CHEMICAL AND PHYSICAL ATTRIBUTES OF A LATOSOL AND COFFEE CROP NUTRITION IN AGROFORESTRY AND CONVENTIONAL MANAGEMENT SYSTEMS

Davi Lopes Carmo[1], Dulcimara Carvalho Nannetti[2], Moacir Souza Dias Junior[3], Tales Machado Lacerda[4], Alex Nogueira Nannetti[5], Lourenço Manuel[6]

(Recebido: 11 de janeiro de 2013; aceito: 22 de abril de 2013)

ABSTRACT: In search of a sustainable coffee sector production, various management practices have been adopted, because it causes changes in the physical and chemical soil attributes, consequently changes the coffee crop nutrition. The aim of this study was to evaluate soil quality by quantifying the physical and chemical attributes of a Red Latosol and the nutritional status of the coffee culture in two management systems: conventional and agroforestry in southern Minas Gerais, Brazil. The study was conducted in the municipality of Machado - MG in 2008. Samples deformed and non-deformed soil were collected for chemical and physical analyses. The chemical analyses evaluated were: contents of P, K^+, Ca^{2+}, Mg^{2+}, H^++Al^{3+}, Al^{3+}, CTC, V, MOS and m. The physical attributes analyzed were Ds, VTP, Ma, Mi and Ma/Mi. Leaves were collected to analyze the contents of N, P, K, Ca, Mg and S. The chemical attributes of the soil in the agroforestry system seemed to be more favorable to the coffee culture, in comparison to the conventional system. The physical attributes did not changed between the management systems. Coffee plants cultivated in agroforestry system promoted positive nutrient cycling, as well as, the macronutrients contents increased in the leaf tissue reaching similar levels of the coffee plantation in conventional system.

Index terms: Soil Sustainability, soil fertility, nutrient cycling, soil structure.

ATRIBUTOS QUÍMICOS E FÍSICOS DE UM LATOSSOLO E NUTRIÇÃO DO CAFEEIRO EM SISTEMAS DE MANEJO AGROFLORESTAL E CONVENCIONAL

RESUMO: *Em busca de uma produção sustentável no setor cafeeiro, várias práticas de manejo são adotadas e essas podem provocar modificações nos atributos físicos e químicos do solo e consequentemente alterar a nutrição do cafeeiro. Objetivou-se, neste trabalho, avaliar a qualidade do solo, mediante a quantificação dos atributos físicos e químicos de um Latossolo Vermelho e o estado nutricional do cafeeiro, em dois sistemas de manejo: agroflorestal e convencional, no Sul de Minas Gerais, Brasil. O estudo foi realizado no município de Machado - MG, em 2008. Foram coletadas amostras deformadas e indeformadas para as análises químicas e físicas do solo e amostras de tecido foliar para a avaliação nutricional dos cafeeiros. As análises químicas do solo constituíram-se de pH, teores de P, K+, Ca2+, Mg2+, H++Al3+, Al3+, CTC, V, MOS e m. Os atributos físicos analisados foram Ds, VTP, Ma, Mi e Ma/Mi. A análise nutricional foi determinada pelos macronutrientes: N, P, K, Ca, Mg e S. Os atributos químicos do solo do sistema agroflorestal apresentaram-se mais favoráveis à cultura do café, em comparação ao sistema convencional. Os atributos físicos do solo não foram alterados entre os sistemas de manejo. A ciclagem dos nutrientes em cafeeiro agroflorestal foi positiva, propiciando teores de macronutrientes em tecido foliar semelhantes aos do cafeeiro convencional.*

Termos para indexação: *Sustentabilidade do solo, fertilidade do solo, ciclagem de nutrientes, estrutura do solo.*

1 INTRODUCTION

Coffee production (*Coffea arabica* L.) under agroforestry systems (AFS) has been widely used in Latin America primarily by farmers. It`s an alternative, and aims to ensure the sustainability of agricultural production and the economy diversity.

The AFSs stand out for the shading provided by multiples species of trees and cultivated land in consortium with high biological diversity of the ecosystem, in which beneficial interactions are exploited between plants of different cycles, sizes and functions with efficiency improvements of water use and decreasing of losses of soil, carbon and nutrients (AGUIAR et al., 2006; CARVALHO; GOEDERT; ARMANDO, 2004; LIMA et al., 2010). In this system the replacement of petroleum products as fertilizers and pesticides for biomass production and increased efficiency in the process of nutrient recycling, the permanent

[1]Universidade Federal de Lavras/UFLA - Departamento de Ciências do Solo/DCS - Cx. P. 3037 - 37.200-000 - Lavras - MG davigoldan@yahoo.com.br
[2]Instituto Federal/IF - Cx. P. 49 - 37750-000 - Campus Machado - MG - dulcimara@mch.ifsuldeminas.edu.br
[3]Universidade Federal de Lavras/UFLA - Departamento de Ciências do Solo/DCS - Cx. P. 3037 - 37.200-000 - Lavras - MG msouzadj@ufla.br
[4]Instituto Federal/IF - Cx. P. 49 -37750-000 - Campus Machado - MG - tales_lacerda@yahoo.com.br
[5]Universidade José do Rosário Vellano/UNIFENAS - 37.130-000 - Alfenas - MG - alexnannetti@axtelecom.com.br
[6]Universidade Federal de Lavras/UFLA - Departamento de Ciências Exatas/DEX - Cx. P. 3037 - 37.200-000 - Lavras - MG zlouremanuel@yahoo.com.br

protection of soil, providing more favorable environment for biological processes that regulate the decomposition process of organic matter, with the improvement of soil quality and environmental preservation, toward the development of a sustainable coffee culture (AGUIAR et al., 2010; HAGAAR et al., 2011; MAIA et al., 2007; PIMENTEL et al., 2005; SOUZA; GRAAFF; PULLEMAN, 2012).

Organic matter is a chemical indicator of soil quality, due to its role in regulating a variety of processes occurring in the soil. It provides energy for biological activity that acts in the decomposition process of organic waste and nutrient release to the plants (TIAN; KANG; BRUSSAARD, 1992) and improves the soil structure by increasing aggregation, porosity and water retention and decreases its density (FRANZLUEBBERS, 2002). Based on this context, to be successful in AFSs, it`s primordial good supply of nutrients through the decomposition process, resulting from paring and biomass produced at the site, so that recycled nutrients meet production needs (MENDONÇA; STOTT, 2003).

Conventional systems are characterized by simplified agroecosystems with the implementation of monocultures. High productivity is achieved, used by large landowners, although losses of biodiversity can happen. There are several downsides to this system, such as: soil degradation, organic matter decline, erosion and compaction because machine traffic with high dependence on external inputs has high costs, overuse of pesticides and fertilizers causing environmental pollution (DONALD, 2004; LEITE et al., 2010; SÁ et al., 2009). This management system fosters the rupture of balance between soil and environment, and may bring negative consequences to the soil changing the physical, chemical and biological attributes of the soil, decreasing the production and increasing the dependence of agricultural fertilizers over time.

Several studies have been conducted in AFSs involving biomass production, carbon storage, nitrogen fixation, growth parameters, morphology, microclimate, water availability, soil parameters, biomass characteristics and decomposition as well as shading (DOSSA et al., 2008; MENDONÇA; STOTT, 2003; OIJEN et al., 2010); however, because of the low yields observed in this system it`s necessary to evaluate the chemical and physical properties of soil, along cultivated with coffee compared to the conventional system, once the information of these attributes in coffee under AFSs are limited.

The chemical and physical attributes of the soil are essential for good coffee nutrition and consequently to obtain good yields over time. Several studies have shown comparisons of productivity, economic gains and social benefits of coffee plantations in agroforestry systems (SOUZA; GRAAFF; PULLEMAN, 2012); however, there are few comparisons of physical and chemical attributes of a same type of soil seamlessly with coffee nutrition.

The aim of this study was to evaluate the physical and chemical attributes of a Red Latosol and the nutritional status of the coffee culture in two management systems: conventional and agroforestry in southern Minas Gerais, Brazil.

2 MATERIAL AND METHODS

Characterization of the study site

The study was conducted in 2008 in the neighborhood of Caiana in two contiguous places of the municipality of Machado, South of Minas Gerais, close to the geographic coordinates 21º 39’ 59” S and 45º 55’ 16” W. The altitude is 900 m and the climate is Cwa, according to Köppen’s classification, presenting mild temperatures, with hot and rainy summer.

The average annual temperature is 21.2 °C, mean monthly maximum of 27 °C and minimum of 14.2 °C, and the average annual rainfall is 1824 mm (MARQUES, 2003). The soil is classified as Red Latosol (EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA - EMBRAPA, 2006), medium texture (273 g kg^{-1} of clay, 459 g kg^{-1} of sand and 268 g kg^{-1} of silt) for coffee plantations under the agroforestry management systems (CAF) and conventional management systems (CC).

Management systems studied

The coffee culture in a conventional system (CC) was established in 1989, spaced 4.0 x 1.0 m, with the cultivar Mundo Novo (*Coffea arabica* L.). For the culture, pits were made to avoid soil disturbance. The soil was always kept covered with invasive plants handled with the application of post-emergence herbicide, twice a year and mechanically, approximately five times a year, with costal motorized grubber.

All cultural practices were performed manually and mineral fertilizers as well as liming were performed as technical recommendations (GUIMARÃES et al., 1999), using NPK formulations (05-20-20), divided in three applications during December to March, according to the chemical analysis of soil and foliar micronutrient fertilization according to leaf analysis.

Coffee culture in agroforestry system (CAF) was established in 1985, with the cultivar Mundo Novo (*Coffea arabica* L.), spaced 3.5 x 1.0 m. In 1998, it was adopted the organic natural production model in agroforestry system in consortium with fruits, eucalyptus and native trees. The bananas and eucalyptus trees grown around the coffee fields serving as windbreaks.

The native trees, fruit trees and annual plants present scattered irregularly between the rows of coffee trees. This crop received total *recepa* in 2001 and has not received application of agricultural inputs since 1997. As of this date, only the management of invasive plants is held with grubber and hoe. Coffee crop nutrition is made by applying coffee straw and leaf litter accumulated through the debris of leaves, spontaneous weeds and twigs from the agroforestry system.

Chemical attributes of the soil

Soil samples were collected with auger for chemical analyses, at the same points samples were collected for physical analyses at the depth of 0–20 cm. Afterthought it was determined the pH (H_2O), phosphorus (P), potassium (K^+), calcium (Ca^{2+}), magnesium (Mg^{2+}) and exchangeable aluminium (Al^{3+}); potential acidity (H^++Al^{3+}), cation exchange capacity (CEC) at pH 7, base saturation (V), organic matter (MOS) and aluminium saturation (m) according to the methodology described by EMBRAPA (2009). The results of the chemical analyses were interpreted according to Guimarães et al. (1999). This sampling was conducted in two plots with different management systems totalizing up 8 samples: (1 depth x 2 management x 4 repetitions). The chemical determinations were performed in a laboratory of soil analysis of the Instituto Federal de Educação, Ciência e Tecnologia do Sul de Minas Gerais - Campus Inconfidentes.

Physical attributes of the soil

Non-deformed samples were collected following the randomized block design, in March 2008, towards the diagonal direction of the coffee plots, in the projection of the top of the tree. The examination of a trench was performed to determine the maximum mechanical resistance layer (CMRM) with a pocket penetrometer, at a depth of 15–18 cm. The non-deformed samples were conducted in two plots with different management systems totalizing up 16 samples: (2 depth x 2 management x 4 repetitions). These samples were collected with an Uhland sampler and aluminum rings of 6.35 cm diameter by 2.54 cm height, at depths of 0–3 cm and 15–18 cm. It was quantified the following attributes: soil density (Ds), total pore volume (VTP), macroporosity (Ma), microporosity (Mi) and the macro and microporosity ratio (Ma/Mi).

Soil density was determined using the Uhland cylinder method (BLAKE; HARTGE, 1986) and particle size analysis using the Bouyoucos method. After saturation, the non-deformed samples were taken to the suction unit at 60 cm water column to obtain matrix potential of -6 kPa on stress table. Then the soil samples were placed in an oven at 105-110 °C for 48 hours to obtain dry soil mass and subsequent determination of the gravimetric water content (EMBRAPA, 1997).

Total porosity was obtained using the following expression: PT = [1 - (Ds/Dp)] according to Vomocil (1965). Microporosity was obtained using the determination of volumetric water content of each sample corresponding to matrix potential of -6 kPa (EMBRAPA, 1997) and macroporosity was obtained by the difference between total porosity and microporosity. The physical analyses were performed at the Department of Soil Science, Federal University of Lavras, in the state of Minas Gerais.

Nutritional Assessments

Leaves of coffee plants cultivated in the place of soil collection were collected to nutritional analyses, totalizing 8 samples. These eaves were from the third and fourth node from the apex to the basis of the plagiotropic branches, in the middle third of the plants in all quadrants totalizing 96 leaves in each repetition. The leaves were washed with deionized water and dried in an oven with forced air circulation at 70 °C until it reached constant weight. The following nutrients were determined: nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), according to the methodology described by EMBRAPA (2009). The leaf analyses were made in the Analysis Laboratory of Soil and Leaf Center for Higher Education and Research Machado, in Minas Gerais state.

Statistical Analysis

Data analysis was performed using software R (R DEVELOPMENT CORE TEAM, 2010) and consisted of the t test to compare the averages of soil attributes in both management systems. The t-test was applied considering two cases, in which the variances were homogeneous and another in which the variances were heterogeneous, verified through Hartley's test.

3 RESULTS AND DISCUSSION

According to the t test, the different management systems changed several chemical attributes of the soil while the physical attributes did not change (Tables 1 and 2). Comparing the physical attributes, between the depths, only the conventional management system presented a significant difference (Table 3).

Chemical attributes of the soil

The Ca^{2+}, Mg^{2+}, V and MOS, had significantly greater contents; and contents of P, H^{+}+Al^{3+}, Al^{3+} e m, had significantly lower levels in the coffee under agroforestry system, when compared to coffee conventional system, while values of K^{+} e CTC did not show any difference (Table 1). The chemical attributes of the soil presented more desirable levels in agroforestry system, in comparison to the conventional system for coffee plantations. The pH values were similar in the different management systems and did not differ significantly.

This result is due through the application of lime based on soil analysis in conventional management, while in agroforestry management, pH maintenance was a result of the complexation of free H^{+} and Al^{3+} by Ca^{2+}, Mg^{2+}, K^{+} and anionic organic compounds from vegetable waste produced on site (AMARAL; ANGHINONI; DESCHAMPS, 2004; PAVINATO; ROSOLEM, 2008).

The low content of P (6.43 mg dm^{-3}) presented for the coffee plantation under agroforestry system is not enough for coffee crop in Brazil (GUIMARÃES et al., 1999), and may be a limiting factor for productivity of this culture system when compared to the conventional system. In agroforestry system, they provide a greater concentration of P in soil due to the intake and maintenance of soil organic matter and favor this element cycling through the reservoir organic phosphorus in the soil (NOGUEIRA et al., 2008); however, this study showed lower levels of P in the soil of agroforestry management, which highlights a probable competition among plants and little is available in these soils.

This result suggests the necessity of a different management, with associations of plants and microorganisms in order to favor the biological processes that increase the available P and improve productivity in agroforestry systems, especially in Latosols, in which, there is high adsorption of this element (LILIENFEIN et al., 2000). The higher content of P presented for coffee under the conventional system can be attributed to the continuous fertilization with phosphate fertilizers, combined with its low mobility in the soil.

The MOS serves to measure imbalances or preservation of agroecosystems; it is used as a criterion to evaluate its sustainability (KAISER; MARTENS; HEINEMEYER, 1995; ROUSSEAU et al., 2012). The AFSs, compared to the conventional monocultures provide the increase of levels of MOS due to the addition of organic materials derived from trees (HAIRIAH et al., 2006; MAIA et al., 2006; SMILEY; KRUSCHEL, 2008). The lowest level of MOS in conventional coffee culture may be related to the smallest amount of locally produced vegetable waste, which makes the decomposition rate greater than the amount of organic waste produced.

The lowest values of H^{+}+Al^{3+} and nulls of Al^{3+} in the ground of agroforestry coffee cultures, may be due to the complexation of Al^{3+} with organic anions released by plant waste (AMARAL; ANGHINONI; DESCHAMPS, 2004; PAVINATO; ROSOLEM, 2008), with improvements of the conditions for plant growth.

The content of Al^{3+} in conventional coffee crop seemed low, and m=14,58 % is pretty below of that tolerated for coffee (25%), according to Guimarães et al. (1999); but higher values found in the agroforestry system proved to be null. The V in conventional coffee (34.23%) is not enough for the coffee culture, with V=60% considered adequate. Coffee agroforestry had a good V=58.63%, indicating that soil fertility is sustainable in this system, probably by recycling nutrients and large accumulation of MOS, don`t requiring corrections.

TABLE 1 - Chemical attributes of a soil cultivated with coffee in conventional management systems (CC) and agroforestry management systems (CAF).

Attribute	Management	Average	Difference	gl	t	p-value
pH	CC	4.99	-0.69	6	-1.47	0.2324
	CAF	5.68				
P (mg dm^{-3})	CC	13.20	6.78	6	6.65*	0.0006
	CAF	6.43				
K^+ (mg dm^{-3})	CC	105.75	-11.50	6	-1.56	0.1707
	CAF	117.25				
Ca^{2+} ($cmol_c$ dm^{-3})	CC	1.73	-2.35	6	-6.08*	0.0009
	CAF	4.08				
Mg^{2+} ($cmol_c$ dm^{-3})	CC	0.75	-0.40	6	-5.66*	0.0013
	CAF	1.15				
H^++Al^{3+} ($cmol_c$ dm^{-3})	CC	6.00	2.19	6	5.28*	0.0116
	CAF	3.81				
	CC	0.50				
Al^{3+} ($cmol_c$ dm^{-3})	CAF	0.00	0.50	6	8.66*	0.0032
	CAF	5.53				
CTC ($cmol_c$ dm^{-3})	CC	8.75	-0.57	6	-1.59	0.1639
	CAF	9.33				
V (%)	CC	34.23	-24.40	6	-7.53*	0.0003
	CAF	58.63				
MOS (g kg^{-1})	CC	1.89	-1.54	6	-3.35*	0.0155
	CAF	3.42				
m (%)	CC	14.58	14.58	6	15.53*	0.0006
	CAF	0.00				

gl-rate of liberty; t-test estimate t; p-is the p-value, when this value is less than 0.04, it means that the two averages that are being compared are statistically different. *significant at 5%.

Physical Attributes of the Soil

The physical attributes of the soil did not differ significantly between conventional and agroforestry management systems (Table 2). This result may be justified by the adoption of soil conservation practices through the management of invasive plants as well as non-revolving of the soil, since the beginning of the implementation of conventional coffee culture, which was expected to present signs of degradation.

The predominant invasive plants on the field were the grasses, maybe it provided beneficial effects to the soil structure (SILVA; SILVA; FERREIRA, 2005).

A study performed by Fialho, Borges and Barros (1991), showed that physical properties of soils were not affected by the use (forest, grassland and eucalyptus) in depth up to 20 cm . Similar results were found by Costa et al. (2003), in a study comparing the physical properties of soil in a management system under direct and conventional preparation with native vegetation. Different results were obtained by Carvalho, Goedert and Armando (2004), in which they found in an agroforestry system with low soil density, higher porosity, when compared to the conventional system. Possibly, this difference is due to the conventional system was cultivated with corn, which often requires soil preparation.

TABLE 2 - Physical attributes of the soil, in conventional management systems (CC) and agroforestry (CAF), in tree top of the coffee tree, at two depths.

Attribute	Management	0–3 cm					15–18 cm				
		Average	Difference	gl	t	p-value	Average	Difference	gl	t	p-value
Ds (Mg m^{-3})	CC	1.19	-0.07	6	-1.51	0.2248	1.29	-0.04	6	-1.09	0.3135
	CAF	1.26					1.33				
VTP (m^3 m^{-3})	CC	0.54	0.04	6	1.57	0.2124	0.49	-0.01	6	-1.19	0.852
	CAF	0.49					0.50				
Ma (m^3 m^{-3})	CC	0.24	0.06	6	2.19	0.0709	0.18	0.01	6	0.28	0.7873
	CAF	0.19					0.17				
Mi (m^3 m^{-3})	CC	0.29	-0.02	6	-1.31	0.2383	0.31	-0.01	6	-0.93	0.3903
	CAF	0.31					0.32				
Ma/Mi	CC	0.84	0.22	6	1.46	0.1938	0.58	0.01	6	0.06	0.9566
	CAF	0.62					0.57				

Ds: soil density; VTP: total pore volume; Ma: macroporosity; Mi: microporosity; Ma/Mi: ratio of macro/microporosity. gl-rate of liberty; t-test estimate t; p-is the t value, when this value is below than 0.05, it means that the two compared averages are statistically different.

TABLE 3 - Physical attributes of the soil between two depths, in the projection of the coffee tree top, in conventional management systems (CC) and agroforestry (CAF).

Attribute	Depth (cm)	CC					CAF				
		Average	Difference	gl	t	p-value	Average	Difference	gl	t	p-value
Ds (Mg m^{-3})	0–3	1.19	-0.11	6	-5.92*	0.001	1.26	-0.07	6	-1.41	0.2082
	15–18	1.29					1.33				
VTP (m^3 m^{-3})	0–3	0.54	0.05	6	5.89*	0.0011	0.49	-0.01	6	0.56	0.5945
	15–18	0.49					0.50				
Ma (m^3 m^{-3})	0–3	0.24	0.06	6	5.46*	0.0016	0.19	0.02	6	0.34	0.742
	15–18	0.18					0.17				
Mi (m^3 m^{-3})	0–3	0.29	-0.02	6	-2.19	0.0709	0.31	-0.01	6	0.56	0.5945
	15–18	0.31					0.32				
Ma/Mi	0–3	0.84	0.2644	6	5.05*	0.0023	0.62	0.05	6	0.28	0.7917
	15–18	0.58					0.57				

Ds: soil density; VTP: total pore volume; Ma: macroporosity; Mi: microporosity; Ma/Mi: ratio of macro/microporosity. gl-rate of liberty; t-test estimate t; p-is the p-value, when this value is less than 0.05, it means that the two averages that are being compared are statistically different. *significant to 5%.

Comparing the depths, soil density presented values significantly higher; the total porosity, the macroporosity and the macro/microporosity ratio had significantly lower values at a depth of 15–18 cm, in comparison to the depth of 0–3 cm, for the coffee culture under conventional system, while in the coffee culture under agroforestry system, there was no difference (Table 3).

This result is due to the less amount of organic material on the surface and subsurface that the conventional system is able to incorporate to the soil, leading to the organic matter decreasing in its profile, when compared to the agroforestry system and consequently interfering on the physical attributes of the soil.

The management of agroforestry systems generates benefits to the soil, such as protection against erosion. It acts assoil protector from the impact of raindrops, provides plant waste disposal, preserves the organic matter and water and contributes positively to the physical attributes of soils (AGUIAR et al., 2006, 2010). Despite the differences in physical attributes found in this study between depths, the values presented by the soil under agroforestry and conventional systems kept within the normal range for the proper development of plants at both depths (HAKANSSON; LIPIEC, 2000; REICHERT et al., 2009).

Nutritional Evaluation

The leaf tissue analysis indicates that the nutrient cycling in agroforestry coffee culture was positive, providing macronutrient contents in leaf tissue similar to those of conventional coffee plantations, with nitrogen content (N) significantly higher and sulfur (S) significantly lower in conventional coffee culture (Table 4).

These results may be directly subjected by the trimming waste agroforestry coffee plantation, in addition to vegetal phytomass produced locally; thus, there are fall and deposition of vegetable waste on the soil and nutrients releasing during the decomposition process (CAMPANHA; SANTOS, 2007; CUNHA et al., 2012).

The trees can extract nutrients from depths of soil not explored by roots of coffee and deposit on the soil surface through the leaf fall, becoming available for coffee (GAMA-RODRIGUES, 2004). Litter formed on the soil surface, improves water infiltration and retention, protects the soil against erosion, provides nutrients and organic matter, that are importants to maintain the productivity (ARATO; MARTINS; FERRARI, 2003; PIRES et al., 2006).

The contents of macronutrients N, K, Ca, Mg were low in both tillage systems, except P that was adequated and S appeared low for conventional coffee (MALAVOLTA, 1992), as per monthly variation in contents for coffee culture.

The low contents presented may possibly be due to the time of collection of leaf tissue, coinciding with the period of fruit growth, which is a strong drain of nutrients, in addition to vegetative growth. Work done by Valarini, Bataglia and Fazuoli (2005), reported that during the period of fruit growth between December and May, there was a decreasing in the content of macronutrients in the leaves, with the exception of Ca which had its content increased.

TABLE 4 - Macronutrient contents in leaf tissue of coffee in conventional (CC) and agroforestry (CAF) systems.

Nutrients (%)	Management	Average	Difference	Gl	t	p-value
N	CC	2.23	0.32	6	4.98*	0.0025
	CAF	1.92				
P	CC	0.18	-0.02	6	-1.96	0.0972
	CAF	0.21				
K	CC	1.55	-0.15	6	-1.57	0.1682
	CAF	1.70				
Ca	CC	0.97	0.05	6	0.92	0.3942
	CAF	0.92				
Mg	CC	0.25	0.00	6	0.08	0.9350
	CAF	0.25				
S	CC	0.15	-0.08	6	-3.61*	0.0113
	CAF	0.23				

gl-rate of liberty; t-test estimate t; p-is the p-value, when this value is lower than 0.05, it means that the two averages that are being compared are statistically different. *significant to 5%.

4 CONCLUSIONS

The agroforestry system exhibited chemical soil attributes more favorable to the coffee culture, compared to the conventional system, with higher concentrations of calcium, magnesium, base saturation and organic matter, except the low available phosphorus. The soil physical properties have not changed between agroforestry and conventional systems but changed between depths only in the conventional system.

The macronutrient content in the leaf tissue of coffee culture under conventional management and agroforestry systems were similar, with the exception of nitrogen and sulfur.

5 ACKNOWLEDGEMENT

To the Instituto Federal do Sul de Minas Gerais (IFSULDEMINAS - Campus Machado) - Brazil, for financial support for this study.

6 REFERENCES

AGUIAR, M. I. et al. Perdas de solo, água e nutrientes em sistemas agroflorestais no município de Sobral, CE. **Revista Ciência Agronômica**, Fortaleza, v. 37, p. 270-278, 2006.

______. Sediment, nutrient and water losses by water erosion under agroforestry systems in the semi-arid region in northeastern Brazil. **Agroforestry Systems**, Heidelberg, v. 79, p. 277-289, 2010.

AMARAL, A. S.; ANGHINONI, I.; DESCHAMPS, F. C. Resíduos de plantas de cobertura e mobilidade dos produtos da dissolução do calcário aplicado na superfície do solo. **Revista Brasileira de Ciência do Solo**, Viçosa, v. 28, n. 1, p. 115-123, jan./fev. 2004.

ARATO, H. D.; MARTINS, S. V.; FERRARI, S. H. S. Produção e decomposição de serrapilheira em um sistema agroflorestal implantado para recuperação de área degradada em Viçosa, MG. **Revista Árvore**, Viçosa, v. 27, n. 5, p. 715-721, set./out. 2003.

BLAKE, G. R.; HARTGE, K. H. Bulk density. In: KLUTE, A. (Ed.). **Methods of soil analysis:** part 1, physical and mineralogical methods. 2nd ed. Madison: American Society Agronomy, 1986. p. 363-375. (Agronomy Monograph, 9).

CAMPANHA, M. M.; SANTOS, R. H. S. Análise comparativa das características da serrapilheira e do solo em cafezais (*Coffea arabica* L.) cultivados em sistema agroflorestal e em monocultura na Zona da Mata, MG. **Revista Árvore**, Viçosa, v. 31, n. 5, p. 805-812, set./out. 2007.

CARVALHO, R.; GOEDERT, W. J.; ARMANDO, M. S. Atributos físicos da qualidade de um solo sob sistema agroflorestal. **Pesquisa Agropecuária Brasileira**, Brasília, v. 39, n. 11, p. 1153-1155, nov. 2004.

COSTA, F. S. et al. Propriedades físicas de um Latossolo Bruno afetadas pelos sistemas plantio direto e preparo convencional. **Revista Brasileira de Ciência do Solo**, Viçosa, v. 27, n. 3, p. 527-535, maio/jun. 2003.

CUNHA, E. Q. et al. Atributos físicos, químicos e biológicos de solo sob produção orgânica impactados por sistema de cultivo. **Revista Brasileira de Engenharia Agrícola e Ambiental**, Campina Grande, v. 16, n. 1, p. 56-63, jan. 2012.

DONALD, P. F. Biodiversity impacts of some agricultural commodity production systems. **Conservation Biology**, Boston, v. 18, n. 1, p. 17-37, Feb. 2004.

DOSSA, E. L. et al. Above and belowground biomass, nutrient and carbon stocks contrasting an open-grown and a shaded coffee plantation. **Agroforestry Systems**, Heidelberg, v. 72, p. 103-115, 2008.

EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA. **Manual de análises químicas de solos, plantas e fertilizantes**. 2. ed. Brasília, 2009. 628 p.

______. **Sistema brasileiro de classificação de solos**. 2. ed. Rio de Janeiro, 2006. 306 p.

EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA. Centro Nacional de Pesquisas de Solos. **Manual de métodos de análise de solo**. 2. ed. Rio de Janeiro, 1997. 212 p.

FIALHO, J. F.; BORGES, A. C.; BARROS, N. F. Cobertura vegetal e características químicas e físicas e atividade da microbiota de um solo vermelho-amarelo distrófico. **Revista Brasileira de Ciência do Solo**, Viçosa, v. 15, n. 1, p. 21-28, 1991.

FRANZLUEBBERS, A. J. Water infiltration and soil structure related to organic matter and its stratification with depth. **Soil Tillage Research**, Amsterdam, v. 66, n. 2, p. 197-205, Sept. 2002.

GAMA-RODRIGUES, A. C. Ciclagem de nutrientes em sistemas agroflorestais na região tropical: funcionalidade e sustentabilidade. In: MÜLLER, M. W. et al. (Org.). **Sistemas agroflorestais, tendência da agricultura ecológica nos trópicos:** sustento da vida e sustento de vida. Ilhéus: SBSAF/CEPLAC/UENF, 2004. p. 64-84.

GUIMARÃES, P. T. G. et al. Cafeeiro. In: RIBEIRO, A. C.; GUIMARÃES, P. T. G.; ALVAREZ-VENEGAS, V. H. (Ed.). **Recomendação para o uso de corretivos e fertilizantes em Minas Gerais:** 5ª aproximação. Viçosa, MG: CFSEMG, 1999. p. 289-302.

HAGGAR, J. et al. Coffee agroecosystem performance under full sun, shade, conventional and organic management regimes in Central America. **Agroforestry Systems**, Heidelberg, v. 82, p. 285-301, Mar. 2011.

HAIRIAH, K. et al. Litter layer residence time in forest and coffee agroforestry systems in Sumberjaya, West Lampung. **Forest Ecology and Management**, Amsterdam, v. 224, n. 2, p. 45-57, Mar. 2006.

HAKANSSON, I.; LIPIEC, J. A review of the usefulness of relative bulk density values in studies of soil structure and compaction. **Soil and Tillage Research**, Amsterdam, v. 53, n. 2, p. 71-85, Jan. 2000.

KAISER, E. A.; MARTENS, R.; HEINEMEYER, O. Temporal changes in soil microbial biomass carbon in an arable soil. **Plant and Soil**, The Hague, v. 170, n. 2, p. 287-295, Mar. 1995.

LEITE, L. F. C. et al. Soil organic carbon and biological indicators in an Acrisol under tillage systems and organic management in north-eastern Brazil. **Australian Journal of Soil Research**, Melbourne, v. 48, p. 258-265, 2010.

LILIENFEIN, J. et al. Chemical fractionation of phosphorus, sulphur, and molybdenum in Brazilian savannah Oxisols under different land use. **Geoderma**, Amsterdam, v. 96, n. 2, p. 31-46, May 2000.

LIMA, S. S. et al. Estoques da serrapilheira acumulada e teores de nutrientes em Argissolo sob manejo agroflorestal no norte do Piauí. **Revista Árvore**, Viçosa, v. 34, n. 1, p. 75-84, jan./fev. 2010.

MAIA, S. M. F. et al. Impactos de sistemas agroflorestais e convencional sobre a qualidade do solo no semi-árido cearense. **Revista Árvore**, Viçosa, v. 30, n. 5, p. 837-848, set./out. 2006.

______. Organic carbon pools in a Luvisol under agroforestry and conventional farming systems in the semi-arid region of Ceará, Brazil. **Agroforestry Systems**, Heidelberg, v. 71, p. 27-38, Apr. 2007.

MALAVOLTA, E. **ABC da análise de solo e folhas**. São Paulo: Agronômica Ceres, 1992. 124 p.

MARQUES, H. S. **Uso de geotecnologias no estudo das relações entre solos, orientação de vertentes e o comportamento espectral de áreas cafeeiras em Machado, Minas Gerais**. 2003. 82 p. Dissertação (Mestrado em Solos e Nutrição de plantas) - Universidade Federal de Lavras, Lavras, 2003.

MENDONÇA, E. S.; STOTT, D. E. Characteristics and decomposition rates of pruning residues from a shaded coffee system in Southeastern Brazil. **Agroforestry Systems**, Heidelberg, v. 57, n. 2, p. 117-125, 2003.

NOGUEIRA, R. S. et al. Formas de fósforo em Luvissolo Crómico Órtico sob sistemas agroflorestais no município de Sobral, CE. **Revista Ciência Agronômica**, Fortaleza, v. 39, n. 4, p. 494-502, out./dez. 2008.

OIJEN, M. et al. Coffee agroforestry systems in Central America: I., a review of quantitative information on physiological and ecological processes. **Agroforestry Systems**, Heidelberg, v. 80, n. 3, p. 341-359, 2010.

PAVINATO, O. S.; ROSOLEM, C. A. Disponibilidade de nutrientes no solo-decomposição e liberação de compostos orgânicos de resíduos vegetais. **Revista Brasileira de Ciência do Solo**, Viçosa, v. 32, n. 3, p. 911-920, maio/jun. 2008.

PIMENTEL, D. et al. Environmental, energetic, and economic comparisons of organic and conventional farming systems. **BioScience**, Washington, v. 55, n. 7, p. 573-582, July 2005.

PIRES, L. S. et al. Erosão hídrica pós-plantio em florestas de eucalipto na região centro-leste de Minas Gerais. **Pesquisa Agropecuária Brasileira**, Brasília, v. 41, n. 4, p. 687-695, abr. 2006.

R DEVELOPMENT CORE TEAM. **R:** a language and environment for statistical computing. Version 12.2.1. Vienna: R Foundation for Statistical Computing, 2010. Available from: <http://www.R-project.org/>. Access in: 12 June 2010.

REICHERT, J. M. et al. Variação temporal de propriedades físicas do solo e crescimento radicular de feijoeiro em quatro sistemas de manejo. **Pesquisa Agropecuária Brasileira**, Brasília, v. 44, n. 3, p. 310-319, mar. 2009.

ROUSSEAU, G. X. et al. Indicating soil quality in cacao-based agroforestry systems and old-growth forests: the potential of soil macrofauna assemblage. **Ecological Indicators**, London, v. 23, n. 2, p. 535-543, May 2012.

SÁ, J. C. M. et al. Soil organic carbon and fertility interactions affected by a tillage chronosequence in a Brazilian Oxisol. **Soil & Tillage Research**, Amsterdam, v. 104, n. 1, p. 56-64, June 2009.

SILVA, R. R.; SILVA, M. L. N.; FERREIRA, M. M. Atributos físicos indicadores da qualidade do solo sob sistemas de manejo na bacia do alto do Rio Grande, MG. **Ciência e Agrotecnologia**, Lavras, v. 29, n. 4, p. 719-730, jul./ago. 2005.

SMILEY, G. L.; KROSCHEL, J. Temporal change in carbon stocks of cocoa-gliricidia agroforests in Central Sulawesi, Indonesia. **Agroforestry Systems**, Heidelberg, v. 73, n. 3, p. 219-231, 2008.

SOUZA, H. N.; GRAAFF, J.; PULLEMAN, M. M. Strategies and economics of farming systems with coffee in the Atlantic Rainforest Biome. **Agroforestry Systems**, Heidelberg, v. 84, n. 3, p. 227-242, 2012.

TIAN, G.; KANG, B. T.; BRUSSAARD, L. Biological effects of plant residues with contrasting chemical compositions under humid tropical conditions-decomposition and nutrient release. **Soil Biology & Biochemistry**, Elmsford, v. 24, n. 10, p. 1051-1060, Apr. 1992.

VALARINI, V.; BATAGLIA, O. C.; FAZUOLI, L. C. Macronutrientes em folhas e frutos de cultivares de café *arábica* de porte baixo. **Bragantia**, Campinas, v. 64, n. 4, p. 661-672, 2005.

VOMOCIL, J. A. Porosity. In: BLAKE, C. A. (Ed.). **Methods of soil analysis**. Madison: American Society of Agronomy, 1965. p. 499-510.