STOCKS AND OXIDIZABLE FRACTIONS OF SOIL ORGANIC MATTER UNDER ORGANIC COFFEE AGROFORESTRY SYSTEMS

Gabriel Pinto Guimarães[1], Eduardo de Sá Mendonça[2], Renato Ribeiro Passos[3], Felipe Vaz Andrade[4]

(Recebido: 16 de janeiro de 2013; aceito: 17 de setembro de 2013)

ABSTRACT: Research evaluating the impact of different management systems coffee are essential for determining soil quality. The objective of this study was to evaluate the impact of production systems for organic coffee and agroforestry on stocks of carbon, nitrogen and organic matter quality in two farms in the region Caparaó- Espírito Santo- Brazil. In farm 1 systems were evaluated primary forest, organic coffee and conventional coffee. In farm 2 systems were evaluated secondary forest, organic coffee intercropped with inga, organic coffee intercropped with leucaena and inga, organic coffee intercropped cedar and conventional coffee full sun. Soil samples were collected in canopy projection coffee in the depths 0-10, 10-20, 20-40, 40-60 and 60-100 cm. The C and N stock reflected the management history in relation to forest areas, with the greatest impact in the 0-10 cm. This depth, to the farm 1, the conventional coffee obtained reductions of 27.3 % and 14.9 % respectively in C and N stocks in relation to organic coffee. For farm 2, reductions in C and N stocks the coffee conventional full sun in relation to agroforestry coffee were 22.1 % and 31.4 %, respectively. The C stocks accumulated were reduced in coffee systems in 28.6 % and 17.4 % respectively in relation to primary and secondary forests. The mineralizable C content was higher in the soil surface layers and in the organic coffee systems compared to conventional coffee, in the farm 2. The coffee agroforestry system provided higher carbon management index in relation to organic coffee without consortium and conventional coffee, providing better soil quality.

Index terms: Organic coffee, agroforestry system, lability of organic matter, soil quality.

ESTOQUES E FRAÇÕES OXIDÁVEIS DA MATÉRIA ORGÂNICA DO SOLO, SOB CAFEEIROS EM SISTEMAS ORGÂNICOS AGROFLORESTAIS

RESUMO: *Pesquisas avaliando o impacto de diferentes sistemas de manejo do cafeeiro são essenciais para determinação da qualidade do solo. Objetivou-se, neste trabalho, avaliar o impacto de sistemas de produção de cafeeiro orgânico e agroflorestal sobre os estoques de carbono, nitrogênio e a qualidade da matéria orgânica em duas propriedades rurais na região do Caparaó- Espírito Santo- Brasil. Na propriedade 1, foram avaliados os sistemas mata primária, café orgânico e café convencional. Na propriedade 2, foram avaliados os sistemas mata secundária, café orgânico consorciado com ingá, café orgânico consorciado com ingá e leucena, café orgânico consorciado com cedro e café convencional a pleno sol. As amostras de solo foram coletadas na projeção da copa do cafeeiro nas profundidades 0-10, 10-20, 20-40, 40-60 e 60-100 cm. O estoque de carbono orgânico total (estoque C) e nitrogênio total (estoque N) refletiram o histórico de manejo com maior impacto na camada 0-10 cm. Nessa profundidade, para a propriedade 1, o cafeeiro convencional obteve reduções de 27,3% e 14,9%, respectivamente no estoque C e estoque N em relação ao cafeeiro orgânico; para a propriedade 2, as reduções no estoque C e estoque N do cafeeiro convencional a pleno sol, em relação aos cafeeiros agroflorestais, foram de 22,1% e 31,4%, respectivamente. Os estoques de C acumulados foram reduzidos nos sistemas cafeeiros em 28,6% e 17,4% em relação às matas primária e secundária, respectivamente. Os teores de C mineralizável foram maiores nas camadas superficiais do solo e nos sistemas de café orgânico, em relação ao café convencional, na propriedade 2. O sistema cafeeiro agroflorestal proporcionou maior índice de manejo do carbono, em relação ao cafeeiro orgânico sem consórcio e convencional, proporcionando melhor qualidade do solo.*

Termos para indexação: *Cafeicultura orgânica, sistema agroflorestal, labilidade da matéria orgânica, qualidade do solo.*

1 INTRODUCTION

The state of Espírito Santo - Brazil has great importance in national agricultural scenario, especially for the production of coffee. The Territory of Caparaó (TC) due to favorable conditions for the cultivation of Arabica coffee is considered one of the main producing regions of the State (ESPÍRITO SANTO, 2008). The TC belong to the Atlantic Rainforest biome, one of the five biodiversity hotspots of Brazil (MYERS et al., 2000), however, indiscriminate deforestation for introduction of crops meant that nowadays only 12-14% was left of the original biome (RIBEIRO et al., 2009).

[1]Universidade Federal do Espírito Santo/UFES - Departamento de Produção Vegetal do Centro de Ciências Agrárias/CCA-UFES Alto Universitário s/n - 29500-000 - Alegre-ES - gabryelpg@yahoo.com.br
[2]Universidade Federal do Espírito Santo/UFES - Departamento de Produção Vegetal do Centro de Ciências Agrárias/CCA-UFES Alto Universitário s/n - 29500-000 - Alegre - ES - eduardo.mendonca@ufes.br
[3]Universidade Federal do Espírito Santo/UFES - Departamento de Produção Vegetal do Centro de Ciências Agrárias/CCA-UFES Alto Universitário s/n - 29500-000 - Alegre - ES - renatoribeiropassos@hotmail.com
[4]Universidade Federal do Espírito Santo/UFES - Departamento de Produção Vegetal do Centro de Ciências Agrárias/CCA-UFES Alto Universitário s/n - 29500-000 - Alegre -ES - felipevazandrade@gmail.com

The substitution of natural ecosystems by crops reduce the input of plant biomass and increase the loss of nutrients and soil organic matter (SOM) (NUNES et al., 2009). This process reduces the stock of total organic carbon (TOC) in the agroecosystems (RANGEL et al., 2008) occurring losses that can reach 50% of the initial content in less than 10 years of soil cultivation (MIELNICZUK et al., 2003).

The same way the carbon (C), most of the nitrogen (N) in the soil is found in the organic form (over 95%) and the SOM forms an important reservoir of potentially available N to plants. Thus, reductions in soil N stocks may occur to the detriment of the replacement of native vegetation with crops. In addition to the reductions in C and N stocks, the introduction of agricultural activities alters the chemical composition SOM, mainly its degree of oxidation and lability (BLAIR; LEFROY; LISLE, 1995; WENDLING et al., 2008). The labile C is present in organic compounds of easy mineralization by soil microorganisms, which may represent, in some environments, 50% of TOC (BLAIR; LEFROY; LISLE, 1995).

The loss of quantity and quality of SOM may compromise the sustainability of agroecosystems, since the greater availability of organic compounds in the soil may increases the cationic exchange capacity, microbial activity, reduce the negative effects of exchangeable aluminum and reduce the adsorption of phosphate to soil colloids (RANGEL et al., 2008).

By exert an important role in the input of organic residues and, consequently, in the SOM stocks and quality, organic and agroforestry systems have gained prominence in recent years due to the sustainable use of soil and environment (CARDOSO; SOUZA; MENDONÇA, 2005; GIOMO; PERREIRA; BLISKA, 2007). But, there is a lack of studies on the impact of these systems on SOM in TC. These systems by prioritizing organic residue inputs have proven effective in increasing the stock of soil C and N close to natural forest conditions (FAVERO; LOVO; MENDONÇA, 2008).

The objective of this study was to evaluate the impact of coffee production under organic and agroforestry systems on the C and N stock and degree of organic C oxidation of two dystrophic Red-Yellow Latosol.

2 MATERIAL AND METHODS

Characterization of the study sites

The study was developed in two farms in agroecological transition from the Territory Caparaó (TC). The farm 1, located in Santa Clara County, the city of Iúna-ES, geographic coordinates of 20º24'10, 5'' S, 41°58'1'' W and altitude of 839 m. It has 14 ha of Arabica coffee under conventional system and 1 ha under organic system, both implemented in 2000. Before the coffee, the area was occupied for 10 years with eucalyptus. At that time, the eucalyptus was cultivated on the (*Brachiaria decumbens* cv. Basilisk) who had occupied the area for 30 years. During this period, the pasture was utilized extractive, that is, were not carried out specific cultural practices. The mowing was held once a year, this being the only management done in the pasture as a method of controlling spontaneous plants. For eucalyptus, holes were opened with mattock and planted seedlings of the variety Cloesiana in the spacing of 10 x 10 m. Thus, there was no great movement of soil with crops. The field of the conventional coffee occupies an area of 1,2 ha with a slope of 33%, spacing of 2,6 x 1 m, Red Catuai variety cultivated by 11 years. Since its implementation the site received t two annual applications of NPK (20-05-20), single super phosphate and liming every two years according to soil analysis. The spontaneous plants were controlled with glyphosate (1.3 L ha^{-1} herbicide commercial) and mowing. The coffee was manually harvested. The site of organic coffee has 17% slope, spacing of 2,8x1 m, Red Catuai variety. The organic fertilizers, produced in farm, were annually applied in canopy projection coffee. The liming was added every two years according to soil analysis. Between the years 2001 to 2007 the fertilizer was applied via organic compost (10 dm^3 per hole), in 2007 there was green fertilization with jackbean (*Canavalia ensiformis* DC.) and between the years 2008 to 2011 the fertilizer was applied with manure corral tanned (10 dm^3 per hole), bovine urine fermented applied in plant and coffee straw. The spontaneous plants were mowing, pests and diseases were controlled with products registered by the state certification "Chão Vivo". The field under organic management is certified since 2005. Plant residues from the weeding and harvesting are returned to the crown projection coffee.

The farm 2 is 12 km away from the farm 1, located in the municipality of Irupi-ES, geographic coordinates 20°21'18'' S, 41º40 '07'' W and altitude of 907 m. It has 9 ha with arabica coffee grown under conventional system and 2 ha under organic management intercropped with trees, both implanted in 1998. Before the implementation of the coffee plantations the area was occupied by another coffee plantation approximately 20 years, however, before the coffee, the area was managed for 30 years with pasture. The mowing was performed once a year, this being the only management done in the pasture as a method of controlling spontaneous plants. The field of the conventional coffee has an area of 2,4 ha, 16% slope, 3x2 m spacing, Red Catuai variety, cultivated by 13 years. The soil management since its implementation was liming held every two years, two annual applications of NPK (20-00-20) and super simple according to soil analysis. The control of pests and diseases is carried whenever necessary with use of agrochemical from external farming inputs. Examples of commercial products that were used when necessary: bidrin to the coffee leaf miner, impact to rust coffee and amistar to fhoma. The control spontaneous plants with mowing and glyphosate applied once a year (1,0 L ha^{-1} of the commercial herbicide), the coffee harvest performed manually. The coffee under organic managements has intercropped with trees, slope of 17%, 3x2 m spacing, Red Catuai variety. The transition process lasted three years and ended in 2005. The organic fertilizer consisted of two applications yearly of 8 dm^3 per hole of organic compost and fermented cattle urine. In 2006 there was also green fertilization with jackbean (*Canavalia ensiformis*). The arrangement of trees in the coffee under organic management is: coffee intercropped with inga (*Inga sessilis*), coffee intercropped with inga (*Inga sessilis*) and leucaena (*Leucaena leucocephala* (Lam.) de Wit [L. glauca (L.) Benth.] cv Peru), coffee intercropped with Australian cedar (*Troona ciliata* var. *australis* (F.v.M.) C.DC) and the coffee under full sun. The trees were planted between the lines of the coffee. The ingá planted in 2007 at a spacing of 5x5 m (400 trees/ ha), the leucaena planted in 2006 with 5x5 m spacing (400 trees/ ha), and cedar planted in 2005 with 3x5 m spacing (667 trees/ ha). The management of spontaneous plants was done with mowing and hoe, diseases with products registered by the certifying state and harvesting done manually. The plant remains from the weeding and harvesting of organic systems agroforestry were left between rows of coffee.

Managements systems evaluated

The treatments consisted of two management systems on farm 1, organic (ORG1) and conventional (CON1) and four management systems on farm 2, organic intercropped with ingá (ORG/IN2), organic intercropped with ingá and leucaena (ORG/IN/LE2), organic intercropped with cedar (ORG/CED2) and conventional full sun (CON2) with three replications for each system. In each farm, as a reference for data comparison, soil samples were collected in forest areas near the coffee. In farm 1, was collected in primary forest with no history of human interference (MP1). In farm 2, it was used an area of secondary forest (MS2) since there was not a primary forest surround the coffee. The MS2 area was left for revegetation in 1980 with deployment of some native species of the Atlantic Forest.

Soil sampling

In the middle third of each area it was demarcated a plot of approximately 0.25 ha. Each plot had three experimental portions of about 110 m^2 for farm 1 (1 m spacing between plants) and 240 m^2 for the farm 2 (2 m spacing between plants). Each plot comprised 5 rows with each row 10 coffee plants. Sampling was carried out in the middle of each plot where initially opened a trench of 1 m deep and performed the collection of soil samples at depths 0-10, 10-20, 20-40, 40-60 and 60-100 cm. In forest fragments were opened three trenches and performed the same procedure for sampling the coffee area. For the physical and chemical characterization of the soil (Table 1), three samples of the A and B horizons were collected separately.

TABLE 1 - Average values (n =3) of the physical and chemical characteristics of the A and B horizons of two properties under different tillage systems of coffee.

Systems	sand	silt	clay	pH	SB	t	T	V
	---------------gkg^{-1} ------------				--------cmol^{c} dm^{-3} -------			%
	-----Horizon A -----							
MP1	375	194	431	4,33	1,47	3,05	18,05	7,97
ORG1	428	184	388	4,99	2,71	3,14	8,65	32,39
CON1	550	105	345	5,27	3,09	3,16	8,71	35,49
MS2	487	120	393	5,67	2,41	2,46	6,65	36,24
ORG/IN2	476	72	452	6,57	3,28	3,28	5,32	62,31
ORG/IN/LE2	500	65	435	6,13	3,29	3,29	6,87	46,82
ORG/CED2	373	68	559	5,53	1,73	1,78	6,35	27,28
CON2	408	56	536	6,77	3,35	3,35	4,94	68,15
	-----Horizon B -----							
MP1	360	181	459	4,56	0,41	1,39	10,42	4,16
ORG1	373	211	416	4,47	1,22	2,45	8,42	13,96
CON1	403	150	447	4,44	0,91	1,47	6,30	14,46
MS2	384	135	481	5,23	1,38	1,86	5,84	22,84
ORG/ IN2	397	76	527	5,83	1,66	1,85	4,76	39,89
ORG/ IN/ LE2	395	80	525	5,13	0,69	0,95	4,76	14,53
ORG/ CED2	302	76	622	4,60	0,49	1,15	5,54	8,66
CON2	351	61	588	5,26	1,58	1,82	5,87	25,28

Texture: the pipette method, pH: soil-water (1:2.5), SB: base sum, t: CEC effective, T: CEC total, V: base saturation. Farm 1: Primary Mata (MP1), Organic Coffee (ORG1) and Conventional Coffee (CON1). Farm 2: Secondary Mata (MS2), Organic Coffee intercropped with Inga (ORG/IN2), Organic Coffee intercropped with Inga and Leucena (ORG/IN/LE2), organic Coffee intercropped with cedar (ORG/CED2) and Conventional Coffee (CON2).

Dependent variables evaluated

The contents of total organic carbon (TOC) were determined by the method described in Yeomans and Bremner (1988) and total nitrogen (TN) by the method Tedesco et al. (1995). With these data we calculated the C and N stocks at each depth and the accumulated stock in 0-100 cm depth. The stocks were calculated by the following formula: stock (Mg ha^{-1}) = content (g kg^{-1}) x Ds x E/10, where Ds = density at depth (kg dm^{-3}) and, E = thicknessof the soil layer (cm).

The oxidizable organic carbon was determined according to Chan, Bowman and Oates (2001). Four fractions C were obtained varying the H_2SO_4 concentration in the oxidation process with dichromate. The C content in the fraction F1+F2 was considered as soil labile carbon (C_L) or mineralization, whereas the non-labile carbon (C_{NL}) was obtained by the sum of the F3+F4 (C_{NL}). The Compartment Carbon Index (CCI) was estimated to know how much TOC was lost with cultivation (CCI) =TOC cultivated /TOC reference. The C lability (L) was measured by the equation L =C_L / C_{NL}, Lability Index (LI) =Lcultivated / Lreference and Carbon Management Index (CMI) = CCI x IL x 100 according to Blair, Lefroy e Lisle (1995).

Statistical Analysis

Comparisons involving the management systems and the areas under forest were obtained through contrasts arising from the split of 2 degrees of freedom for treatment in farm 1 (MP1, ORG1 and CON1) and 4 degrees of freedom for treatment in farm 2 (MS2, ORG/IN2, ORG/IN/LE2, ORG/CED2 and CON2) (Table 2). The significance of contrasts with one degree of freedom was tested by F test (P <0.15, 0.05 and 0.01) obtained by analysis of variance in a completely randomized design using the statistical program Sisvar.

The contrasts C1 and C2 are related to farm 1: C1 compared native forest to the coffee systems; and C2 compared the organic coffee system to the conventional coffee system. The contrasts C3 and C4 refer to the farm 2: C3 compared secondary forest to the coffee systems; C4 evaluated coffee agroforestry systems to conventional coffee system.

3 RESULTS AND DISCUSSION

The data of C and N stocks are presented in Table 3. The MP1 and MS2 have obtained C stock higher compared to coffee systems (Table 3, C1 and C3), however, in the MS2, the N stocks not differ in relation to coffee systems (Table 3, C3).

The ORG1 was obtained, compared to CON1, higher C stock in the surface layer 0-10 cm and higher N stock in layer 10-20 cm (Table 3, C2). Agroforestry systems favored an increase in C and N stock compared to conventional at 0-10 cm (Table 3, C4).

Analyzing the accumulated stock up to 1 meter deep it was not found effect among management organic and conventional systems on the C and N stock (Table 4, C2). Differently, the coffee under agroforestry systems reached C stock of 34,07 Mg ha^{-1} superior in relation to CON2. For N stock, coffee under agroforestry systems obtained 1,97 Mg ha^{-1} higher than the CON2 (Table 4, C4).

TABLE 2 - Contrasts (C) used in the comparison between the different management systems.

Systems	C1	C2	C3	C4
MP1	2	0	-	-
ORG1	-1	1	-	-
CON1	-1	-1	-	-
MS2	-	-	4	0
ORG/IN2	-	-	-1	-1
ORG/IN/LE2	-	-	-1	-1
ORG/CED2	-	-	-1	-1
CON2	-	-	-1	3

Farm 1: Primary Mata (MP1), Organic Coffee (ORG1) and Conventional Coffee (CON1). Farm 2: Secondary Mata (MS2), Organic Coffee intercropped with Inga (ORG/IN2), Organic Coffee intercropped with Inga and Leucena (ORG/IN/LE2), organic Coffee intercropped with cedar (ORG/CED2) and Conventional Coffee (CON2).

TABLE 3 - Averages carbon stock (C stock) and nitrogen stock (N stock), values and significance of contrasts at depths 0-10, 10-20, 20-40, 40-60 and 60-100 cm in two farms under different tillage systems of coffee.

Systems/ Contrasts	C stock	N stock	C stock	N stock	C stock	N stock	C stock	N stock	C stock	N stock
	0 - 10		10 - 20		20 - 40		40 - 60		60 - 100	
	------------------ Mg ha^{-1} ------------------									
MP1	60,19	3,14	59,97	2,32	121,04	3,86	75,98	2,74	113,80	4,73
ORG1	56,41	2,47	36,41	1,73	57,43	2,03	61,21	1,96	97,13	3,44
CON1	41,01	2,10	33,09	1,08	65,85	2,04	57,10	1,95	110,02	3,30
MS2	50,19	1,65	42,26	1,34	67,13	1,97	55,56	1,55	88,95	2,78
ORG/IN2	40,49	1,33	37,00	0,99	45,64	1,75	37,40	1,46	93,04	2,76
ORG/IN/LE2	47,92	2,22	37,15	1,43	58,70	2,07	42,82	1,68	71,31	2,50
ORG/CED2	43,60	1,61	36,70	1,14	53,98	1,77	45,45	1,54	87,55	2,93
CON2	34,27	1,18	27,29	0,87	41,61	1,50	47,39	1,35	74,94	2,19
					Contrastes					
C1	22,9 *	1,7 *	50,4 **	1,8 **	119 **	3,7 **	33,7 *	1,9 $^{\#}$	20,5 $^{\#}$	2,7 $^{\#}$
C2	15,4 *	0,4 ^{ns}	3,3 ^{ns}	0,7 *	-8,4 ^{ns}	-0,01 ^{ns}	4,11 ^{ns}	0,3 ^{ns}	-12,9 ^{ns}	0,14 ^{ns}
C3	34,5 *	0,3 ^{ns}	30,9 $^{\#}$	0,9 $^{\#}$	68,6 *	0,8 ^{ns}	49,2 **	0,2 ^{ns}	28,9 ^{ns}	0,8 ^{ns}
C4	-29,2 *	-1,6 **	-28,3 $^{\#}$	-0,9 $^{\#}$	-33,5 $^{\#}$	-1,1 $^{\#}$	16,5 ^{ns}	-0,6 $^{\#}$	-27,0 ^{ns}	-1,6 **

Farm 1- Mata Primary (MP1), Organic Coffee (ORG1) and Conventional Coffee (CON1). C1 = (CON1-2MP1-ORG1), C2 = (CON1-ORG1). Farm 2 - Secondary Forest (MS2), Organic Coffee intercropped with inga (ORG/IN2), Organic Coffee intercropped with leucaena and inga (ORG/IN/LE2), Organic Coffee intercropped with cedar (ORG/CED2), Café Conventional (CON2). C3 = (4MS2-ORG/IN2- ORG/IN/LE2- ORG/CED2-CON2), C4 = (3CON2-ORG/IN2- ORG/IN/LE2- ORG/CED2). ns, #, *, **: not significant, significant at 15, 5 and 1%, respectively, for test F.

The data of oxidizable organic carbon are presented in Table 5. The coffee systems reduced the levels of C_L, C_{NL} and the values of L and LI providing a reduction of SOM quality (Table 5, C1 and C3). Due that, the coffee systems had the lowest amount of SOM (lower CCI) providing a lower CMI.

The C_L content in the soil was not increased in ORG1system in relation to CON1, but the content C_{NL} was higher at 0-10 cm depth. Despite the greater CCI in the ORG1, values of IL were lower in the 0-10 and 20-40 cm (Table 5, C2). These data show the exchange of nutrient that is characterized for conversion from chemical to organic management of the coffee, did not provide higher nutrient cycling in the coffee system. Differently, the coffee system under agroforestry presented in relation to CON2 increases in the values of LI in the 0-10 cm and also increases in the CCI at 10-20 and 20-40 cm, providing greater CMI (Table 5, C4).

The coffee cultivation after deforestation in the Atlantic Forest reduced the C and N stocks with greater impacts on conventional management. However, the data of the coffee agroflorestry no significance in N stocks at each depth and accumulation in relation to MS2, demonstrates that the coffee agroforestry system is retrieving the SOM stocks tending to balance its stocks.

Rangel, Silva and Guimarães (2007) working with medium textured Latosol cultivated for 11 years with conventional Arabica coffee in the same biome under different planting spacing reported reductions of 45% in C stocks and 30% in N stocks in relation to the soil under forestry in 0-10 cm depth. Other data of coffee under different agroforestry arrangements in the same biome (MENDONÇA et al., 2001; WENDLING et al., 2008) indicate that the ability of agroforestry to improve C and N stocks in the soil is strongly dependent to number and type of trees.

TABLE 4 - Average carbon stock (C stock 100) and average nitrogen stock (N stock 100), value and significance of the contrasts in the 0-100 cm depth of two farms under different tillage systems of coffee.

Systems	C stock100	N stock100	Contrasts	Value and significance the contrasts for the C stock	Value and significance the contrasts for the N stock
	Mg ha^{-1}				
				0-100 cm	
MP1	430,98	16,79			
ORG1	308,59	11,61			
CON1	307,09	10,31	C1	246,28 **	11,65 *
			C2	1,50 ^{ns}	1,30 ^{ns}
MS2	304,09	9,30			
ORG/IN2	253,56	8,29	C3	212,09 **	2,94 ^{ns}
ORG/IN/LE2	257,89	9,90	C4	-102,21 *	-5,89 *
ORG/CED2	267,29	8,98			
CON2	225,51	7,09			

Farm 1- Mata Primary (MP1), Organic Coffee (ORG1) and Conventional Coffee (CON1). C1 = (CON1-2MP1-ORG1), C2 = (CON1-ORG1). Farm 2 - Secondary Forest (MS2), Organic Coffee intercropped with inga (ORG/IN2), Organic Coffee intercropped with leucaena and inga (ORG/IN/LE2), Organic Coffee intercropped with cedar (ORG/CED2), Café Conventional (CON2). C3 = (4MS2-ORG/IN2- ORG/IN/LE2- ORG/CED2-CON2), C4 = (3CON2-ORG/IN2- ORG/IN/LE2- ORG/CED2). ns, #, *, **: not significant, significant at 15, 5 and 1%, respectively, for test F.

Agroforestry systems obtained higher stocks in relation to CON2, increasing by 15.1% and 27.4% respectively in C and N stocks until 1 meter deep. The higher stocks obtained in the coffee under agroforestry systems are due to organic fertilization with compost and constant input of plant biomass from aerial and root pools as shown in a different place (MENDONÇA et al., 2001). Agroforestry also provides reduction of water erosion, favoring the accumulation of organic matter and nutrients, enhancing nutrient cycling in the system (FAVERO; LOVO; MENDONÇA, 2008).

Reductions of mineralizable or labile C content occurred at depth in the two studied farms. Our data support the data obtained by Andrade, Oliveira and Cerri (2005) and Rangel et al. (2008), emphasizing that systems that prioritize frequent input of organic material tend to have higher levels of mineralizable C (BLAIR; LEFROY; LISLE, 1995; CHAN; BOWMAN; OATES, 2001) being that this increase is mainly related to the free light fraction of the SOM (MAIA et al., 2007). To maintain the soil sustainability is important to have balance between the disposable and recalcitrant pools. The easily oxidizable SOM works as a source of prompt mineralization of nutrients and recalcitrant SOM pool, important to protect the soil against hydric erosion and improve chemical and physical soil properties (LOSS et al., 2009).

The MP1, CON1, MS2 and ORG/IN/LE2 systems presented higher levels of C_L (F1 + F2) compared to C_{NL} (F3 + F4) in the 0-10 cm depth. The low values of C_L in ORG1 should be related to the high decomposition rate of bovine manure added in this coffee system, being rapidly consumed by soil microbes (SILVA; MENDONÇA, 2007). Due to the lower content of C_L, L was also lower in relation to CON1 providing lower CMI in ORG1, reducing its soil quality. These results indicate that there is a need for concomitant input of organic material with high and low decomposition rate, promoting the nutrient cycling, soil cover and carbon stock increase. These inputs are obtained with the combination of trees residue to organic compost as presented in the farm 2. The mineralizable C content was higher than in the agroforestry systems as follow: ORG/IN/LE2> ORG/CED2> ORG/IN2> CON2. Thus, the higher organic input from vegetal residues of the tree species promoted great LI, CCI and CMI improving soil quality, as observed for the ORG/IN/LE2, which is similar to MS2.

TABLE 5 - Average levels, values and significance of the contrasts of labile carbon (C_L), non-labile carbon (C_{NL}), lability (L), ratio labile carbon / total organic carbon (C_L /TOC), the compartment carbon index (CCI), lability index (LI) and carbon management index (CMI).

Systems / Contrasts	C_L (F1+F2)	C_{NL} (F3+F4)	L	C_L/TOC	CCI	LI	CMI
	g kg-1			%			
0-10 cm							
MP1	45,15	31,96	1,41	58,85	1,00	1,00	100,00
ORG1	15,00	35,55	0,42	29,67	0,66	0,30	19,31
CON1	17,20	16,49	1,04	44,54	0,45	0,58	26,25
MS2	24,18	23,83	1,02	50,48	1,00	1,00	100,00
ORG/IN2	13,33	19,85	0,69	40,35	0,70	0,68	47,11
ORG/IN/LE2	23,00	18,33	1,31	55,50	0,86	1,22	104,92
ORG/CED2	14,17	22,75	0,62	37,72	0,78	0,60	48,67
CON2	12,50	19,03	0,68	39,99	0,67	0,66	42,63
Contrasts							
C1	58,10 **	11,87 ns	1,59 **	43,50 **	0,89 **	1,11 **	154,44 **
C2	-2,20 ns	19,06 **	-0,62 #	-14,86 **	0,21 *	-0,28 *	-6,93 ns
C3	33,72 **	15,34 #	0,79 #	28,36 #	0,99 **	0,83 #	156,68 **
C4	-13,00 *	-3,86 ns	-0,59 #	-13,60 ns	-0,32 ns	-0,52 *	-72,8 *
10-20 cm							
MP1	31,00	39,28	0,86	44,66	1,00	1,00	100,00
ORG1	10,67	27,03	0,43	28,80	0,53	0,72	27,45
CON1	8,57	21,23	0,40	28,13	0,42	0,86	23,40
MS2	15,33	24,30	0,63	38,64	1,00	1,00	100,00
ORG/IN2	9,67	21,80	0,45	28,43	0,79	0,72	56,78
ORG/IN/LE2	13,33	20,01	0,67	40,14	0,85	1,07	90,65
ORG/CED2	12,83	21,09	0,61	37,9	0,86	0,98	83,63
CON2	9,50	17,75	0,53	34,42	0,69	0,85	60,40
Contrasts							
C1	42,77 **	30,30 *	0,89 *	32,39 *	1,05 **	0,42 *	149,15 **
C2	2,10 ns	5,80 ns	0,03 ns	0,67 ns	0,11 *	-0,14 ns	4,05 ns
C3	16,00 **	16,55 *	0,26 ns	13,68 ns	0,81 *	0,39 ns	108,54 *
C4	-7,33 #	-9,65 #	-0,14 ns	-3,21 ns	-0,42 #	-0,21 ns	-49,87 ns
20-40 cm							
MP1	18,17	49,82	0,37	26,79	1,00	1,00	100,00
ORG1	6,67	26,59	0,25	19,84	0,49	0,72	35,25
CON1	9,33	20,00	0,51	32,75	0,43	1,34	56,59
MS2	10,67	20,93	0,51	33,28	1,00	1,00	100,00
ORG/IN2	6,67	13,52	0,49	28,91	0,67	1,04	72,53
ORG/IN/LE2	10,17	17,22	0,59	37,14	0,90	1,21	111,59
ORG/CED2	10,33	16,44	0,66	39,03	0,88	1,35	114,04
CON2	7,17	13,45	0,55	35,25	0,68	1,10	75,77

Continua ...

TABELA 5 - Continuação ...

	Contrasts						
C1	20,33 **	53,06 **	-0,02 ns	0,99 ns	1,08 **	-0,06 ns	108,16 **
C2	-2,67 ns	6,59 ns	-0,26 #	-12,90 #	0,07 #	-0,62 *	-21,34 #
C3	8,33 #	23,38 **	-0,26 ns	-7,19 ns	0,88 #	-0,70 ns	26,0 ns
C4	-5,67 ns	-6,53 ns	-0,09 ns	0,67 ns	-0,41 #	-0,28 ns	-70,86 *

Farm 1- Mata Primary (MP1), Organic Coffee (ORG1) and Conventional Coffee (CON1). C1 = (CON1-2MP1-ORG1), C2 = (CON1-ORG1). Farm 2 - Secondary Forest (MS2), Organic Coffee intercropped with inga (ORG/IN2), Organic Coffee intercropped with leucaena and inga (ORG/IN/LE2), Organic Coffee intercropped with cedar (ORG/CED2), Café Conventional (CON2). C3 = (4MS2-ORG/IN2- ORG/IN/LE2- ORG/CED2-CON2), C4 = (3CON2-ORG/IN2- ORG/IN/LE2- ORG/CED2). ns, #, *, **: not significant, significant at 15, 5 and 1%, respectively, for test F.

4 CONCLUSIONS

In the farm 1, from 0-10 cm, the conventional coffee obtained reductions of 27,3 % and 14,9 % respectively in ESTC and ESTN in relation to organic coffee. This depth, for farm 2, reductions in ESTC and ESTN coffee conventional full sun in relation to agroforestry coffee were 22,1 % and 31,4 %, respectively.

Addition of organic matter with high mineralizable as compost and bovine manure in organic coffee does not have the potential to improve soil quality in hilly regions.

Organic agroforestry coffee with diversified and constant input of plant residues provides soil cover and greater carbon management index, promoting the improvement of soil quality in hilly regions.

5 ACKNOWLEDGEMENTS

A Fapes (Research Foundation of the Espírito Santo State) for financing the research and scholarship for the first author. To the colleagues Paulo, Victor, Wallas and Jocelina for the contribution in the soil sampling and laboratory analysis.

6 REFERENCES

ANDRADE, C. A.; OLIVEIRA, C. de; CERRI, C. C. Qualidade da matéria orgânica e estoques de carbono e nitrogênio em Latossolo tratado com biossólido e cultivado com eucalipto. **Revista Brasileira de Ciência do Solo**, Viçosa, v. 29, n. 5, p. 803-816, 2005.

BLAIR, G. J.; LEFROY, R. D. B.; LISLE, L. Soil carbon fractions based on their degree of oxidation, and the development of a carbon management index for agricultural systems. **Australian Journal of Agricultural Research**, Victoria, v. 46, p. 1459-1466, 1995.

CARDOSO, I. M.; SOUZA, H. N.; MENDONÇA, E. S. Biodiversidade, recurso genético e cuidados fitossanitários. **Revista Ação Ambiental**, Viçosa, v. 31, p. 18-20, 2005.

CHAN, K. Y.; BOWMAN, A.; OATES, A. Oxidizible organic carbon fractions and soil quality changes in an paleustalf under different pasture leys. **Soil Science**, Baltimore, v. 166, n. 1, p. 61-67, 2001.

ESPÍRITO SANTO. Secretaria de Estado da Agricultura, Abastecimento, Aquicultura e Pesca. **Plano estratégico de desenvolvimento da agricultura capixaba:** novo Pedeag 2007-2025, região do Caparaó. Vitória, 2008. 284 p.

FAVERO, C.; LOVO, I. C.; MENDONÇA, E. S. Recuperação de área degradada com sistema agroflorestal no vale do Rio Doce, Minas Gerais. **Revista Árvore**, Viçosa, v. 32, n. 5, p. 861-868, set./out. 2008.

GIOMO, G. S.; PERREIRA, S. P.; BLISKA, F. M. M. Panorama da cafeicultura orgânica e perspectivas para o setor. **O Agronômico**, Campinas, v. 59, n. 1, p. 33-36, 2007.

LOSS, A. et al. Frações oxidáveis do carbono orgânico em Argissolo Vermelho-Amarelo sob sistema de aléias. **Revista Brasileira de Ciência do Solo**, Viçosa, v. 33, n. 5, p. 867-874, 2009.

MAIA, S. M. F. et al. 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. 127-138, 2007.

MENDONÇA, E. S.; LEITE, L. F. C.; FERREIRA NETO, P. S. Cultivo do café em sistema agroflorestal: uma opção para recuperação de solos degradados. **Revista Árvore**, Viçosa, v. 25, n. 3, p. 375-383, 2001.

MIELNICZUK, J. et al. Manejo do solo e sua relação com os estoques de carbono e nitrogênio do solo. In: CURI, N. et al. (Ed.). **Tópicos em ciência do solo**. Viçosa, MG: SBCS, 2003. cap. 5.

MYERS, N. et al. Biodiversity hotspots for conservation priorities. **Nature**, London, v. 403, n. 6772, p. 853-858, 2000.

NUNES, L. A. P. L. et al. Impacto do monocultivo de café sobre os indicadores biológicos do solo na zona da mata mineira. **Ciência Rural**, Santa Maria, v. 39, n. 9, p. 2467-2474, set. 2009.

RANGEL, O. J. P.; SILVA, C. A.; GUIMARÃES, P. T. G. Estoque e frações da matéria orgânica de Latossolo cultivado com cafeeiro em diferentes espaçamentos de plantio. **Revista Brasileira de Ciência do Solo**, Viçosa, v. 31, p. 1341-1353, 2007.

RANGEL, O. J. P. et al. Frações oxidáveis do carbono orgânico do Latossolo cultivado com cafeeiro em diferentes espaçamentos de plantio. **Ciência & Agrotecnologia**, Lavras, v. 32, n. 2, p. 429-437, mar./abr. 2008.

RIBEIRO, M. C. et al. The Brazilian Atlantic Forest: how much is left, and how is the remaining forest distributed?: implications for conservation. **Biological Conservation**, Essex, v. 142, n. 6, p. 1141-1153, 2009.

SILVA, I. R.; MENDONÇA, E. S. Matéria orgânica do solo. In: NOVAIS, R. F. et al. (Ed.). **Fertilidade do solo**. Viçosa, MG: Sociedade Brasileira de Ciência do Solo, 2007. p. 275-374.

TEDESCO, M. J. et al. **Análise de solo, plantas e outros materiais**. 2. ed. Porto Alegre: UFRGS, 1995. 174 p.

WENDLING, B. et al. Mudanças no carbono e nitrogênio em diferentes compartimentos da matéria orgânica sob sistema agrossilvipastoril. **Ciência Florestal**, Santa Maria, v. 21, n. 4, p. 643-655, 2011.

YEOMANS, J. C.; BREMNER, J. M. A rapid and precise method for routine determination of organic carbon in soil. **Communications in Soil Science and Plant Analysis**, New York, v. 19, p. 1467-1476, 1988.