indicate significant difference in comparisons between areas, for each depth, and different lowercase letters in the row indicate significant difference in comparisons between depths, for each area, by Ttukey's T test at 5% significance. Key: CV: Coefficient of variation (%); P: Pasture; ISF: Dense Ombrophilous Forest in initial successional stage; ISF: Dense Ombrophilous Forest in medium successional stage; MSF: Dense Ombrophilous Forest in advanced successional stage; ASF:

Significant differences were observed for Sd between the areas only for the surface layer of the soil (0-10 cm), with a decrease in the means of this variable according to the advance of the successional stage of the forest (Table 3). As for the significant differences between depths, within each successional stage, ASF presented lower Sd in the surface soil, in relation to the other depths under this vegetation cover.

Tabela 3. Densidade do solo (Ds) da vertente sul do Parque Nacional do Itatiaia, RJ, sob diferentes coberturas e usos do solo, em diferentes profundidades (cm).

Table 3. Bulk density (Bd) of the southern slope of Itatiaia National Park, RJ, under different coverages and land uses, at different depths (cm).

VARIABLE	Area	0 - 10	10 - 20	20 - 30	30 – 40
Sd ($Mg\ m^{-3}$)	P	0.99 Aa	0.94 Aa	0.83 Aa	1.04 Aa
	ISF	0.88 Aa	0.88 Aa	0.89 Aa	0.97 Aa
	MSF	0.77 Ba	0.81 Aa	0.84 Aa	0.82 Aa
	ASF	0.68 Bb	0.91 Aa	0.98 Aa	1.00 Aa
	CV = 14.03%				

Different uppercase letters in the column indicate significant difference in comparisons between areas, for each depth, and different lowercase letters in the row indicate significant difference in comparisons between depths, for each area, by Ttukey's T test at 5% significance. Key: CV: Coefficient of variation (%); P: Pasture; ISF: Dense Ombrophilous Forest in initial successional stage; ISF: Dense Ombrophilous Forest in medium successional stage; MSF: Dense Ombrophilous Forest in advanced successional stage; ASF:

Regarding the C levels in the SOM fractions, significant differences were found for the humin fraction, which was higher in the ASF, in relation to pasture (Table 4). No differences were observed between the other fractions (fulvic and humic acids) and granulometric fractions (particulate organic carbon and organic carbon associated with minerals) of SOM, in the comparison of soil plant covers among themselves. In general, the results of chemical fractionation of SOM showed the predominance of the humin fraction in all areas, and the increase in the stability of organic matter was observed as a function of the advance of the successional stage, with lower mean values in the pasture cover, followed by ISF, MSF and ASF. For granulometric fractionation, no significant differences were found between the coverages; however, the values of TOC and organic carbon associated with minerals were comparatively higher in the pasture area, and the values of particulate organic carbon in the ASF area.

Tabela 4. Fracionamento químico e granulométrico da matéria orgânica do solo da vertente sul do Parque Nacional do Itatiaia, RJ, sob diferentes coberturas e usos, na profundidade de 0-10 cm.

Table 4. Chemical and granulometric fractionation of soil organic matter from the southern slope of Itatiaia National Park, RJ, under different coverages and uses, at a depth of 0-10 cm.

VARIABLE	**Area**	**0 – 10**
Fulvic acid	P	3.97 A
	ISF	4.34 A
	MSF	4.28 A
	ASF	4.46 A
	CV = 14.03%	
VARIABLE	**Area**	**0 – 10**
Humic Acid	P	3.70 A
	ISF	4.34 A
	MSF	4.74 A
	ASF	4.48 A
	CV = 21.32%	
VARIABLE	**Area**	**0 – 10**
Humin	P	23.46 B
	ISF	24.57 AB
	MSF	24.67 AB
	ASF	33.83 A
	CV = 31.56%	
VARIABLE	**Area**	**0 - 10**
Particulate organic carbon	P	10.72 A
	ISF	8.80 A
	MSF	10,30 A
	ASF	12,27 A
	CV = 43.01%	
VARIABLE	**Area**	**0 - 10**
Organic carbon associated with minerals	P	28.65 A
	ISF	18,82 A
	MSF	21.08 A
	ASF	21,81 A
	CV = 45.97%	

Different capital letters in the column indicate significant difference in comparisons between areas, by Duncan's T test at 5% significance. Key: CV: Coefficient of variation (%); P: Pasture; ISF: Dense Ombrophilous Forest in initial successional stage; ISF: Dense Ombrophilous Forest in medium successional stage; MSF: Dense Ombrophilous Forest in advanced successional stage; ASF:

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DISCUSSION

The low values for the averages of the sand fraction in the soil surface, which were verified in the pasture areas, can be attributed to the relative increase of the clay fraction, due to the loss of sand by erosion in the A horizon and loss of the surface horizon itself, with exposure of the subsurface horizon (BA or even B). This pattern was previously mentioned for the Middle Paraíba do Sul Valley, resulting from the association of factors such as the absence of forest cover, soil compaction caused by cattle trampling and steep declivity (DANTAS and COELHO NETO, 2013). In contrast, in areas with forest cover, the drag energy of surface waters is less, due to the protection of the soil, performed by the forest and the litter layer, against the direct impact of rainwater. Under these conditions, the superficial horizon of the soil loses mainly the finer particles, such as clay, which promotes the relative increase in the contents of the sand fraction on the surface. As for the predominance of the clay fraction in all coverings, it can be attributed to the influence of the source material, coming from sediments derived from syenite, alkaline rocks that originate clayey soils (BARRETO, 2013).

The decrease in C levels in depth, a fact already expected in forest areas, may have negatively influenced the availability of P, since the levels of this element in weathered soils are generally associated with soil carbon levels. This pattern is based on the fact that, in weathered soils and without the addition of fertilizers, the main source of phosphorus is the organic matter (ARAÚJO *et al*., 2011).

It is believed that the absence of changes in N levels was influenced by the fact that there are generally high values of coefficient of variation, in experimental plots under natural conditions. However, Fernandes *et al.* (2014) observed in Pinheiral (RJ) that the highest levels of N in the soil occur in forest areas at different successional stages, probably due to better chemical conditions and the amount of plant material brought to the soil, to the detriment of a pasture area. This pattern indicated differences between forest cover and pasture with regard to strategies for the acquisition, transport and assimilation of inorganic forms of N, which would be more efficient in forest ecosystems, thus favoring the incorporation of N in biomass and its further mineralization during the decomposition of organic matter in the soil.

The soils in the studied areas were characterized as acids, as they have pH averages below 6.0 (EMBRAPA, 2011). The highest pH values were observed in the pasture, being significantly different from the forest areas, in all depths. However, the pasture did not undergo any type of management, that is, the soil was not limed. Thus, this result was probably due to the levels of organic acids (fulvic and humic) relatively higher than those found in the soil under the forest areas, which led to a decrease in the pH values in this vegetation cover.

In general, the soils of the forest and pasture areas showed low levels of mineral elements, when compared to the soils evaluated by Fernandes *et al*. (2014), in the Middle Vale do Paraíba do Sul. The exception was only for Na^+ and K^+, whose values were higher in the present study, in relation to those values found by the authors previously mentioned. This pattern can be attributed to: the nature of the parent material of the INP soils, formed by previously altered colluvial sediments; the intense weathering associated with tropical soils; and the prevailing humidity conditions in the park.

The lowest mean values of Na^+ (0-10 cm and 10-20 cm) and V% (0-10 cm and 10-20 cm) quantified in the ASF area, in relation to other coverages, can be attributed to the location of that area in the upper slopes. This condition of steep slopes, associated with high rainfall, will favor the loss of bases from the top to the bottom of the slope. This same pattern was described by Braga *et al.* (2015), who verified the increase in soil fertility from a catena from the top to the bottom of the slope. However, despite the fact that the pasture area is located in a portion of the slope above the ISF, an inverse pattern was observed for the S Value, with the increase in organic matter in the pasture that was probably responsible for the base retention.

It was also verified, in comparison to the study by Fernandes *et al*. (2014), low Ca^{+2} concentration in the ASF and pasture areas, in addition to values of this nutrient below the limit quantifiable by the titrometric method in the ISF and MSF areas. This result was attributed to the low levels of Ca^{+2} in the minerals that constitute the parent material of the soils, predominantly sediments originating from syenites and gneisses rocks (BARRETO, 2013).

The Sd values were relatively low for mineral soils (below 1.0 Mg m^{-3}) (MARCOLIN *et al.*, 2013). This result may be related to the greater amount of organic material, which favors aggregation and increases porosity, and the presence of many roots in soil samples, especially in ASF (0-10 cm), which had the lowest Sd averages. As for the comparison between coverages, Santos *et al*. (2010) obtained higher values of Sd in pasture areas compared to secondary forest, a fact that was attributed to the trampling of the soil by cattle. However, the pasture area has not been used with animals, which allowed the partial recomposition of soil aggregation, also favored by grass roots.

In addition to the different soil coverages evaluated in this study, the altitudinal influence must also be considered, since the ecosystems occur along an altimetric gradient that extends from 660 m in ISF to 880 m in altitude, where the area is located ASF. According to Vieira *et al*. (2011), in their studies in Dense Ombrophilous Forest up to the level of 1,000 meters, the altitudinal elevation favors greater carbon stocks and the consequent stabilization of the SOM, since the authors observed the direct correlation between the decrease in air and soil temperature and the increase in the carbon stock. Therefore, forest formations present in high levels, such as Montana and Altomontana forests, tend to store more C and N in the soil, due to the decrease in respiration rates and the activity of decomposing organisms (SOUSA NETO *et al*., 2011).

Corroborating the studies by Vieira *et al*. (2011), the relationship between the carbon in the alkaline extract (C-EA = carbon fulvic acid + carbon humic acid) and the carbon in the humin fraction (C-EA / C-HUM) showed results below 0.5. This result indicated that the most stable fractions predominated over the other fractions (fulvic and humic acids) in all evaluated coverings, mainly in ASF. In this area, the high values for the humin fraction indicated the high stability of SOM, which is a favorable aspect because it indicates the decrease in the potential for loss of C, either through respiration, erosion or translocation.

The studies carried out by Vieira *et al*. (2011) in high-elevation ecosystems confirmed the tendency for SOM to stabilize. On the other hand, a reduction in C stocks was observed, mainly at altitudes above 2 thousand meters (LOOBY *et al*., 2016), due to the physiological restrictions imposed on plant species, with the consequent decrease in biomass production in ecosystems.

The lower values of fulvic and humic acids may be a function of the complexation of organic molecules from the decomposition of plant material added to the soil, with the consequent formation of structures with greater molecular complexity, such as humin. Or even losses by leaching, as indicated by the humic acid/fulvic acid ratio with values greater than 1.0 in the forest (FONTANA *et al*., 2006), favored by the steepness and accentuated rainfall index. Another relevant factor is mineralization, especially in the initial stages of forest succession, in which the nitrogen content of the biomass and the high temperatures favor microbial activity. In the pasture area, the humic acid/fulvic acid values (0.93) were low. This result may have occurred due to the degradation of humin, or due to the action of another factor in the system, which is disfavoring the formation of complex molecules (FONTANA *et al*., 2006).

Although the high values of organic carbon associated with minerals are indicative of a certain stability of the SOM, the average values of humin were significantly lower in the pasture area, compared to the forest areas. This result suggested the lower stability of SOM in the pasture (PEREIRA *et al*., 2012). High values of carbon in the soil in pasture areas result from the quantity and quality of vegetable residues added in systems with a predominance of grasses (LOSS *et al*., 2014).

The higher values of particulate organic carbon and, consequently, the lower values of organic carbon associated with minerals may be due to the greater supply of litter and the quality of plant material in the ASF area. Although these variables were not evaluated in the study, Fernandes *et al.* (2014) found that litter added ~~brought~~ to the soil in advanced stages of the forest succession showed a high C/N ratio, a condition that, when associated with the low temperatures observed in high elevations, influences the decrease in mineralization rates. Thus, the particulate plant material is preserved in the SOM.

CONCLUSIONS

- The different coverages analyzed, pasture and Ombrophilous Dense Forest in different successional stages, and the position on the slope of the experimental areas influenced the physical and chemical variables of the soil and the distribution pattern of the fractions of soil organic matter.
- The absence of anthropic action in the pasture area favored an increase in carbon levels, which occurred in the form of less stable molecules. In areas of forest cover, besides the high carbon contents, an increase in the stability of the organic molecules was observed as a function of the advancement of the successional stage. This fact indicated that such coverings are more efficient in sequestration and stabilization of C in the soil, in comparison with pasture areas.
- In general, the different coverings evaluated presented values of C in the soil that indicated its conservation in the systems. This aspect emphasized the importance of preserving the soil's organic matter.

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