Impact of Agricultural Management on Quality of Soil, Carbon Storage and Carbon Stratification

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Abstract— *The aim of this study was to characterize the carbon storage - Ec (Mg ha^{-1}), carbon stratification ratio, carbon management index (CMI) in various systems use and management: a) Native forest (NF), b) improved pasture of Tanzania grass (TIP), c) degraded pasture of Tanzania grass (DP), d) hay area (H) with Urochloa (syn. Brachiaria sp) and e) Corn crop conventionally cultivated for 10 years (CTC). The experiment was conducted at Institute of Animal Science, at Sertaozinho, São Paulo State, Brazil. The experimental design was randomized blocks with six replicates. The Ec, in Mg ha^{-1}, adjusted variations in soil density, related to changes in land use were for native forest (112.9), improved pasture (81.6), system of conventional maize (78.2), field of hay (75.1) and degraded pasture (66.5). The highest values of carbon stratification (SR) were the forest (1.98), and lower in degraded pasture and conventional maize (1.10) - are considered poor in quality, while the improved pasture (1.28) and the area of hay (1.23) of media quality and while the forest considered great quality. For the different systems of use and management, low CMI values indicate a loss of soil quality related to native forest (100%), the values obtained in improved pasture (58%) indicate that there is potential for advances in the soil quality, adjusting grazing management and fertilization of annual replacement.*

Keywords*— *Carbon management index, Carbon stratification ratio, Organic carbon.

I. INTRODUCTION

The different systems of agricultural exploration can change the deposition of plant residues on the soil and may increase or decrease carbon storage in the soil, acting either as a source or a drain for carbon into the atmosphere (Cerri *et al*., 2009). The adopted management system acts directly on the amount of carbon in the soil. Intensive soil tilling as used in conventional agriculture enhances losses by erosion and causes macro aggregates to break into smaller units and favors the exposure of the labile fraction of organic matter oxidants, causing its mineralization. This system also exposes residues to microbial action and attacks by their enzymes, resulting in an increase of CO_2 emissions (Bruce *et al.*, 1999; Six *et al*., 1999).

Changes in land use may increase the losses of stored carbon, which may be bigger than its sequestration. The conversion of grasslands into crop production causes losses in stored carbon varying from 14% to 33% (Soussana *et al*., 2010). Furthermore the deposition of pasture residues, predominantly dead leaves, stems and roots with high C: N ratio represent an average time of permanency usually long for the carbon stored in the soil, and grasslands can be considered overall as a carbon sink (Goudriaan, 1992). A FAO report (2010) presents pastures (native and cultivated) as the second largest potential sink of global carbon sequestration (C), with ability to drain 1.7 billion tons of C per year from the atmosphere, followed by forests, whose estimated capacity reaches 2 billion tons of C per year. Brazil, with about 197 million ha of pastures, stands as the country with the largest capacity for contribute to mitigating global warming through biological carbon sequestration (Braga, 2006; Corsi and Goulart, 2006), by recovering degraded areas, using a crop-livestock integrated system.

Common examples of change in the land use are forests turned into pastures for grazing or into conventionally cultivated crops. The conversion of forests into pastures with adequate management can enhance carbon storage, but if pastures were poorly managed it will induce C losses; however the conversion of native vegetation to conventional agriculture invariably reduces C stocks (Carvalho, 2010).

The use of appropriate management grazing practices, especially the replacement of soil fertility, enables the accumulation of C in the soil at a rate of 0.3 t of C. ha^{-1}. year^{-1}, which corresponds approximately to the mitigation of 1 t of CO_2 equivalent ha^{-1} year^{-1}. This value, quite conservative, would be enough to nullify approximately 80% of the annual emission of methane from an adult beef cattle, estimated at 57 kg which is equivalent to 1.42 tons of CO_2 (57 kg CH_4 . year^{-1} x 25 potential global warming gas = 1.42 t CO_2-eq) (Machado *et al.*, 2011).

The quantification of C stocks in the soil can point out the most appropriate land use and which can be more efficient and environmental-friendly. The different uses for grasslands (improved pastures, hay areas, corn silage areas) could be used to partially mitigate greenhouse gas emissions on ranches that raise beef cattle. The variations in labile and recalcitrant fractions of organic matter change with alterations in land use. The labile fraction is highly sensitive to changes in management, and represents an important nutrient reservoir, releasing them in the short term for plants, as well as energy and C to microorganisms in the soil (Conte *et al.*, 2011; Silva *et a.l*, 2011). Moreover, recalcitrant fractions, especially humic substances, act as regulators of chemical and biological soil and plant processes (Loss *et al*., 2010) and are important to the sequestration of atmospheric C (Mendonça and Silva, 2007). Carbon Management Index (CMI) can be used as an indicator of the quality of soil management, enabling its evaluation, whether the quality of the soil is improving or not: higher CMI values indicate soil of higher quality (Blair *et al*. 1995; Campos *et al*, 2011). IMC can be used to measure changes in soil organic matter, and considers aspects of labile organic matter, making it possible to compare the changes that occur in total organic C and labile C indifferent land use systems (Loss *et al*., 2011).

The stratification ratio of carbon (SR) is the ratio between the stock of soil organic carbon in two distinct layers, the surface usually with strong influence of soil management practices, and the adjacent layer, which is less affected by agricultural operations (Franzluebbers, 2002). Higher SR values suggest better soil quality. The values of SR in degraded soils of temperate climates are usually less than 2.0. For tropical soils studies relating SR and retention of organic matter and soil quality are rare.

The objective In this study was to evaluate changes in carbon stocks, as well as in the carbon management index, in an Eutroferric Red Latosol soil under different land use and several management systems: Forest, artificial degraded pasture with *Panicum sp. var. Tanza*nia, improved artificial pasture with *Panicum sp. cv. Tanzania,* hay area, and conventionally managed corn crop in the municipality of Sertaozinho, at São Paulo State, Brazil.

II. MATERIAL AND METHOD

2.1 Study area

The study was conducted at the Institute of Animal Science - IZ, Agencia Paulista de Tecnologia do Agronegocio (APTA) at Advanced Technology Research Center of Agribusiness Beef Cattle (21° 10' S, 48° 5' W) in the municipality of Sertaozinho, Sao Paulo State (Brazil). The climate is tropical humid -Aw - Köppen-Geiger, with an average annual temperature of 24° C and average annual rainfall of 1,312 mm (Figure 1).

2.2 Treatments and Experimental Design

The land uses were: a) Native forest (NF), b) improved pasture of Tanzania grass (TIP), c) degraded pasture of Tanzania grass (DP), d) hay area with *Brachiaria sp.* (H) and e) Corn crop conventionally cultivated for 10 years (CTC). The historical of these areas are presented in Table 1.

The experimental period was from October 2008 to March 2010. The experimental design was a randomized block design, with five replicates per treatment. For each land use every division was made searching its "homogeneity"; to provide better control the samples were taking in pairs in each situation. The areas within each system had the same topographical and edaphoclimatic conditions, differing only in land use. Samples were taken in the trenches at the depth of 0-5 cm, 5-10 cm, 10-20 cm, 20-30 cm and 30-40 cm for measurements of organic carbon in each different land use and soil management system. For evaluation of soil density, three undisturbed samples were collected in each system and depth (0-5, 5-10, 10-20, 20-30 and 30-40 cm), with the aid of a 100 cm^3 volumetric ring, according to EMBRAPA (1997). In the corn areas, sampling was performed after the grain harvest. In all systems of land use and management, the plant residues were removed from the soil surface before the samples were collected.

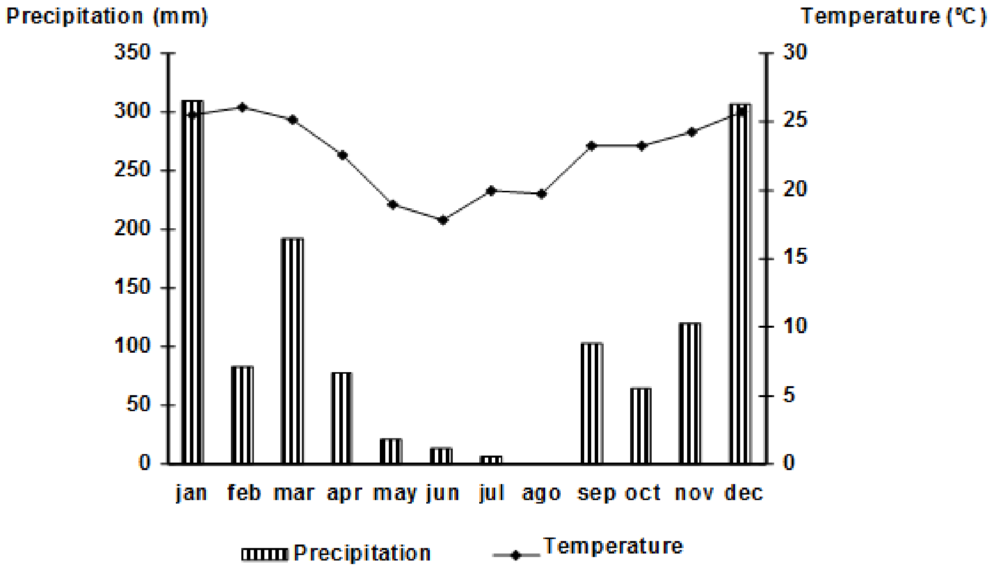

FIGURE 1. LONG-TERM MONTHLY MEANS OF PRECIPITATION (BARS) AND TEMPERATURE (LINE + SYMBOL)) AT THE INSTITUTE OF ANIMAL SCIENCE, IN THE MUNICIPALITY OF SERTAOZINHO (SÃO PAULO STATE, BRAZIL).

2.3 Soil Analysis

The soils of the experimental areas were classified as Eutroferric Red Latosol (EMBRAPA 1999) clayey, and had the following composition: grading 70.1% clay, 10.0% fine sand, 0.16% coarse sand and 18.0% silt. Soils collected were characterized physically and chemically. Each replicate consisted of three sampling points for each treatment at the layers of 0 to 20 cm (Table 2).

TABLE 1
HISTORICAL CHARACTERIZATION OF THE STUDIED SITES: NATIVE FOREST (NF), IMPROVED PASTURE (TIP), DEGRADED PASTURE (DP), FIELD HAYING (H) AND CONVENTIONAL TILLAGE CORN (CTC), STORY OF LAND USE ON EUTROFERRIC RED LATOSOL, SERTAOZINHO (SP).

Use systems	History soil areas
Native Forest (NF)	Reserve Augusto RUSCHI – transition between the biomes Atlantic Forest and Savannah Atlantic forest, aged 100 years, away from the savannah biome by 800 meters.
Tanzania improved pasture (IP)	Field seeded with *Panicum maximum cv. Tanzania*, 20 years old under semi-intensive grazing and use 0.7 to 1.2 animal unit per hectare per year and soil fertility management. Initial annual dose of 200 kg of fertilizer formula 00-20-00 and topdressing with 300 kg per ha of formula 20-00-20 and a second topdressing with300 kg per ha of formula 20-05-20.
Degraded pasture with Tanzania (DP)	Field seeded with *Panicum maximum cv. Tanzania*, established 20 years ago with no defined management and without soil fertility management.
Field haying (H)	Field seeded with *Urochloa brizantha (Hochst. Ex A. Rich.) RD Webster*, established 20 years ago, cutting hay annually, without nutrient reposition, but for the last two years, when was annually top dressed with 300 kg per ha of formula 20-00-20.
Conventional tillage corn (CTC)	Field in conventional tillage for 10 years. Base fertilization with 300 kg per ha of formula 08-28-16 and top dressed with 300 kg per ha of formula 20-00-20.

TABLE 2
ANALYSIS RESULTS FOR SOIL CHARACTERIZATION UNDER DIFFERENT LAND USE AND MANAGEMENT SYSTEMS AT THE MUNICIPALITY OF SERTAOZINHO (SP).

Systems/Layers	pH	OM	P	K	Ca	Mg	H+Al	T	V	Ds
cm		g kg^{-1}	mg dm^{-3}	_______mmol$_c$ Kg^{-1}_______					%	kg dm^{-3}
DP										
0-5	4.5	43	4	1.2	5	5	64	75.2	14.9	1.35
5-10	4.3	33	21	0.8	7	4	80	91.8	12.9	1.35
10-20	4.2	32	16	0.9	6	4	85	95.9	11.4	1.31
IP										
0-5	5.9	39	18	8.9	44	14	25	91.9	72.8	1.35
5-10	6.3	39	13	5.8	61	17	25	109	77.0	1.35
10-20	5.7	37	13	17	45	15	25	102	75.5	1.29
H										
0-5	4.7	49	4	1.5	12	7	52	72.5	28.3	1.16
5-10	4.4	35	20	0.7	3	2	58	63.7	8.9	1.33
10-20	4.2	30	6	0.7	2	2	59	63.7	7.4	1.23
CTC										
0-5	5.9	38	13	5.8	43	14	28	90.8	69.2	1.37
5-10	5.5	40	9	3.6	29	11	42	85.6	50.9	1.31
10-20	5.4	37	8	2.7	26	10	41	79.7	48.6	1.28
NF										
0-5	6.4	73	6	4.8	12	3,4	90	110	18.3	1.01
5-10	4.7	41	9	1.8	24	11	88	125	29.5	1.22
10-20	4.9	38	9	1.9	25	10	90	127	29.1	1.21

Systems: DP - degraded pasture, IP – Tanzania improved pasture, H – Hay Field, CTC – conventional tillage corn and NF – native forest. OM organic matter; T cation exchange capacity and base saturation V soil, soil density Ds

The samples were air-dried, homogenized, grounded and screened through a 100 mesh sieve and analyzed by dry combustion (Nelson and Sommers, 1996) in the elemental analyzer LECO CN 2000 in the Laboratory for Environmental Biogeochemistry (CENA-USP). The content of total C was determined by dry combustion in the elemental analyzer LECO CN-2000. The isotopic ratio ^{13}C / ^{12}C in the soils of the pasture areas was obtained from the release of CO_2 due to combustion at 550° C of the soil sample, separated by gas chromatography and continuous flow determined in the mass spectrometer Finnigan Delta Plus.

C stocks were calculated from the values of C and the values of the density of soil and soil layers (Equation 1) (Bernoux et al., 1998).

E = Ds.h.C (Equation 1), where E is the carbon stock of the soil (Mg ha^{-1}); Ds, soil density; h, thickness of the sampled layer; and C, the carbon content of the soil.

Because the samples were collected from the established layers, the calculation of inventory needed to be adjusted due to variations in soil density after the change in land use. Therefore, the methodology described by Ellert & Bettany (1996) and Moraes et al. (1996) was used to adjust the soil carbon to an equivalent soil mass, according to the calculations presented in Sisti et al. (2004) (Equation 2).

Ec = Σn-iE + {[Mai - (ΣnMa - ΣnMr)] Ti}(2), where Ec is the corrected C stock by soil mass (Mg ha^{-1}); Σn-iE, the sum of the stocks of layers without the last sampled layer; Mai, the soil mass of the last layer of sampled soil ; ΣnMa, the sum of the total mass of sampled soil; ΣnMr, the sum of the mass of soil reference; and Ti, the content of C in the last sampled layers.

After correcting the C stocks by the mass of soil sampled, it was possible to determine the annual rate of accumulation of C in the soil, which was estimated based on changes in C stocks over time (Equation 3).

T C = (Ctx - Cti) / t (3), where TC is the rate of change of C stocks in the soil (Mg ha^{-1} yr^{-1}); Ctx, the stock of C in the final time (Mg ha^{-1}); CTi, the C stock at the initial time (Mg ha^{-1}); and t, time (years).

The stratification ratio of carbon (SR) was calculated as proposed by Franzluebbers (2002): SR = Carbon Stocks in the surface layer in (0 - 0.10m) / carbon stock in the adjacent layer (0.10 to 0.20 m).

The determination of the labile C (LC) was carried out on 1 g of soil screened in a sieve with a mesh of 0.210 mm, mixed in a 50 mL centrifuge tube along with 25 ml of $KMnO_4$ (0.033 mol L^{-1}). The solution was stirred horizontally at 130 rpm for one hour and centrifuged at 960 g for five minutes. 100 uL of the supernatant was pipetted into test tubes of 10 ml of distilled water. Samples were read in a spectrophotometer at a wavelength of 565 nm, and the standard curve determined by LC (Shang and Tiessen, 1997). The non-labile (CNL) was determined by the difference between the total organic carbon and C labile.

The native forest was adopted as the reference system, and the Carbon Pool Index (CPI) was calculated as: CPI = cultivated COT / COT reference. Based on changes in the proportion of CL (CL = lability / CNL) in the soil, we calculated the index of lability (IL) IL = L grown / L reference. These two values were used to calculate the Carbon Management Index (CMI) obtained with the equation: CMI =ICC x IL x 100, according to the methodology proposed by Blair et al., (1995).

2.4 Statistical analysis

The analysis of variance (ANOVA) was used to detect differences among the studied areas. Because they are arranged in different sampling sites, the means were compared using the test for multiple comparisons, Student-Newman-Keuls test - SNK ($p < 0.05$). The Statistical analysis was performed using the SAS (2010) program.

Analysis of variance (Kruskal-Wallis) was used to detect Significant Differences among treatments. The means were statistically separated using the Student Newman-Keuls test ($p < 0.05$).

III. RESULTS AND DISCUSSION

The carbon content of the soil decreased ($P < 0.05$) with increasing sampled depth for the areas under native vegetation, pasture, conventional corn and hay area (Table 3). It was observed that the surface layers have the higher values, since there is a tendency of accumulation of plant material on the soil surface. On the areas of conventional crop corn and hay field, the adoption of a management that keeps the crop residues and any voluntary plant growth during the winter fallow, incorporating everything into the soil just before a new crop is seeded (in the case of corn) or maintain a healthy root system through cutting the aerial parts of the plants (as is the case for the hay field) resulted in carbon content in those treatments slightly above the amount considered minimum and critical to the quality of the soils, which is 20.0 g kg^{-1}.

TABLE 3
CARBON CONTENT (G KG-1) IN DIFFERENT LAYERS OF SAMPLED SOILS UNDER DIFFERENT MANAGEMENT SYSTEMS AT SERTAOZINHO – SP.

Layers (cm)	Degraded pasture (DP)	Conventional tillage corn (CTC)	Hay field (H)	Tanzania improved pasture (IP)	Native forest[1] (NF)
0 – 10	22.1aB	22.7 aB	24.4 aB	22.8 aB	33.1 aA
10 – 20	15.5 bcA	19.2 abA	15.1 cA	18.8 bA	23.8 bA
20 – 30	12.2 cA	17.0 bA	14.0 cdA	16.3 cA	24.9 bA
30 – 40	12.4 cA	9.8 cA	11.1 dA	9.0 dA	18.3 cA
CV (%)	12.3	11.9	14.2	13.2	12.9

[1]Biological Reserve Augusto RUSCHI – Atlantic forest biome in transition to cerrado. CV = coefficient of variation. Means followed by the same letter do not differ significantly at p < 0.05, with capital letters in the line comparing systems and the lowercase letters in the columns comparing depths.

The different land uses have no significant differences (P <0.05) in all layers except on the surface layer (0-10 cm) where native forest had a higher carbon content. The organic matter in the surface layers bring as a result a significant effect on nutrient cycling, aggregation, microbial activity, movement and storage of water and gas exchange with the atmosphere (Cerri et al., 2009).

Our results are consistent with studies conducted by Oliveira et al. (2004) and Paulino et al. (2014b) which observed values of organic matter that were significantly higher in surface layers in comparison to deeper layers. Kemper and Kock (1966) indicated that many soils in the Western United States and Canada suffered significant decline in structural stability when the soil organic carbon (SOC) was below 20 g kg^{-1}. Nevertheless, this value of 20 g kg^{-1} SOC (equivalent to ca. 34 g kg^{-1} organic matter) is a critical threshold of soil quality. In tropical soils the organic matter have a faster turnover than temperate soils, due to enhanced decomposition under the higher moisture and temperature regime of the tropics . Six et al. (2002) Paul & Clark (1989) attributed the soil C increase subjected to more conservation tillage systems, similar to pasture, to two main factors: 1) physical protection of the organic compounds against microbial decomposition, favored by the C occlusion in the soil aggregates; and 2) chemical protection of organic compounds through their interaction with minerals and cations, which hinders their decomposition. Soil organic matter values varying from 15.7 to 48.8 g kg^{-1} were described by several authors in tropical conditions Siqueira Neto et al. (2010) and Trinidade et al (2007). The strategy of amending and fertilizing in established pastures increased the amount of organic matter, mainly in the surface layers.

Carbon stocks in the soil were higher in native forest (112.9 Mg C ha^{-1}), followed by those of improved pasture (81.6 Mg C ha^{-1}) mainly due to the input of organic matter on the soil surface (Table 4). When litter is kept as a soil cover in the forest , without burning or plowing preventing oxidation of organic matter, the microorganisms in the soil decompose organic matter to an equilibrium, since decomposition is offset by fallen leaves, branches etc.

The average soil carbon stocks in the 0-40 cm layer in native forest cultivated in Atlantic forest biome (soil clayey with high fertility) was superior to those reported by Perrin et al., (2014) in Amazonia Forest biome (soil sandy with low fertility). Quesada et al. (2014) estimated that carbon stocks in the 0 – 2m soil depth correspondent to the more frequent range of values (100-200 Mg ha^{-1}) in Amazonia. The values of carbon stocks in the conventional corn system, of 78.2 Mg C ha^{-1} is related to the historic of the area, which was formerly a degraded pasture and was prepared for planting corn plowing and harrowing; It was used fertilizer at a rate of 300 kg / ha of NPK formula 08-28-16 at seeding and 300 kg / ha of 20-00-20 in topdressing; after harvest all plant material was incorporated into the soil. With regard to the pasture studied it was found a smaller carbon stock (EC) in degraded pastures, pastures of Tanzania and in the hay field with *Urochloa* due to less return of plant material to the soil in those areas, leading to lower values on carbon stocks.

TABLE 4
CARBON STOCK (MG HA-1) IN DIFFERENT LAYERS OF SAMPLED SOILS UNDER DIFFERENT MANAGEMENT SYSTEMS AT SERTAOZINHO - SP.

Layers (cm)	Degraded pasture (DP)	Conventional tillage corn (CTC)	Hay field (H)	Tanzania improved pasture (IP)	Native forest[1] (NF)
0 – 10	23.1aB	22.2 cB	25.1 aB	27.0 aB	48.8 aA
10 – 20	16.8 bA	20.5 bA	20.7 bA	21.0 bA	23.8 bA
20 – 30	14.4 cBC	18.4 bAB	17.2 bC	17.9 cAB	24.5 bA
30 – 40	12.2 cA	16.8 cB	12.1 aB	15.7 cA	15.8 cB
Total stock	66.5 D	78.2 B	75.1 C	81.6 B	112.9 A
CV (%)	12.4	13.4	14.2	13.2	11.2

[1]Biological Reserve Augusto RUSCHI – Atlantic forest biome in transition to Cerrado. CV = coefficient of variation. Means followed by the same letter do not differ significantly at p < 0.05 with capital letters in the line comparing systems and the lowercase letters in the columns comparing depths. Differences were considered significant at P < 0.05.

Grasses are important to increasing the storage and / or sequestration of carbon, especially in tropical areas where these species are more resistant to degradation because of a higher fiber content (Carvalho et al., 2010), as long as there is no limitations on the fertility of the soil for a high vegetal mass productivity, a fact that just happened on improved fertilized pasture, when the vegetal residues and especially the root systems present continuous renovation and high rhizosphere effect. Several studies with pastures in different soil management at Brazil presented values from 40.7 to 75.1 Mg ha^{-1} (Paulino et al., 2014a). These data corroborate D`Andréa et al. (2004) who worked with *Urochloa*.

Considering the total carbon stock in soil organic matter and that 1.0 ton of C is equivalent to 3.6 tons of CO (IPCC, 2007) and comparing the degraded pasture, the conventional cultivated corn area, and the hay area with the improved pasture, there were emissions or no sequestering of CO_2 of 54.4, 12.2 and 23.4 Mg ha^{-1}, respectively. On the other hand, comparing the different land uses: Tanzania grass in degraded pasture, hay field with *Urochloa brizantha*, conventional cultivated corn, and improved pasture area, with the values of the forest – savanna transition biome (used as the reference value and / or higher value of carbon stock) it was observed total values of 167.4; 136.4; 125.3 and 113.0 Mg ha^{-1} of CO_2 emitted or not sequestered respectively.

The total area of cultivated pastures in Brazil is about 150 million ha, with most of them presenting signs of early degradation mainly due to the lack of fertilization. The recovery of 15 million hectares or 10% of the area of degraded pasture with the use of lime and fertilizer and the implementing of a crop-livestock integration system in 4 million hectares would increase the average stock rate from 0.4 AU ha^{-1} to 3.0 AU ha^{-1} with a conventional tillage corn a significant effect on the beef and dairy cattle herds without the need to open new areas for ranching or farming. In addition it would expand the potential mitigation of greenhouse gases in the range of 100 and 125 million Mega grams of CO_2 equivalent, ensuring conservation of soil, water and wildlife (Moraes et al., 2012). It was verified that the management of fertilizer on the farm at Sertaozinho increased the productivity of the pasture, increased vegetal residues and hence carbon storage, especially in comparison to degraded pasture with the improved one.

The losses (%) of carbon stored in the soil to the atmosphere for the different land uses systems that replace the native forest, to the depth of up to 40 cm, were 41.1%; 33.5%; 30.7% and 27.7 % for the degraded pasture of Tanzania grass, the hay field, the conventional cultivated corn and the improved pasture, respectively. These values were higher than those obtained by Houghton (2005a) that found values for losses in carbon stock between 12-25% on degraded pastures and improved pastures replacing native forests.

Productive alternatives may become interesting if the environmental cost were added to the traditional model of agriculture, and are feasible in the proposed new development models, such as agro forestry (SAF) and crop-livestock integration. However, both the storage capacity, and the sequestering are compromised with the exchange of the original vegetation by agropastoril systems (Lindoso, 2009).

The comparison of the land uses showed the biggest values of labile carbon stocks (CL) in the forest (21.9 Mg ha^{-1}), followed by improved pasture and hay field with 11.7 to 9.4 Mg ha^{-1} respectively. The corn system and degraded pasture had stocks of CL of 8.4 and 5.3 Mg ha^{-1}, either similar or lower than the others. The largest differences occurred on the stock in the topsoil, where the native forest had higher levels of labile carbon. There was a decrease in CL stocks with depth; only in improved pastures stocks remained higher below 10 cm and were higher than the degraded pasture or conventional cultivated corn (Figure 2). The average values of labile organic C were 8; 11; 13; 16 and 22%, for the degraded pasture, conventional cultivated corn, hay field, improved pastures and native forest, respectively. In aerated soils under subtropical climate, this labile fraction of OM is usually 10-20% of the stock of organic C (Bayer, 2006; Vieira et al., 2007).

Regarding the stratification ratio of carbon (SR) the highest values were found in native forest (1.98) and the lowest in degraded pasture and conventional cultivated corn (1.10). The SR has a linear relationship with the soil quality index. The critical values for tropical soils are not well known yet, but a value of 1.5 has previously been reported for subtropical soils (Lal, 2010 and Canalli et al., 2010). Canalli et al., (2010) evaluating the quality of management in areas of no-till, suggested that in systems with low quality management and SR values <1.0 in soils, turning conventional tillage to no-till would bring SR values from 1.0 to 1.2. If the no-till system was used to its optimal it would increase SR from 1.2 to 1.5 and in a high quality soil SR would reach values > 1.5. In this study and using this criterion, degraded pasture, and conventional cultivated corn would be considered of poor quality, while the improved pasture area and hay field of good quality and forest would be considered of excellent quality (Figure 2). Franzuebbers (2010) reports the high SR directly gives the soil a higher superficial quality, increasing water infiltration in the soil layer, the aggregates stability and retention of nutrients.

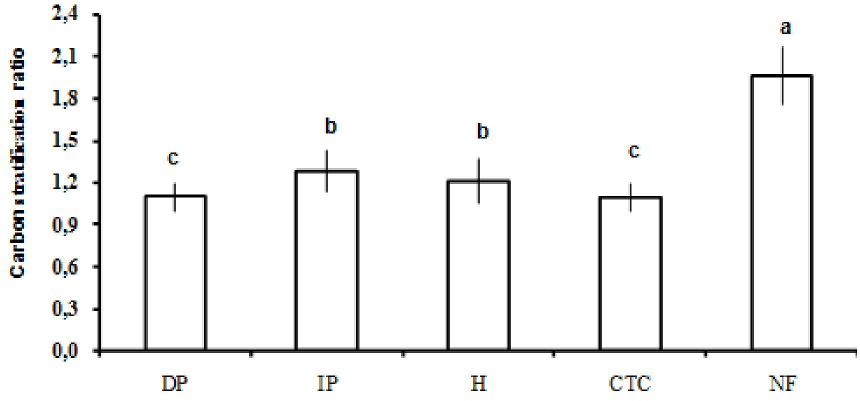

FIGURE 2: STRATIFICATION CARBON RATE (C STOCK IN THE SURFACE LAYER 0 - 0.10M / CARBON STOCK IN THE ADJACENT LAYER 0.10 TO 0.20 M) FOR THE DIFFERENT LAND USES: DEGRADED PASTURE (DP), IMPROVED PASTURE (IP), HAYING (H), CONVENTIONAL TILLAGE CORN (CTC) AND NATIVE FOREST (NF).

The carbon management index (CMI) values for the different land use systems shown that the native forest had a higher CMI and it was used as the reference value = 100, which decreased significantly in improved pasture (58%) and even more in degraded pasture (23%), while for the hay field and conventional tillage corn CMI values were in between the improved and degraded pastures, with 44% and 40%, respectively (Figure 3). Higher CMI values were related to higher deposition of plant residues in the soil, providing carbon sequestration; otherwise inadequate management determines lower CMI (Portugal et al., 2008). These results highlight the importance of labile carbon in evaluations of CMI, where forest and improved pasture showed higher values than the degraded pasture.

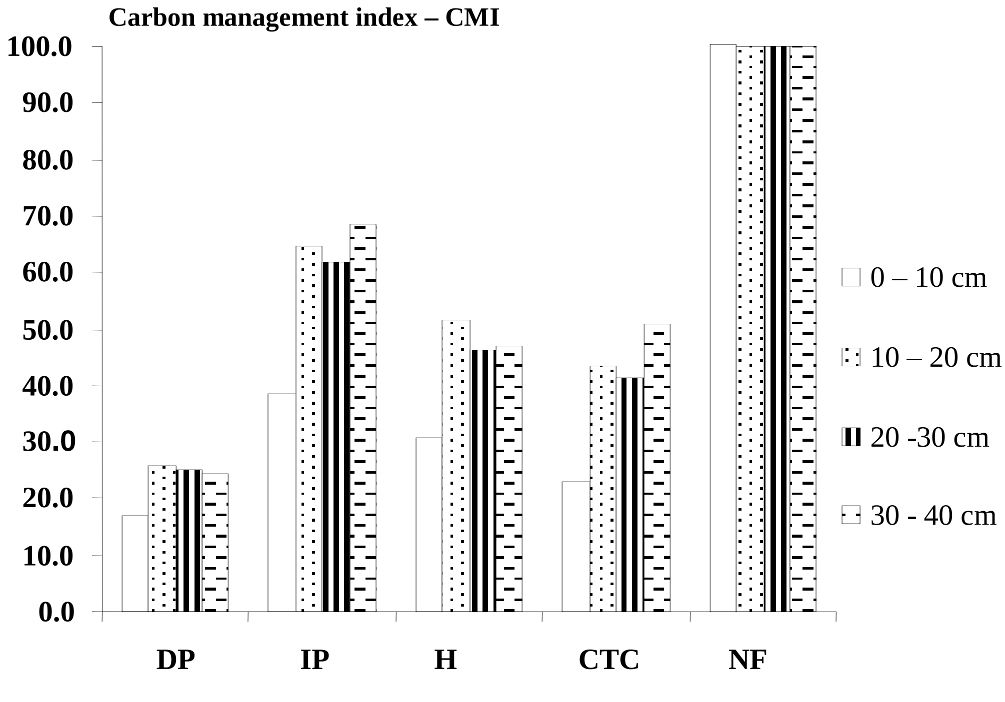

FIGURE 3: CARBON MANAGEMENT INDEX - CMI FOR THE DIFFERENT LAND USE SYSTEMS AND SOIL MANAGEMENT: DEGRADED PASTURE (DP), IMPROVED PASTURE (IP), HAYING (H), CONVENTIONAL TILLAGE CORN (CTC) AND NATIVE FOREST (NF), AT SERTAOZINHO (SP).

According to Moraes et al., (2012) the recovery of 15 million hectares or 10% of the area of degraded pasture, only by using fertilizers and the crop-livestock integration, would increase the stock rate average in several Brazilian regions to about 3 AU ha^{-1}, with significant effect on the beef and dairy cattle herds, without the need for opening new areas for agriculture or livestock production. In addition, it would expand the potential mitigation of greenhouse gases in the range of 100 and 125 million Mega grams of CO_2 equivalent, also ensuring conservation of soil, water and wildlife.

The use of varieties of cultivated grasses such as *Urochloa* sp. and *Panicum* second Thornton and Herrero (2010) are good from the standpoint of reduction of GHS emissions per unit of production since, besides allowing an increase in the number of animals in comparison to native pastures, are able o sequester atmospheric carbon, incorporating it into the soil because of the abundance of the root system.

Carvalho et al. (2010) observed that the conversion of native forest to pasture can cause the removal of atmospheric CO_2, but the magnitude of this removal occurs differently depending on soil fertility and the use or not of inputs. In that study, the authors found that non-degraded cultivated pastures, maintained in fertile soils showed an accumulation of carbon (accumulation of 0.46 Mg C ha^{-1} yr^{-1}), while the cultivated pastures in soils of low fertility had lost carbon, depending on the degree of degradation (losing from 0.15 to 1.53 Mg C ha^{-1} yr^{-1}, in the non-degraded and degraded pastures, respectively).

Soil organic carbon stock and its change with time and depth are key indicators of agricultural productivity potential and environmental health. This is because soil organic matter is a reservoir of biologically derived nutrients, a mediator of soil structural development, and a regulator of nutrient flux to the atmosphere and to receiving water streams. Perennial agricultural systems of pastures and woodlands often contain greater soil organic carbon than annually cultivated cropping systems (Paulino et al., 2014b and Franzluebbers, 2015).

On the other hand, the conversion of these non-degraded pastures in agriculture (soy or sorghum) released on average 1.44 Mg C $ha^{-1}yr^{-1}$ to the atmosphere. In the same study, it appears that the crop-livestock integration system, however, sequestered atmospheric C, with accumulation rates ranging from 0.82 to 2.58 Mg ha^{-1} yr^{-1}, with the accumulation rate depending on the crop, weather, and for how long the area is already in the system (Carvalho et al., 2010).

Pasture fertilization and integrated crop-livestock (ICL) systems are recommended as best practice to replace nutrients to the soil while the investment can be covered by the sale of grain. Literature relates that pasture carrying capacity increases from 0.5 AU (450 kg LW) ha^{-1} under degraded condition to 2.5 AU ha^{-1} in ICL. The improved pasture production and to increases soil C stocks, but the impact of the system on N_2O and CH_4 emissions should also be accounted for. With the respective stocking rates it was possible to estimate emissions on a per hectare basis. Carcass production (CWE) was 43 % higher with the ICL system compared to the degraded conditions. The area required to rear the herd under ICL was 80 % lower. The C-footprint for 1 kg CWE was reduced by approximately 45 %. The C accumulated in the soil and wood/tree biomass would help to compensate emissions for about 10 to 20 years (Alves et al., 2015).

IV. CONCLUSION

A land use systems and the soil management decreased the carbon inventory in comparison to native forest.

The areas used as hay fields, conventional corn crop and degraded pastures showed lower carbon management index (CMI) values which indicates lost of soil quality in comparison to native forest.

The use of fertilizers and adequate management recovered pastures which presented expressive increase in carbon accumulation and enhanced the CMI.

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