OXIDIZABLE ORGANIC CARBON FRACTIONS AND SOIL AGGREGATION IN AREAS UNDER DIFFERENT ORGANIC PRODUCTION SYSTEMS IN RIO DE JANEIRO, BRAZIL

[FRACCIONES DE CARBONO ORGÁNICO OXIDABLE Y AGREGACIÓN DEL SUELO EN DIFERENTES ÁREAS EN LOS SISTEMAS DE PRODUCCIÓN ORGÁNICA, RIO DE JANEIRO, BRASIL]

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SUMMARY

The effect of organic management can influence positively the edaphic properties. The aim of this study was to evaluate the degree of organic carbon oxidation and the soil aggregation indexes in areas under organic management and different plant covers. The selected systems were: conventional tillage (corn - CT), no-tillage (eggplant – NT), passion fruit - *Desmodium* sp intercrops, fig cultivation, agroforestry system (AFS) and a secondary forest area. The soil samples were collected at 0-5 and 5-10 cm depths. The total organic carbon (TOC) was quantified and separated into four fractions (F1, F2, F3 and F4) with decreasing degrees of oxidation, by the use of increasing quantities of sulfuric acid. Aggregate stability was determined by wet sieving, using the indices of mean weight diameter (MWD), geometric mean diameter (GMD) and sensitivity index (SI). The area under corn cultivation presented the lowest TOC concentrations and aggregation indices, in the two depths evaluated. The areas under eggplant and fig presented the highest TOC concentrations at the 0-5 cm depth, and the highest MWD at the 5-10 cm depth. There were SI values above 1 in the areas under fig and passion fruit. In general, the F1 fraction represented the largest proportion of TOC in all areas and in the two depths evaluated. The AFS presented the lowest proportions of TOC in the four fractions (0-5 cm). The area under eggplant (0-5 cm) presented the highest carbon concentrations in the F1, F2 and F3 fractions. However, at the 5-10 cm depth, this behavior was observed in the area under corn, except for the F1 fraction. The results indicate that the management adopted in the area under corn did not favor soil aggregation and TOC. In the other areas, the SI determined indicates that the tillage practices associated to plant cover, in organic systems, preserved soil aggregation when compared to the forest area, at the 0-5 cm depth. The oxidizable carbon concentrations were influenced by the management systems adopted, with higher values in the areas where more plant residues were added to the soil.

Key Words: plant residues; green manure; conventional tillage and no-tillage.

RESUMEN

La forma como se gestionan los recursos orgánicos aplicados al suelo puede influir las propiedades de éste. Este estudio tuvo como objetivo evaluar el grado de oxidación del carbono orgánico y las tasas de agregación del suelo en sistemas con manejo orgánico y diferentes cultivos de cobertura. Los sistemas seleccionados fueron formas de cultivo y cubierta vegetal: labranza tradicional del suelo (maíz-CT), labranza cero (berenjena-NT), consorcio maracuyá - *Desmodium* sp, cultivo de higos, agroforestales (AFS) y bosque secundario. Se colectaron muestras de suelo a profundidades de 0-5 y 5-10 cm en todos ellos. Se cuantificó el carbono orgánico total (TOC) y se realizó su fraccionamiento, para separar el carbono en cuatro fracciones (F1, F2, F3 y F4), con grados decrecientes de oxidación, mediante el uso de cantidades crecientes de ácido sulfúrico. Se determinó la estabilidad de agregados en húmedo mediante peso medio de diámetro (MWD), diámetro medio geométrico (GMD) y el índice de sensibilidad (SI). El área bajo cultivo de maíz mostraron menores niveles de TOC y el índice de agregación, en las dos profundidades estudiadas. Si bien los ámbitos de la berenjena y el higo mostraron niveles más altos en el TOC de 0-5 cm de profundidad, y MWD en la profundidad de 5-10 cm. Valores de SI más de 1 se encontraron en las áreas del higo y maracuyá. En general, la fracción F1 representados la mayoría de los TOC y en todos los ámbitos, tanto en las profundidades estudiadas. El SAF tiene la proporción más baja del COT en las cuatro fracciones (0-5 cm). El área de berenjena (0-5 cm) mostraron mayores niveles de carbono en las fracciones F1, F2 y F3. Sin embargo, la profundidad de 5-10 cm, este comportamiento se observó para el área de cultivo de maíz, excepto para la fracción F1. Los resultados indican que la dirección adoptada en el área de maíz que está desfavoreciendo la agregación de los suelos y el TOC. Al igual que en otros ámbitos, el SI encuentrado muestra que la forma de cultivo, asociadas con el tipo de cubierta vegetal, en los sistemas orgánicos, son la preservación de la agregación del suelo, en comparación con el área de bosque, en la profundidad de 0-5 cm. Los niveles de carbono oxidables fueron influenciados por los sistemas de gestión adoptados, siendo mayor en las áreas que más contribuyen a la tierra los residuos de la planta.

Palabras clave: residuos vegetales; abono verde; labranza tradicional y labranza cero.

INTRODUCTION

Human intervention on natural ecosystems for changing its use to agricultural activities decreases soil organic matter (SOM) stocks and alters soil chemical composition (Silva *et al*., 1999). Those impacts have been more often investigated in annual cropping systems due to their extensive areas, known cropping history and economic importance. Studies conducted on this subject indicate that SOM losses reach more than 50% of the initial values in relatively short periods (less than 10 years), specially in sandy soils and soils under less conservationist management practices (Mielniczuk *et al*., 2003). However, there are few studies assessing the impact of tillage on the SOM content of the oxidizable carbon fractions under annual and perennial crops in organic systems.

Agricultural development inevitably involves a certain degree of physical transformation of the landscape and ecosystem. It is essential to develop strategies including methods and procedures that are ecologically sustainable, are compatible with the maintenance and rehabilitation wile ensuring food security (Altieri and Nicholls, 2000).

Thus, organic agriculture, which is an ecological system of production management that promotes and enhances biodiversity, biological cycles and soil biological activity, emerges as a way to reduce these problems, since it includes several conservation practices (Campanhola and Valarini, 2001). The use of plant or animal-derived organic matter is known to improve soil properties under the organic production management (Cardozo *et al*., 2008; Loss *et al*., 2009a).

Organic agriculture provides an environment for the development of natural processes and biological interactions in positive ground, through the spatial and temporal diversification of the production system, contributing to soil fertility with lower intakes of external inputs. In this form of management are used various agricultural practices such as use of green manure with leguminous species, use of organic fertilizers (cow manure and / or broiler litter), among others (Silva *et al*. 2009; Loss *et al*. 2009a,b).

Furthermore, tropical soils are submitted to high temperatures and decomposition rates with high organic carbon availability to microbial action, thus decreasing soil organic matter content and consequently aggregate stability. Its depends on a continuous organic matter supply that can compensate for rapid soil organic carbon losses, and depend also of the soil management and mulch (Bronick and Lal, 2005).

Aggregate size and soil aggregation status can be determined by indices such as the mean weight diameter (MWD), in which a high value represents a high percentage of aggregates retained in the larger diameter sieves, and the geometric mean diameter (GMD) (Castro Filho *et al.*, 1998).

Besides these indices, Bolinder *et al*. (1999) presented the sensitivity index (SI), which evaluates the influence of different types of management practices and plant covers on aggregate stability. The higher this value, the closer the area is to natural conditions.

To evaluated different soil carbon oxidation fractions, Chan *et al.* (2001) introduced a modification in the classic C determination method developed by Walkley-Black (1934). In the original method, C was determined by using a single sulfuric acid concentration (12 mol L^{-1}). With the change proposed by Chan *et al*. (2001), it was possible to separate four fractions with decreasing oxidation degrees, by using increasing quantities of sulfuric acid. A drawback of using this method is the difficulty in comparing results with the methods described by Blair *et al.* (1995) and Shang and Tiessen (1997), since it is evident that by changing the concentrations of acids and oxidizers, certain previously unmodified carbon forms will be oxidized by the oxidizing solution proposed by Chan *et al*. (2001).

The lack of results demonstrating the effect of organic cropping systems on soil attributes such a SOM oxidation degree is one of the justifications for this study. Such evaluations are essential for understanding this system's dynamics in the ecosystem.

The objective of this work was to evaluate the organic carbon oxidation degree and the aggregation indices (MWD, GMD and SI) of an Ultisol under different organic production systems for 13 years.

MATERIAL AND METHODS

This study was conducted in the "Fazendinha Agroecológica do km 47", which is an Integrated Agroecological Production System (IAPS) site (Almeida *et al*., 1999). The IAPS was established in 1993 and occupies an area of 59 ha where agroecological practices are implemented. The area which is located at the Embrapa Agrobiology, in Seropédica, Rio de Janeiro State, Brazil, (longitude 22º 45', latitude 43º 41') at 33 meter altitude, and the climate is an Aw type according to the Köppen classification. The soil in the experimental area is classified an Ultisol (Embrapa, 2006) with a sandy loam texture in the A horizon, and had been routinely cultivated with fruit and vegetable crops.

Five areas measuring 0.12 ha each included:

1 - Fig (*Ficus carica*) cultivation, with seven years of implementation, the subtext being covered by grasses (*Paspalum notatum*). The organic fertilizer used in the planting of the fig consisted of 30 liters per pit of cow manure, being: 1/3 placed in the bottom of the pit and 2/3 homogenized with the soil removed from the pit, and later returned. In coverage, for initial training of the orchard, we used 4.5 kg of broiler litter within a radius of 50 cm apart from each plant. At the beginning of the planting of fig (1999) was used as a cover crop to soil the siratro (*Macroptilium artropurpureum*). This legume has remained in the area until 2002, then being used sunnhemp (*Crotalaria juncea*) by the year 2003. Then the area was conquered by grasses (*Paspalum notatum*). At the time of collection of soil samples for this study (2005), the area with fig was covered only with vegetable waste resulting from cutting of bahiagrass (*Paspalum notatum*), and there was no influence of the legume mulch. It was only sampled the soil, removing the mulch surface;

2 - Maize (*Zea mays*) cultivation, in that area for eight years is being conducted experiments with rotation of crops such as maize (*Zea mays*), bean (*Phaseolus vulgaris*), okra (*Abelmoschus esculentus*), collard greens (*Brassica oleracea*), eggplant (*Sonalum melogena*), by using the conventional tillage (CT) soil with plowing and harrowing. This area is used for the legumes (*Crotalaria juncea* and *Crotalaria spectabilis*), both in the consortium and / or in the form of pre-cultivation.

3 - Eggplant (*Sonalum melogena*) cultivation, with the same sequence of crop rotation and timing of utilization of maize area (CT), however in no-tillage (NT). This area makes use of the following legumes: gray velvet beans (*Mucuna pruriens*), dwarf velvet beans (*Mucuna deeringiana*), *Crotalaria spectabilis* and *Crotalaria juncea*, associated with the main crop. When collecting samples of soil, areas with eggplant (NT) and corn (CT) had no more cover crops covering the soil. In these areas (NT and CT) is always added farmyard manure in the pits and / or ridges at planting of vegetable crops (doses ranging from 50 to 100 kg ha^{-1} N, depending on culture and its necessity) and broiler litter in coverage (doses ranging from 100 to 200 kg ha^{-1} N).

4 - Passion fruit (*Passiflora edulis*) - *Desmodium* sp. intercrops, being this area cultivated with passion fruit since 1996. This area has always been done with legumes intercrops, and from 1996 until 2000 used *Arachis pintoi*. Then the passion fruit was intercropped with *Desmodium* sp. The distance between the lines of passion fruit and legumes was 3 m. The organic fertilizer used in cultivation of passion fruit comprised 30 liters per pit of cow manure, and carried two fertilized coverage broiler litter per year, at a dose equivalent to 100 kg ha^{-1} N.

5 - Agroforestry system (AFS) with five years since implementation formed by banana (*Musa sapientum*), açaí palm (*Euterpe oleracea*), cacao (*Thebroma cacao*), papaya (*Carica papaya*) and guapuruvu (*Schizolobium parahyba*). The AFS did not receive any additional fertilization, with the nutrients being supplied by the input and decomposition of the crops residues.

A tropical seasonal deciduous secondary forest located next to the experimental area was selected as reference for the soil natural conditions.

The areas under cultivation with eggplant (NT), passion fruit – *Desmodium* sp. intercrops and maize (CT) were separated by bands of 1.5 m wide, where crops are grown açai palm (*Euterpe oleracea*). In the areas planted with figs and the AFS, the band was formed by trees of carambola (*Averrhoa carambola*), and which were amongst the first three areas, separated by a conveyor belt of 4 m wide.

The management of soil fertility of the areas was initiated with the soil acidity through the incorporation of lime, being first made in 1993, during the deployment of IAPS, in an amount based on the results of analysis of soil for each plot. The organic fertilizers used in IAPS, on average, the following nutrient contents (g kg^{-1}): N = 37.25, Ca = 50.03, Mg = 6.23, P = 22.68, K = 23.93 (broiler litter) and N = 15.20, Ca = 9.68, Mg = 3.43, P = 2.24, K = 5.80 (cow manure). This characterization of fertilizers (broiler litter and cow manure), used in IAPS is due to an historical analysis through a variety of existing work carried out on site (Loss *et al*. 2009a,b; Silva *et a*l., 2009).

Five undisturbed soil samples were collected in each area at 0-5 and 5-10 cm depths in the inter-row of each crop, on November 2005. The samples were air-dried and passed through 8-mm and 4-mm sieves. All the areas studied were flat terrain, with sandy-loam in all areas (average values of 784, 168 and 48 g kg^{-1} at the 0-5 cm and, 770, 168 and 62 g kg^{-1} on the depth 5-10 cm, respectively, for sand, silt and clay). The sampling points of soil samples were carried out in a zig-zag pattern between the rows of crops, not to compromise the root system of the same.

The aggregate distribution by mean diameter classes ($8.0 \geq X > 2.0$ cm, $2.0 \geq X > 1.0$ cm, $1.0 \geq X > 0.5$ cm, $0.5 \geq X > 0.25$ cm and $0.25 \geq X > 0.105$ cm) were obtained by wet-sieving the soil samples (Embrapa, 1997). Soil aggregates (25 g) were weighed from the fraction retained on the 4 mm sieve, prewetted with an atomizer, placed on a set of five sieves of 2, 1, 0.5, 0.25 and 0.105 mm mesh and sieved for 15 min on a Yooder vertical homogenization equipment (Kemper and Chepil, 1965). After shaking, the material retained in each sieve was removed, separated by flushing with water, placed on previously weighed and identified plaques, and left on a muffle until reaching constant weight. After drying, the retained aggregate mass was obtained for each sieve, and the mean weight diameter (MWD) and geometric mean diameter (GMD) indices were calculated.

The aggregation indices (MWD, GMD and SI) were calculated according to the following formulas:

$$MWD = \sum x_i y_i \qquad \text{Equation 1}$$

where MWD is the mean weight diameter; x_i is the mean diameter of the size class (mm); y_i is the proportion of each size class with respect to the total sample.

$$GMD = \exp (\Sigma\, wi \ln xi / \Sigma\, wi) \qquad \text{Equation 2}$$

where GMD is the geometric mean diameter; *wi* is the weight of aggregates of each size class (g); and ln *xi* is the natural logarithm of the mean diameter of size classes.

$$SI = MWD_t / MWD_o \qquad \text{Equation 3}$$

where SI is the sensitivity index; MWD_t is the soil MWD value considered in each management system tested (eggplant, corn, fig, passion fruit and AFS), and MWD_o is the soil MWD value in the original plant cover (secondary forest). An index value higher than one indicates an increase in aggregate stability, and a value lower than one indicates a decrease in aggregate stability.

The soil total organic carbon (TOC) content was quantified according to Yeomans and Bremner, 1988) and the carbon fractionation by oxidation degree was performed according to (Chan *et al*., 2001; Rangel *et al*., 2008; Loss *et al*., 2009c). A soil samples weighing 0.5 g were placed in a 250 mL Erlenmeyer and 10 mL $K_2Cr_2O_7$ 0.167 mol L^{-1} then of H_2SO_4 corresponding to 3, 6, 9 and 12 mol L^{-1} concentrations were added. The oxidation was performed without an external heat source and the extracts were titrated with a $Fe(NH_4)_2(SO_4)_2.6H_2O$ 0.5 mol L^{-1} solution using phenanthroline as indicator. The carbon fractionation produced four fractions, with decreasing degrees of oxidation:

-Fraction 1 (F1): C oxidizable by $K_2Cr_2O_7$ under 3 mol L^{-1} of H_2SO_4;

-Fraction 2 (F2): the difference in oxidizable C extracted between 6 and 3 mol L^{-1} of H_2SO_4;

-Fraction 3 (F3): the difference in oxidizable C extracted between 9 and 6 mol L^{-1} of H_2SO_4;

-Fraction 4 (F4): the difference in oxidizable C extracted between 12 and 9 mol L^{-1} of H_2SO_4.

The experiment was carried out under an entirely randomized design. The results were analyzed for data normality and homogeneity by the Lilliefors and Cochran and Barttlet tests, respectively. The results obtained were submitted to analysis of variance with application of the F test, and the mean values were compared by the Scott-Knott test at 5% (Scott and Knott, 1974).

RESULTS AND DISCUSSION

Total organic carbon and oxidizable carbon fractions

The area under corn presented the lowest total organic carbon (TOC) values in the two depths evaluated (Table 1). This effect is caused by the conventional soil tillage management in this area, with practices such as plowing and disking. These practices cause the disruption of soil aggregates (Graham *et al*., 2002; Bertol *et al*., 2004; Six *et al*., 2004; Fontana *et al*., 2010), exposing the previously protected organic matter to microbial action, thus accelerating its decomposition (Reicosky, 2002) and leading to lower TOC content (Pinheiro *et al*., 2004; Loss *et al*., 2009a).

Similar results than the present study were reported by Nyamadzawo *et al*. (2009) assessing the mineralization of aggregate-protected carbon in maize fallow systems under conventional and no-tillage in Central Zimbabwe. These authors observed that continuous corn cultivation in conventional tillage has been the disruption of aggregates, exposing the soil organic matter that was protected in its interior, with consequent increase of mineralization and subsequent decrease in TOC.

The soil under fig and eggplant gave higher TOC concentrations than the other treatments at both depths. This effect could be attributed to the litter input from the inter-row grass (*Paspalum notatum*) clippings applied as mulch on the fig rows. According to Merlin *et al*. (2005), the addition of waste cut from *Paspalum notatum* ranged from 25 to 32 t ha^{-1}. Since the eggplant area was under a no-tillage crop rotation system which led to the accumulation of plant residues on the soil surface. The influence of leguminous green manures in these areas also stands out, in agreement with Silva *et al*. (2009) and Ribas *et al.* (2003). This practice can increase the TOC content when green manures are introduced along with the crop, as reported by Duda *et al.* (2003) and Loss *et al.* (2009b)
The soil under corn had lower TOC values (0-5 cm) than the area under secondary forest. This indicates that the organic management of the other areas is increasing the TOC content when compared to the area under secondary forest, with a more expressive effect only at the 0-5 cm depth, where there was a greater variation (statistical differences) among treatments. This behavior is relevant mainly in the short term and on the soil surface, where the main changes due to agricultural practices take place.

Fraction F1, the labile carbon fraction, represents most of the TOC in the two depths studied, especially at the 0-5 cm layer (Table 1). The eggplant area, under no-tillage, presented the highest carbon value in fraction 1, followed by the fig area. Fractions F2 and F3 also presented higher values in the eggplant and fig areas. This behavior indicates that soil management has led to increases in this fraction's (F1) carbon content, since management systems which add organic matter to the soil via plant residues present higher values in this fraction (Blair *et al.*, 1995; Chan *et al.*, 2001). This behavior demonstrates that no soil disturbance associated with the addition of cow manure and broiler litter more green manure in the eggplant and fig areas is providing increases in the carbon fraction (F1). According to Blair *et al*. (1995) and Chan *et al*. (2001), the management systems that add organic matter to soil through plant residues have higher values of this fraction.

Table 1. Oxidizable carbon fractions of an Ultisol under different production systems in Seropédica, Rio de Janeiro State, Brazil.

Areas evaluated	Oxidizable carbon fractions (g kg^{-1})				
	0-5 cm				
	F1	F2	F3	F4	TOC
Eggplant (NT)	11.9(47) A	3.80(15) A	7.40(29) A	1.75(7) B	25.33 B
Corn (CT)	4.38(40) D	2.22(20) B	2.22(20) C	0.57(5) B	11.06 E
Fig	8.88(29) B	3.72(12) A	3.78(12) B	3.75(12) A	30.50 A
Passion fruit	5.10(24) D	2.76(13) B	1.62(8) C	1.41(7) B	20.78 C
AFS	4.30(20) D	2.00(9) B	1.40(6) C	1.05(5) B	21.97 C
Secondary forest	6.45(36) C	3.75(21) A	3.62(20) B	3.10(17) A	18.02 D
Calculated F	63.58**	3.43*	30.35**	6.83**	44.11**
C.V.(%)	12.37	32.58	27.02	54.44	10.43
	5-10 cm				
Eggplant (NT)	4.76(28) A	3.80(22) A	2.34(14) C	1.83(11) A	17.27 A
Corn (CT)	4.56(43) A	1.68(16) B	3.54(34) B	0.27(3) B	10.48 B
Fig	4.46(23) A	1.86(10) B	1.26(6) C	1.77(9) A	19.28 A
Passion fruit	5.16(30) A	1.38(8) B	2.34(14) C	0.81(5) B	17.23 A
AFS	4.68(27) A	2.30(13) B	5.00(29) A	1.45(8) A	17.17 A
Secondary forest	3.34(22) A	1.72(11) B	5.43(35) A	1.59(10) A	15.43 A
Calculated F	19.36*	5.98**	13.27**	6.51**	16.13**
C.V.(%)	3.26	36.56	30.37	42.05	10.45

Values in the same column followed by the same letter are not significantly different (Skott-Knott <0.05). Values in parenthesis are percentages of TOC for each fraction (F1, F2, F3 and F4). *,** significant at 5 and 1%, respectively, by the F test. CV = coefficient of variation.

Assessing the oxidized carbon fractions in alley cropping system, Maranhão State, Brazil, Loss *et al*. (2009c) observed that the addition of crop residues added to soil after harvest of legumes (*Acacia mangium, Leucaena leucocephala, Cajanus cajan and Clitoria fairchildiana*) favored largest inputs of easily decomposable organic matter, resulting in higher contents of F1 fraction.

In general, the highest TOC proportion was verified in the F1 and F2 fractions, which implies a predominance of more bioavailable (fraction more susceptible to degradation) soil organic matter. In an evaluation of the organic carbon oxidizable fractions of an Oxisol cultivated with coffee in Minas Gerais State, Brazil, Rangel *et al.* (2008) also reported higher proportions of TOC in these fractions that in F3 and F4 fractions.

Soils from the secondary forest contained higher carbon contents in the F1, F2 and F3 fractions when compared to the AFS, passion fruit and corn plots. For the F1 fraction, the eggplant and fig areas presented higher carbon concentrations than the forest area. The area under NT had higher values than the forest area in the F1 and F3 fractions, with no significant differences in the F2 fraction. These results indicate that the organic management in the NT system has led to an increase in carbon content in these fractions, with more bioavailable organic matter compared to the secondary forest area.

In the comparison between the corn and eggplant areas at the 0-5 cm depth, the eggplant plots had the highest carbon concentrations in the F1, F2 and F3 fractions. At the 5-10 cm depth, however, this effect was only observed in the F2 and F4 fractions, while there were higher concentrations in the corn area in fraction F3 (Table 1). This effect is caused by the no-tillage management in the eggplant area and conventional tillage in the corn area, since both areas have the same crop rotation and experiment duration (Loss *et al*., 2009a,b).

The larger proportions of TOC in the F1, F2 and F3 fractions (0-5 cm) observed in the eggplant, corn, fig and passion fruit areas compared to AFS areas (where no green manures had been used and which had the shortest time since implementation) can be related to the use of green manures consorted with or preceding the crops (pre-cultivation) (Loss, 2008). Nevertheless, the highest value for fraction F3 at the 5-10 cm depth was observed in the AFS area. This effect can be related to the accumulation of organic compounds with high chemical stability and molecular weight originated from SOM decomposition and humification (Stevenson, 1994). Among these compounds, there is the humin fraction (Rangel *et al*., 2008) that represented 72% of TOC in the AFS (Loss, 2008).

Similar results were found by Rangel *et al.* (2008), when comparing organic carbon oxidizable fractions in a Oxisol under coffee and under a native forest in Minas Gerais State, Brazil. The authors observed that the F3 and F4 fractions from the forest area represented higher proportions of TOC than in the cultivated area. In the present study, the F3 fraction (5-10 cm) from the AFS area had similar values to the secondary forest area. This indicates higher similarity between these areas when compared to the cultivated areas, regarding the more stable oxidizable carbon fractions.

Soil aggregation indices

The MWD and GMD values of the soils under corn were different from the other systems in both depths (Table 2). Soil disturbance tillage and disking operations which destroyed the larger aggregates (>2.00 mm) into smaller aggregates (between 0.250 and 0.105 mm), thus reducing the MWD and GMD values.

Conventional soil preparation practices disrupt aggregates in the plow layer and accelerate organic matter decomposition, reflecting negatively on soil aggregate resistance (Carpenedo and Mielniczuk, 1990;Campos *et al.*, 1995; Six *et al*., 2004; Zotarelli *et al*., 2005; Denef *et al*., 2007; Salton *et al*., 2008; Loss *et al*., 2009a).

In a studying which compared different soil preparation and covers crops on an Oxisol in Paty do Alferes, Rio de Janeiro State, Pinheiro *et al.* (2004) observed lower MWD and GMD values at the 0-5 cm depth where vegetables and corn were grown under conventional soil tillage. This behavior was also attributed to soil preparation practices, in which soil plowing and disking caused the disruption of larger aggregates into smaller units, leading to a larger proportion of smaller aggregates in the conventional system.

However, Cruz *et al.* (2003) reported different results than the present study when evaluating physical attributes and organic carbon in an Ultisol with the same texture as the study area, under the following management systems: conventional tillage under black oat, conventional tillage under a black oat / hairy vetch consortium, no-tillage under corn / hairy vetch and black oat, and native pasture. The authors did not find any differences between the management systems at the 0-10 cm depth, with average MWD values between 2.930 and 3.520 mm. Those results differ from the results observed in this study, since the conventional tillage area (under corn) stood out from the other IAPS areas, presenting the lowest MWD value.

Table 2. Average MWD and GMD values (mm) of the areas evaluated under different plant covers at the 0-5 and 5-10 cm depths, at SIPA, Seropédica, Rio de Janeiro State, Brazil.

Areas evaluated	MWD		GMD	
	0-5 cm	5-10 cm	0-5 cm	5-10 cm
Eggplant (NT)	3.389 A	2.932 B	1.770 A	1.489 A
Corn (CT)	2.009 B	1.550 D	0.854 B	0.630 B
Fig	3.632 A	2.695 B	2.359 A	1.322 A
Passion fruit	3.820 A	2.395 C	2.707 A	1.266 A
AFS	3.379 A	2.455 C	2.112 A	1.320 A
Secondary forest	3.591 A	3.450 A	1.839 A	1.540 A
Calculated F	14.82**	9.72**	7.35**	3.82*
C.V.(%)	11.52	14.71	26.97	21.51

Values in the same column followed by the same letter are not significantly different by the Scott-Knott test at 5% for the different plant covers. *,** significant at 5 and 1%, respectively, by the F test. CV = coefficient of variation

In the areas with other plant covers, the soil wet-dry cycles were possibly intensified, since plant residues were left on the soil, contributing to soil moisture retention for a longer period. Additionally, the absence of mechanization contributes to lower aggregate disruption. This effect can be observed at the 0-5 cm layer, where all areas except for corn presented similar MWD and GMD values (Table 2).

At the 5-10 cm depth, the average MWD values were better indicators than GMD values in identifying changes caused by management practices in the areas studied. The area under secondary forest stands out with the highest values, followed by the areas under eggplant and fig. The higher MWD values in the eggplant and fig areas compared to the corn, passion fruit and AFS areas are due to higher humin and humic acid fractions values (Loss, 2008; Loss *et al*., 2010). According to Fontana *et al*. (2010), in a study on soil aggregation and humic substances in different management systems, observed that the humin and humic acid fractions are highly correlated with the highest values of MWD foud. This pattern, ultimately lead to better soil aggregation (Souza and Melo, 2003).

The lower sensitivity index (SI) values were found in the corn area under conventional soil tillage, in both depths (Figure 1). Those results demonstrate the deleterious effect of this management system on soil aggregation.

In an evaluation of the physical properties of a Humic Cambisol under conventional tillage and no-tillage in crop rotation and succession compared to a native pasture in Santa Catarina State, Brazil, Bertol *et al.* (2004) found similar results to those observed in this study. The authors reported SI values 23 % lower than one in the conventional tillage system, and SI values close to one in the no-tillage system.

In this study, SI values were higher at the 0-5 cm depth in areas without soil disturbance, with values of 1.01 in the fig cropping site, 1.06 in the passion fruit cropping site and 0.94 in the eggplant and AFS sites (Figure 1). These indices suggest that the management systems adopted preserved the aggregates, indicating similar conditions to those observed in the secondary forest site.

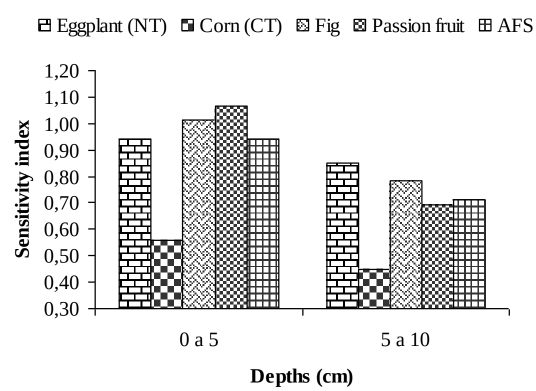

Figure 1. Sensitivity index for aggregate MWD an Ultisol submitted to different management and tillage systems, as compared to the secondary forest site.

At the 5-10 cm depth, the eggplant site (NT) and fig can be highlighted, having presented the highest SI (0.85 and 0.80, respectively). These results are supported by high values of MWD found in these areas (5-10 cm), agreeing with the results found by Fontana *et al.* (2010), where higher values of SI were related with the highest values of MWD.

CONCLUSIONS

The organic management implemented in the fig, eggplant, passion fruit and AFS areas has promoted an increase in TOC content, when compared to the secondary forest area, at the 0-5 cm depth. The oxidizable carbon concentrations were influenced by the adopted management systems, with higher values in the areas with higher crop residue input and/or maintenance on the soil. The no-tillage system presented higher carbon concentrations in the F1, F2 and F3 fractions when compared to conventional soil tillage at the 0-5 cm depth. The management adopted in the corn site is detrimental to soil aggregation. The MWD proved to be more adequate than GMD in highlighting the differences due to plant cover type and tillage practices at the 5-10 cm depth in organic systems.

The system of land use with fig and eggplant, due to the higher TOC and carbon F1, F2 and F3 fractions (0-5 cm) lead in the best areas for agricultural production. In these areas, the highest values of MWD and SI (5-10 cm) indicate greater protection of SOM within the aggregate, with lower emissions of greenhouse gases (mainly C-CO_2) into the atmosphere.

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