

OXIDIZABLE FRACTION OF ORGANIC CARBON IN AN ARGISOL UNDER DIFFERENT LAND USE SYSTEMS

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ABSTRACT: The objective of this study was to evaluate carbon input in labile and stable fractions in an ARGISOL of northwestern Brazil under different land use systems. Use systems being evaluated include: forest - MA (reference), agrosilvopasture - TCP (teak, cocoa and pasture); agroforest - TC (teak and cocoa); teak forest at 8 and 5 years - T8 and T5, and pasture - PA. In each system three furrows were made at depths of 0-5 cm, 5-10 cm and 10-20 cm. An area consisting of native vegetation (forest) adjacent to the experiment was sampled and used as control treatment. The use systems MA, T8 and T5 had higher levels of total organic carbon (COT) and the MA system had higher levels of labile carbon (CL) than the other systems, with the exception of TC at a depth of 10-20 cm. In the MA system, COT levels were higher in comparison to use systems TCP, TC and PA while CL levels were higher than the levels observed in use systems TCP and TC. In most cases being analyzed, CL levels were lower than COT levels, therefore this trait can be used as an indicator to assess anthropogenic changes relating to the maintenance or condition of soil organic matter.

Key words: Soil compartments, Amazonia, lability.

FRAÇÃO OXIDÁVEL DO CARBONO ORGÂNICO DE UM ARGISSOLO SOB DIFERENTES SISTEMAS DE USO

RESUMO: Neste estudo, objetivou-se avaliar o aporte de carbono nas frações lábil e não lábil em um ARGISSOLO do noroeste brasileiro, em diferentes sistemas de uso do solo. Os sistemas de uso avaliados foram: mata - MA (referência), agrosilvopastoril - TCP (teca, cacau e pasto); agroflorestal - TC (teca e cacau); florestal teca com 8 e 5 anos - T8 e T5 e pastagem - PA. Em cada sistema foram abertas três trincheiras nas profundidades de 0 a 5; 5 a 10 e 10 a 20 cm. Uma área sob vegetação nativa (mata) adjacente ao experimento foi amostrada e usada como referência. Os sistemas de uso MA, T8 e T5 tiveram maiores teores de carbono orgânico total (COT) e o sistema MA de carbono lábil (CL) do que os demais sistemas, com exceção do TC na profundidade de 10 a 20 cm. No sistema MA, os teores de COT foram maiores em relação ao sistema de uso TCP, TC e PA e os teores de CL foram maiores do que os observados nos sistemas de uso TCP e TC. Os teores de CL, na maioria dos casos analisados, foram menores que os de COT e, por essa razão, esse atributo pode ser usado como indicador para avaliar as mudanças antropogênicas na manutenção ou no estado da matéria orgânica do solo.

Palavras-chave: Compartimentos do solo, Amazônia, labilidade.

1 INTRODUCTION

Oxidizable or labile fraction is intended to describe the biologically active components of soil organic matter (MOS), being a constituent part of organic compounds more rapidly mineralizable in reactions catalyzed by microbial enzymes present in the soil, and thus directly associated with CO₂ release into the atmosphere (TAVARES, 2010). According to Powlson et al. (1987), labile carbon is susceptible to alterations brought about by changes in the environment. More prone to variations than total soil organic carbon, it enables greater applicability for detection of impacts brought about by different land use systems, in connection with soil and air quality.

Every organic fraction present in the soil in the form of residue is MOS and may include fresh and partially decomposed matter, humus composts and charred material, whether associated or not with the mineral fraction, and another part constituted by the living biomass of organisms (ROSCOE; MACHADO, 2002).

MOS levels are very susceptible to forest management practices, particularly in regions of tropical and subtropical climate, in which the exposed organic matter is decomposed by bioactive organisms (AGUIAR et al., 2009). Likewise, when MOS is protected in the interior of smaller soil aggregates or by strong bonding to the mineral fraction, its levels may remain close to original levels for several crop years (CONTE et al., 2011).

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Roscoe and Buurmam (2003) found MOS levels close to original vegetation levels after 30 crop years in Red Latosols cultivated by using both no-till and conventional tillage systems.

In order to determine whether and in which compartments C is being accumulated, methods have been used of physical fractionation of MOS that include granulometric techniques (MARTINS et al., 2009), densimetric techniques or a mixture of both (CONCEIÇÃO et al., 2008).

The organic fraction of soil composed of soil carbon plays a key role in the sustainability of that soil and in the sustainability of production systems (BODDEY et al., 2010).

Carbon (C) may accumulate in labile or stable fractions of MOS, which may affect the durability of its effect regarding retention time in the atmosphere, causing changes to the physical, chemical and biological properties of soils (FELLER; BEAR, 1997).

The residence time of every labile fraction protected inside soil aggregates is greater than the free fraction, it being better protected in microaggregates than in macroaggregates (SIX et al., 2006). This justifies the accumulation of C in labile fractions of MOS, as a result of difficult organism accessibility (BAYER et al., 2004).

Looking to obtain indices to assess the effectiveness of different land use systems and different types of management and thus promote soil quality and agroecosystem sustainability, Blair et al. (1995) proposed a Carbon Management Index (IMC) which takes into consideration aspects of MOS lability. It is calculated by computing the Carbon Pool Index (ICC) and the Lability Index (IL).

ICC is the ratio of total organic carbon of the sampled system to organic carbon of the reference system ($ICC = COT \text{ of used system} / COT \text{ of reference system}$), and IL is obtained by computing the ratio of carbon lability of the sampled system to carbon lability of the reference system ($IL = L \text{ of used system} / L \text{ of reference system}$).

With the above in mind, the objective of this work was to evaluate C levels in the labile and stable fractions of MOS, in a region of northwestern Brazil subjected to different land use systems.

2 MATERIAL AND METHODS

2.1 Characteristics of the study site

The project was carried out in a private property located 13.5 km away from Colorado do Oeste, southern

Rondônia state, between geographical coordinates 13°09'29.4" south latitude and 60°37'50.6" west longitude, at an altitude of 330-417 meters, with an average maximum temperature of 35°C and an average minimum temperature of 19°C, and average annual precipitation exceeding 2.000 mm (RONDÔNIA, 2002).

For this study, six areas in close proximity to each other were selected (Figure 1), including: (i) primary forest vegetation/native forest (MA), (ii) agrosilvopasture consisting of teak, cocoa and pastureland (TCP), (iii) agroforest consisting of teak and cocoa (TC), (iv and v) forest consisting of teak at 8 years and teak at 5 years (T8 and T5) and (vi) pastureland cultivated with *Brachiaria brizantha* (PA). Soil was sampled in three furrows of 40x60x20 cm at depths of 0-5 cm, 5-10 cm and 10-20 cm, for each land use system. The land use history of each of these areas is summarized in Table 1.

According to Köppen classification, the local climate is Aw type, hot and humid with tropical rains, having two well defined seasons: summer from May to September which is when lower rates of rainfall are observed, around 750-810 mm, that is, 30% to 40% of the total, and winter from October to April, which is when higher rates of rainfall occur, around 1,470-1,500 mm or 60% of the total, with daily rain over a period of 100 days (RONDÔNIA, 2002).

The relief in the experimental area is mountainous, with most of the town of Colorado do Oeste (RO) sitting in the southwestern slope of the Parecis plateau at altitudes 400m above sea level. The predominating soil types in areas of smoothly rugged terrain are eutrophic Red-Yellow Argisols, eutrophic Red Argisols, eutrophic Cambisols, while in smoother terrain the predominating soils are dystrophic Yellow Latosols and Quartzarenic Neosols (RONDÔNIA, 2002).

2.2 Determination of total organic carbon and labile carbon

The total soil organic carbon (COT) was quantified via wet oxidation of the organic matter, using a potassium dichromate solution in acidic medium, with an external heat source (YEOMANS; BREMNER, 1988). The labile carbon was quantified via oxidation with $KMnO_4$ (333 mmol.L^{-1}), as proposed by Blair et al. (1995) and modified by Shang and Tiessen (1997), while the stable carbon (CNL), which is the C not oxidized by $KMnO_4$, was given as the difference ($CNL = COT - CL$).



Figure 1 – General view of locations where soil was sampled.

Figura 1 – Vista geral dos locais onde foram retiradas as amostras de solo.

Table 1 – Characteristics of the land use systems in each selected area.**Tabela 1** – Características dos sistemas de uso das áreas escolhidas.

Use system	Symbol	History
Native Forest	MA	Area of open semideciduous submontane tropical forest, emergent canopy having about 20% to 50% of deciduous trees in drought periods.
Agroforest system with teak at five years	T5	Teak introduced in December 2001 in 7.0 ha, with spacing of 3x2 m, where the primary forest had been manually felled, followed by burning. In the first two years rice, corn and beans were intercropped in between rows, followed by soil coverage with kudzu (<i>Pueraria montana</i>)
Agroforest system with teak at eight years	T8	Teak introduced in 1998, where the primary forest had been manually felled in June 1975, followed by burning, and then coffee planting (<i>Coffea canephora</i>). In between rows, it was intercropped with rice, corn and beans for 4 years, with no fertilization. In year five, a grass pasture was introduced (<i>Brachiaria brizantha</i>). Nine years later, in 1984, pine (<i>Schizolobium amazonicum</i>) was planted in 10 ha with spacing of 3x5 m between plants. As some seedlings died, teak was planted to replace them. In December 2000, the soil was covered with Kudzu (<i>Pueraria montana</i>).
Agroforest system with teak, cocoa and pasture	TCP	Teak introduced in 1998, the history of the area being the same as for T8, yet in December 2000 a portion of this area in between trees in the rows was intercropped with cocoa, with only teak and pasture remaining in the area.
Agroforest system with teak and cocoa	TC	Teak introduced in 1998, the history of the area being the same as for T8, yet in December 2000 a portion of this area in between trees in the rows was intercropped with cocoa, with only teak remaining in the area
Extensive pasture	PA	Area opened in 2001, with manual tree felling, followed by burning and planting of grass (<i>Brachiaria brizantha</i>), which was extensively yet unevenly grazed by cattle, with some areas being underused and other areas, overused.

1 g of the soil sample was passed through a 0.5 mm sieve, containing around 25 mg of organic C, with samples being placed in 50 mL centrifuge tubes and adding 25 mL of the KMnO_4 333 mmol.L^{-1} solution. The tubes were then capped and shaken for one hour at 60 rpm in a horizontal shaker, followed by centrifugation at 2,000 rpm for five minutes. 1.0 mL of the supernatant was pipetted into a 250 mL volumetric flask, completing the volume with deionized water. To construct the standard curve 1.0 mL was pipetted from six standard solutions of KMnO_4 with concentrations ranging from 280 to 333 mmol.L^{-1} , using the same dilution ratio.

The absorbance of the solutions was determined using a spectrophotometer with a selected wavelength of 565 nm. The variation in KMnO_4 concentration, as read from the standard curve, was used for estimating the amount of oxidized C (labile C) considering that 1.0 mol of KMnO_4 was consumed in the oxidation of 0.75 mol (9 g) of carbon. Based on the changes in COT from a reference system to a sampled system, a Carbon Pool Index (ICC) was calculated as follows: $\text{ICC} = \text{cultivated COT} / \text{reference COT}$. Based on the changes in the proportion

of CL (i.e. $L = \text{CL} / \text{CNL}$) in the soil, a Lability Index (IL) was determined as follows: $\text{IL} = \text{cultivated L} / \text{reference L}$. These two indices were used for calculating the Carbon Management Index (IMC), given as follows: $\text{IMC} = \text{ICC} \times \text{IL} \times 100$ (BLAIR et al., 1995).

This experiment used a completely randomized design with three replicates for each land use system. Treatments consisted of one reference sample (native vegetation/forest) and five different land use systems.

Data were subjected to analysis of variance and the means test (Scott-Knott at the 5% probability level), according to Banzatto and Kronka (1992), using SAEG software (RIBEIRO JÚNIOR, 2001).

3 RESULTS AND DISCUSSION

CL levels were higher ($p < 0.05$) respectively in the MA, T5, T8 systems, followed by the PA system (Table 2), in the 0-5 cm and 5-10 cm layers. For all systems, higher values were observed within a single system at the depth of 10-20 cm due to the protection of soil aggregates at greater depths. The greatest difference in CL level relative to the MA system was found for the TC system.

Table 2 – Labile and stable organic carbon in different land use systems.**Tabela 2** – Carbono orgânico lábil e não lábil em diferentes sistemas de uso.

Treat	Depth	CL	CNL	COT	ICC	IL	IMC	L
		-----g kg ⁻¹ -----						
MA	0-5	4.85 Ba	15.02 Aa	19.87 Aa	1.00	1.00	100 Aa	0.3229
	5-10	5.26 Ba	10.50 Aa	15.76 Aa	1.00	1.00	100 Aa	0.5010
	10-20	5.41 Aa	3.38 Ba	8.79 Ba	1.00	1.00	100 Aa	2.6933
T8	0-5	3.87 Bb	14.70 Aa	18.57 Aa	0.93	0.82	76.20 Ab	0.2633
	5-10	4.25 Bb	11.49 Aa	15.74 Aa	1.00	0.74	73.74 Aa	0.3699
	10-20	5.32 Aa	2.56 Ba	7.88 Ba	0.90	0.77	69.17 Bb	2.0781
T5	0-5	3.74 Bb	13.91 Aa	17.65 Aa	0.89	0.83	73.96 Ab	0.2689
	5-10	4.66 Ab	9.96 Aa	14.62 Aa	0.93	0.93	86.64 Aa	0.4679
	10-20	5.31 Aa	2.54 Ba	7.85 Ba	0.89	0.78	69.32 Ac	2.0906
TCP	0-5	3.45 Bb	10.87 Ab	14.32 Ab	0.72	0.98	70.84 Ab	0.3174
	5-10	4.20 Ab	6.45 Bb	10.65 Ab	0.68	1.30	87.84 Aa	0.6512
	10-20	4.80 Ab	3.11 Ca	7.91 Ba	0.90	0.57	51.57 Bd	1.5434
TC	0-5	3.25 Bb	12.6 Ab	15.85 Ab	0.80	0.80	63.72 Bc	0.2579
	5-10	4.12 Bb	5.55 Bc	9.67 Bb	0.61	1.48	90.92 Aa	0.7423
	10-20	4.70 Ab	2.45 Ca	7.15 Ba	0.81	0.71	57.94 Bc	1.9184
PA	0-5	3.87 Bb	9.98 Ab	13.85 Ab	0.70	1.20	83.71 Aa	0.3878
	5-10	4.25 Ab	4.96 Bc	9.21 Ab	0.58	1.71	99.96 Aa	0.8569
	10-20	5.24 Aa	1.75 Cb	6.99 Ba	0.80	1.11	88.41 Aa	2.9943

MA¹= forest, T8² teak 8 years, T5³= teak 5 years, TCP⁴= teak, cocoa and pasture, TC⁵= teak and cocoa, PA⁶=pasture. CL=labile carbon, CNL=stable carbon, COT=total organic carbon, ICC=carbon pool index, IL= lability index, IMC=carbon management index and L=lability. *Means followed by different letters, a capital letter within the same system and a small letter between different systems, differ from each other by the Scott-Knott test (P<0.05).

CL levels in the MA system at the depths of 0-5 cm and 5-10 cm were higher than in all systems being evaluated, similarly to results found by Zinn (2005).

All land use systems and all three layers being considered, it was found that CL levels increased with deeper depths due to greater protection of organic matter there.

The MA system had the highest level of the CL fraction (4.85 g kg⁻¹) in the 0-5 cm layer, while the TC system had the lowest CL fraction (3.25 g kg⁻¹), a result that demonstrates that in the uppermost layer there can be losses due to erosion, reduced microbial activity or other losses that include exposure to the sun. This fraction also decreased in the 5-10 cm layer (1.14 g kg⁻¹) when comparing the MA system with the TC system, while in the 10-20 cm layer the amount of lost CL decreased, the greatest loss being 0.61 g kg⁻¹ from the MA system to the TC system, possibly more

favorable to microbial activity and less protection of the CL inside smaller aggregates, similarly to results found by Bavoso et al. (2010) and Ferreira et al. (2011).

A difference was found (p>0.05) in CL levels at the 0-5 cm and 5-10 cm depths between the MA system and the other systems (T5, T8, PA, TCP and TC). The difference found in the 10-20 cm layer between MA and TC regarding CL, according to Aguiar et al. (2009), was probably due to the lack of grass species to help structure the soil. Bavoso et al. (2010) concluded that different land use systems did to add significant values of MOS accumulation between the sampled systems, and results confirm and demonstrate that CL levels in the MOS are largely susceptible to the quality of soil management systems, enabling to check the short- and medium-term effect depending on the management being used (FABRIZZI et al., 2008, cited by CHAVEZ et al., 2009).

The higher CL values found in MOS of the MA system, in surface layers, are related to greater addition and decomposition of plant residues on the soil surface, reduced microbial activity due to dropping soil temperature and increasing aeration, there also being greater physical protection of the MOS inside soil aggregates (BALESDENT et al., 2000).

As regards stable carbon (CNL), a difference was found in the 0-5 cm layer between the MA system and the TCP and PA systems, a decrease of 27.6% being found for the TCP system, and 33.5% for the TC system. A difference was also found in the 5-10 cm layer between the MA and the TCP, TC and PA systems. In the 10-20 cm layer, a difference was observed for the MA and PA systems in relation to the other systems, probably due to less accumulation of pasture-originated material. Aggregation is associated to physical protection of labile fractions of MOS, reducing biodegradation (BALESDENT et al., 2000).

Unlike CL, CNL had higher values for the MA and for the T8 and T5 systems, at 0-5 cm and 5-10 cm depths. At the 10-20 cm depth, PA was the only system showing a difference, providing the lowest results, probably due to the greater quantity of grass species in this system, as observed by Kluthcouski et al. (2006).

As for the carbon management index (IMC), a statistical difference was found in the 0-5 cm layer for the MA and PA system in relation to the other systems, with similar results found by Fraga (2002), it also being noted that the greater the intensity of crop cultivation and soil exposure, the lower IMC values are. In the 5-10 cm layer, there was no difference between the other systems and the MA system. In the 10-20 cm layer, a difference was observed for the MA and PA system in relation to the other use systems, similarly to results found by Leite et al. (2003), who found IMC values above 100 in pasture systems.

The IMC value in the 5-10 cm layer did not differ between the systems. In the studied profile (0-20 cm), the IMC ranged from 51.57 (TCP 10-20 cm) to 99.96 (TC 5-10 cm) within the use systems. As cited by Blair et al. (1995) and confirmed by several researchers, IMC values below 100 are typically found in studies where land use and management practices are degrading and indicative of a negative impact on the levels of organic matter, affecting soil quality as a result (COSTA et al., 2004), as was observed in all systems, with all layers having values below 100. Therefore, the most negatively affecting system at the 0-5 cm layer was the TC system, followed by the T8 system at the 5-10 cm layer, and the TCP system at the 10-20 cm depth layer.

All land use systems contributed to a reduction in the COT levels with increased depth, and at surface level the differences between systems were probably due to greater exposure of organic material to the effects of rain and sunlight in some systems (RIBEIRO et al., 2011). Therefore, the land use systems where organic matter was less exposed to degradation, including MA, T8 and T5, had better preserved COT levels. One possible reason for this is that the MA system having greater diversity of organic material, as reported by Faria et al. (2008) and Leite et al. (2003), there is continuous input and deposition of material on the soil surface. With the T5 and T8 systems, the deposited organic material is composed of leaves, branches and miscellaneous matter as was also reported by Almeida et al. (2010). Although the PA system did not contribute to COT at depth, the IMC and CL contributed in such way that even without organic input being deposited on its surface, this system explores the soil volume and preserves the aggregates, proving as efficient as the MA system in preserving CL levels, as was verified by Conte et al. (2011).

4 CONCLUSION

Manual felling of native vegetation, followed by burning and crop cultivation in the first two years, dramatically decreases soil carbon levels.

Different land use systems changed total organic carbon levels and oxidizable fractions. Labile carbon levels were reduced more intensely than total organic carbon levels, with the MA system having higher labile carbon levels.

Intercropped systems had higher IMC values in the surface layer (0-5 cm), while the PA system had a higher value for this index in the 5-10 cm layer.

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