SIMULATION OF USE AND MANAGEMENT EFFECTS ON THE SOIL ORGANIC MATTER POOLS OF THE ATLANTIC FOREST BIOME, BRAZIL

SIMULAÇÃO DOS EFEITOS DO USO E MANEJO SOBRE OS COMPARTIMENTOS DA MATÉRIA ORGÂNICA NO SOLO NO BIOMA DA FLORESTAL ATLÂNTICA, BRASIL

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ABSTRACT: Soil organic matter simulation in areas under long term use provides an important tool to test future scenarios, enabling the adoption of less impressive management to environment. The purposes of the present study were: a) to simulate, with the Century model, the impacts on soil organic matter, according to the adoption of different crop management, with forage purposes, in two different soils and; b) to validate the Century model for these managements and soils by comparing the simulated values with those measured in the field. The following treatments were evaluated: in the Oxisol area – brachiaria pasture with fertilizer (BPw) and without fertilizer (BPwo), the Incept area – corn for silage (CS), Coast Cross pasture (CC) and sugar cane field (SC). The microbial biomass represented the active compartment of carbon and nitrogen, the particle free light fraction represented the slow compartment of carbon and nitrogen and the passive pools were determined by the difference of the total minus the active and the slow pools (passive = total – (active + slow)). The Century model showed great potential to simulate the dynamics of the total C and N stocks for tropical soils, which was confirmed by similarity between the simulated values and those measured in the field.

KEYWORDS: Century model. Carbon. Nitrogen. Tropical soils.

INTRODUCTION

The soil organic matter (SOM) has been directly associated to soil quality. Many studies have shown that in most environments the SOM improves soil structure and aggregation, increases water infiltration, prevents superficial sealing, reduces erosion and increases yield (REEVES, 1997). Likewise, it is very important for decisions on management systems that have CO_2 atmospheric sequestration potential which also contributes to the mitigation of climate changes (WATSON et al., 2000).

The growth information of SOM dynamics (SHAFFER; HANSEN, 2001), conceptual models which describe C and N processes in the soil have been developing (MOLINA; SMITH, 1998). In one comparison among nine models, two most used models, Century and RothC, presented the best results (SMITH et al., 1997). From then on, these two models began to be used with higher frequency.

Although the Century model was developed to simulate organic matter dynamics in temperate region pastures, its use in tropical climate regions and under different management systems has presented satisfactory results (VALLIS et al., 1996; SILVEIRA et al., 2000; CERRI et al., 2003; LEITE et al., 2004a; LEITE et al., 2004b;).

The Century model is composed of 3 sub models, plant material production, water and soil organic matter dynamics. The first two feed the third, generating the necessary data related to the moisture and soil temperature, crop nutrients in and out, quantity and quality of crop residue produced, etc. (PARTON et al., 1987). The SOM sub model is divided in pools (active, slow and passive), regarding its recycling time and decomposition rates. The active is represented by the microbial biomass and derivative products, with a recycling time up to 5 years. The slow pool is represented by the light organic matter, derivatives from crop residues or application of organics in the soil, with the recycling time estimated between 20 to 40 years. And for the last, the passive, represented by the material very resistant to decomposition and physical and chemically protected by the soil, which may take from 200 to 500 years to recycle (STEVENSON, 1994).

Models may offer an important contribution to the study of the SOM dynamics, but for both,

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they should be tested and validated under the most varied conditions, so that they may be utilized with confidence. Once tested and it validation has been proved, the models may also be utilized to simulate future soil management and use events, providing useful assistance for choosing the most appropriate ways to improve the soil quality in the most varied of agro ecosystems.

The purposes of the present study were: a) to simulate, with the Century model, the impacts on soil organic matter, according to the adoption of different crop management, with forage purposes, in two different soils and; b) to validate the Century model for these managements and soils by comparing the simulated values with those measured in the field.

MATERIAL AND METHODS

Studied area localization and sampling

The study was carried out at EMBRAPA (Brazilian Company for Agricultural Research) – DAIRY, which is located in the city of Coronel Pacheco in the state of Minas Gerais (latitude - 21° 14', longitude - 43°15' and altitude de 435 m). The regional weather is classified as Aw, according to Köppen, with an annual average temperature of 21° C, of rainfall annual average of 1581 mm and Atlantic forest as native forestation.

On this site mostly two types of soil occur, Oxisols on the slope and high areas and Inceptisols from alluvial origin in river beds, classified according to Soil Taxonomy (SOIL SURVEY STAFF, 2010). Areas of different uses and management of both soils were utilized. The sampling was done in June of 2004, at two different depths, 0.0 to 0.10 and 0.1 to 0.2 m. As the Century model works with the 0.0 to 0.2 m depth, both depths were added obtaining only one value. Each composite sample was obtained from 10 simple samples. As the areas were being worked in the field, they were divided into four imaginary quarters, where the samples were taken. Each of these quarters was considered to be one replication for statistical use.

Treatments and sequence of simulated events

For each treatment on different soils scenarios were simulated prior to the sampling and after that, until the year of 2050. For the later estimate, we simulated the continuous management existing at the time of the sampling for the analysis, as can be seen in Table 1. For each type of soil, one forest at the same condition was utilized as reference. The most detailed description for each treatment is presented below.

The forests on Inceptsol and Oxysol were secondary, which means they were restored after deforestation.

Table 1. Soil type , treatments and brief history of the soil management

Soil type	Treat. (name)	Simulated scenarios by the model
Oxisol	Brachiaria pasture with fertilizer (BPw)	- 1950 – deforestation -1950 to 1988 – *Panicum numidianum* - 1989 to 2002 – *Pennisetum purpureum* - 2003 to 2050 – brachiaria pasture
	Brachiaria pasture without fertilizer (BPwo)	- 1950 – deforestation - 1950 to 1985 – *Panicum numidianum* - 1986 to 2050 – brachiaria pasture
Inceptisol	Corn silage (CS)	- 1935 – deforestation - 1935 to 1973 – vegetables growing - 1974 to 1985 – *Panicum numidianum* - 1986 to 2050 – Corn silage
	Coast Cross pasture (CC)	- 1935 – deforestation - 1935 to 1979 – *Panicum numidianum* - 1980 to 1982 – pasture oat - 1983 to 1991 – grain corn summer - 1992 to 2050 – pasture coast cross
	Sugarcane (SC)	- 1935 - deforestation - 1935 to 1989 – *Panicum numidianum* - 1990 to 2050 – sugarcane

The fertilized pasture area, under Oxysol (BPw), was deforested in 1950, when *Panicum numidianum* was sown which did not receive fertilizer. From 1989 to 2003 Brachiaria *brizantha* sowen. At this time it 3 Mg ha^{-1} of limestone and phosphorous fertilization (100 kg ha^{-1} of P_2O_5) was added at the implementation period and 40, 20 and 20 kg ha^{-1} of P_2O_5, N and K_2O annually, respectively. From 1994 on, it began to receive N (50 kg ha^{-1}), P_2O_5 (30 kg ha^{-1}) and K_2O (200 kg ha^{-1}). Between 1998 and 2003, 100 kg ha^{-1} of 20-05-20 was applied. In 2003, at the time of brachiaria sowing, fertilizer was not added, although after its establishment 250 kg ha^{-1} of 20-05-20 was applied on December 2003. The other area, with brachiaria pasture without fertilizer (BPwo) is located at the same coordinate. This area, however, was not cultivated with *Panicum numidianum* as the prior one, but the following stages were similar, except for the fertilization, which did not occur.

On the Inceptisol area, the deforestation occurred in 1935, when the actual corn (*Zea mays*) area was cultivated with vegetables until 1973, *Panicum numidianum* without fertilization until 1985 followed by corn for silage twice a year, fertilized according to its recommendation. The pasture with Coast Cross area (*Cynodon dactylon L.*), (CC) until 1979 was utilized with *Panicum numidianum* without fertilizer and with a light grazing. From 1980 until 1982, the area was utilized for oat pasture (*Avena strigosa*) intercropped with *Lolium multiflorum* under irrigated pasture during winter. This pasture received 80 kg ha^{-1} of P_2O_5 during sowing and 100kg ha-^{1} of N and 100kg ha-^{1} of K_2O as coverage. From 1983 until 1991, corn was sown for grain during summer. During 1992, a study was done with Coast cross which received 200 kg ha^{-1} of P_2O_5 more 200 kg ha^{-1} of N and K_2O as coverage until 2002, when the fertilization changed to 1000 kg ha^{-1} of (20-05-20) plus 50 kg ha^{-1} of N as coverage during summer. Three tons per hectare of limestone was used during Coast Cross implementation and another 1000 kg ha^{-1} every two years. On the sugar cane area (*Saccarum offinarum L.*) (SC) *Panicum numidianum* without fertilizer and vegetables crops were cultivated until 1989. The sugar cane received fertilization up to the fifth year, 300 kg ha^{-1} of 8-30-16, and the yield was around 70 Mg ha^{-1} during the first four years and after that the yield decreased up to 40 Mg ha^{-1} because of the lack of correct management.

Chemical and Physical Analysis

The total organic carbon (TOC) was determined via wet oxidation (YEOMANS; BREMNER, 1988). For quantification of the total nitrogen (TN), the samples were subjected to sulfuric digestion with subsequent Kjedahl distillation (TEDESCO et al., 1995).

To release C and N from the microbial biomass to the 0.5 mol L^{-1} K_2SO_4 extracting solution the extraction-irradiation method was used (ISLAM; WEIL 1998), by using a microwave oven with 2450 MHz frequency and 900 W energy for 180 seconds (ISLAM; WEIL, 1998; FERREIRA et al., 1999). Carbon was quantified via wet oxidation, whereas N was quantified by Kjedahl distillation after sulfuric digestion (TEDESCO et al., 1995).

After correcting the moisture, the microbial C (C_{MIC}) and N (N_{MIC}) were calculated, based on the difference of the irradiated and non irradiated sub samples, by using a flow factor (Kc) of 0.33 (SPARLING; WEST, 1988) and 0.54 (BROOKES et al., 1985) for C and N, respectively. The microbial quotient that is the proportion of C_{MIC}/TOC and N_{MIC}/TN was also calculated. The C_{MIC} and N_{MIC} were utilized to represent the soil active pool.

The soil particle free light fraction (PFLF) was separated, based on the density and size difference (CAMBARDELLA; ELLIOTT, 1994), in which the liquid density (NaI) was 1.8 kg L^{-1} and the sieve utilized to separate the light material from the extracting solution had 0.25 mm of diameter. The material withheld in the sieve was washed and dried at 65° C, ground and analyzed with a Perkin Elmer series II 2400 CHNS/O analyzer. The C and N contained in the material were used to represent the intermediary recycling time compartment, which is the slow.

The compartment with the longest recycling time, the passive, was determined by difference: Passive (C and N) = total (TOC and TN) – (active (C and N) + slow (C = N). The C and N stock was calculated by multiplying the C and N contents by the soil bulk density.

Century v4.5 model validation

Balanced simulations (10,000 years) were done for the forest area, utilizing the local variables, such as texture, density and weather, as input data (Table 2).

A file was created to perform the balance simulation of the Atlantic forest type vegetation. For all areas, the model was run to adjust to the plant yield sub model, where the primary yield or crop yield were maintained according to the field or literature data, so that it could run the model and generate soil organic matter values. This procedure is called reversed simulation, since good results for the soil organic matter sub model is not expected if the plant yield sub model is generating unreal values, since the second feeds the first.

Table 2. Main entrance variables utilized for the Century model simulation

Variables	Oxisol	Inceptisol
Sand (g g^{-1})	0.35	0.41
Loam (g g^{-1})	0.08	0.08
Clay (g g^{-1})	0.57	0.51
Soil bulk density (g cm^{-3})	1.12	1.25
pH (H_2O)	4.25	4.25
Monthly rainfall (Jan to Dec) (cm $month^{-1}$)	31.06; 19.48; 19.09; 8.20; 4.70; 2.67; 2.12; 2.17; 6.93; 12.09; 20.73; 28.90	
T^0 C monthly minimum average (Jan to Dec) (^{0}C)	18.8; 19.1; 18.3; 16.1; 13.4; 10.9; 10.2; 11.5; 13.5; 16.1; 17.7; 18.5	
T^0 C monthly maximum average (Jan to Dec) (^{0}C)	30.2; 30.8; 30.0; 28.1; 26.6; 25.6; 25.2;26.6; 26.9; 27.9; 29.7; 27.8	

For each treatment, the model simulated the Atlantic forest deforestation and its conversion to the studied treatments, estimating the C stocks for each compartment through the years (deforestation until 2050). The treatment simulations began with the data generated by the balance simulation. Values simulated by the Century for September were compared with those measured, allowing the validation.

The Century model function, as well as its sub models, equations and assumptions and the way that the coefficients were determined may be seen with more details elsewhere (PARTON et al., 1987; PARTON et al., 1988; LEITE; MENDONÇA, 2003).

RESULTS AND DISCUSSION

Balance simulations

For the balance simulation some changes were needed on the fixed variables file of the model (FIX 100), so that the compartment decomposition rates could fit to those from the studied forest. Without this adjustment it would not be possible to run the model for the tropical conditions, since it was developed and validated for temperate climate. In the tree file (TREE 100), a first yield of 6.0 Mg ha^{-1} $year^{-1}$ was considered which is similar to that found in tropical forests (SILVEIRA et al., 2000). After those adjustments the model was run simulating a 10.000 year period, allowing the pool stabilization.

At the end of 10,000 years, the pools had been stabilized, according to the values shown in Table 3. For TOC and its pools, the simulated values were very close to those measured, even for the forest on the Oxisoil as well as the Inceptisol. For TN, the simulated values were similar to those measured, however, for the slow compartment, the model underestimated the measured values.

Table 3. Comparison between C and N stocks in different pools observed in the field and estimated by the Century model through the balance simulation of 10,000 years, in Coronel Pacheco/MG

Pools[/1]	Stocks (Mg ha^{-1})		Pools[/2]	Stocks (Mg ha^{-1})	
	Observed	Estimated		Observed	Estimated
Forest Oxisol					
TOC	49.52 (2.77)	49.14	TN	4.48 (0.19)	4.36
C active	1.31 (0.10)	1.38	N active	0.14 (0.02)	0.11
C slow	3.84 (0.29)	3.87	N slow	0.36 (0.07)	0.20
C passive	43.35 (2.45)	43.89	N passive	3.98 (0.15)	4.04
Forest Inceptisol					
TOC	60.64 (1.53)	60.33	TN	4.89 (0.16)	4.97
C active	1.92 (0.13)	1.87	N active	0.15 (0.02)	0.16
C slow	5.29 (0.54)	5.24	N slow	0.63 (0.02)	0.33
C passive	53.43 (1.72)	53.23	N passive	4.11 (0.16)	4.48

[/1] total organic carbon (TOC) and active compartments (C active), slow (C slow) and passive (C passive); [/2] Total nitrogen (TN) and active compartments (C active), slow (C slow) and passive (C passive)

With these results, it is expected that the model is able to satisfactorily simulate the TOC stocks and its pools. For N, even with a small deviation in the pools, good results running the model for field scenarios are expected.

Field Scenario simulation in the Oxisol area

From the values obtained by the balanced simulation in the forest on the Oxisol, the TOC and TN behavior and their respective pools (active, slow and passive) may be seen in Figures 1 and 2. Because of the deforestation (1950), the TOC and TN stocks and their respective pools (active and slow) increased considerably, however, after a few years these stocks became similar to the original values. It is an expected behavior (STEVENSON, 1994), because even with the burn after the deforestation, much plant material from the native vegetation remained in the area, which was incorporated, thereby increasing, mainly the active and slow compartment, and therefore the total stocks.

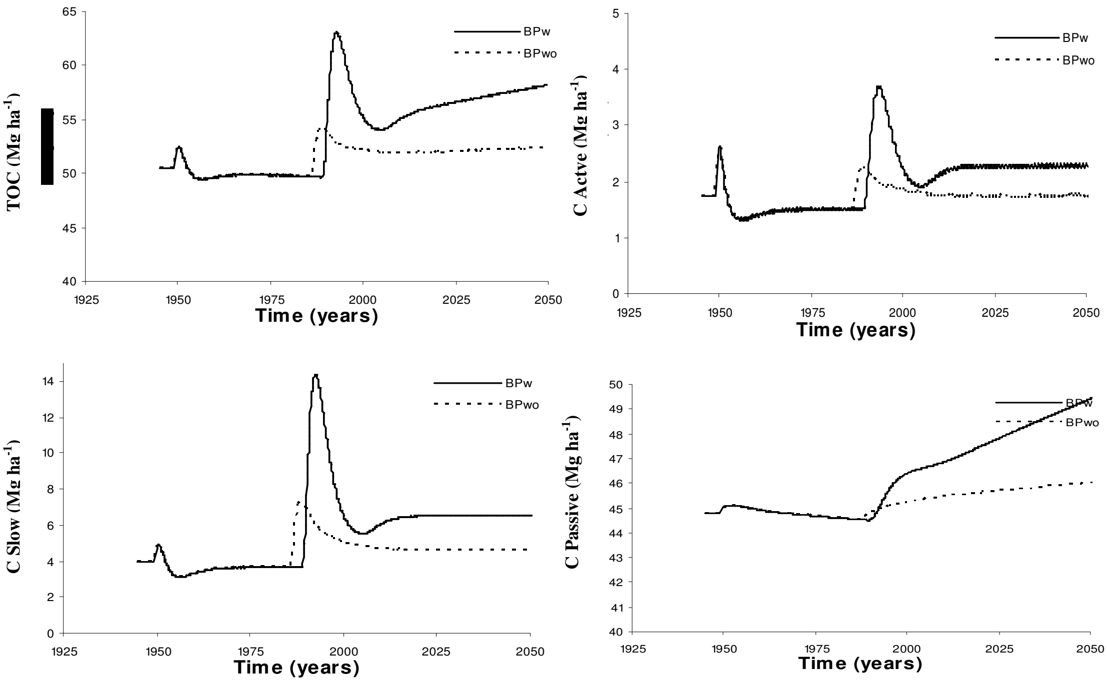

Figure 1. Total organic carbon (TOC), active (C active), slow (C slow) and passive pools (C passive) in the Oxisol area for brachiaria pasture with fertilization (BPw) and without fertilization (BPwo), estimated by the Century model, in Coronel Pacheco/MG. (Data source vary monthly).

In 1985 (BPwo) and 1988 (BPw), when the replacement from *Panicum numidianum* to *Brachiaria* sp. occurred, the total TOC and TN stocks and pools presented significant increase, having a reduction in the following years, with exception of the passive C. This effect is related to the incorporation of the plant residue from the soil surface by plowing and harrowing, from many years of *Panicum numidianum* accumulation, but it did not remain because of its decomposition. Harrowing and plowing this material accelerated its decomposition rate, and in a few years the most labile pools return to their initial stocks. This behavior also occurs when there is deforestation, and was also noticed after the substitution of native pasture by annual crops in Russia (MIKHAILOVA et al., 2000).

The stocks of TOC and active, slow and passive pools were higher in the fertilized treatments (BPw) when compared to the treatment without fertilizer (BPwo) (Figure 1). When considering quantitative terms, the positive effect of the fertilization in 2050 was 5.90; 0.54; 1.89 and 3.44 Mg ha^{-1} for TOC and active, slow and passive pools, respectively. This C gain was proportionate to the higher production of plant biomass in the fertilized area, with a higher intake of C. This shows the importance of fertilization on soil fertility management plans. For TN and active, slow and passive pools, the same behavior was noticed (Figure 2). The increase in wheat cultivation over a certain time caused the same effect, in other words, increased the soil C and N stocks, and this increase was attributed to a higher biomass yield (FRANZLUEBBERS et al., 1994). The use of crop rotation that procides a higher intake of plant material, together with a low tillage rate also contributed to increase the TOC stocks in the soil (AMADO et al., 2001; DEBARBA, 2002).

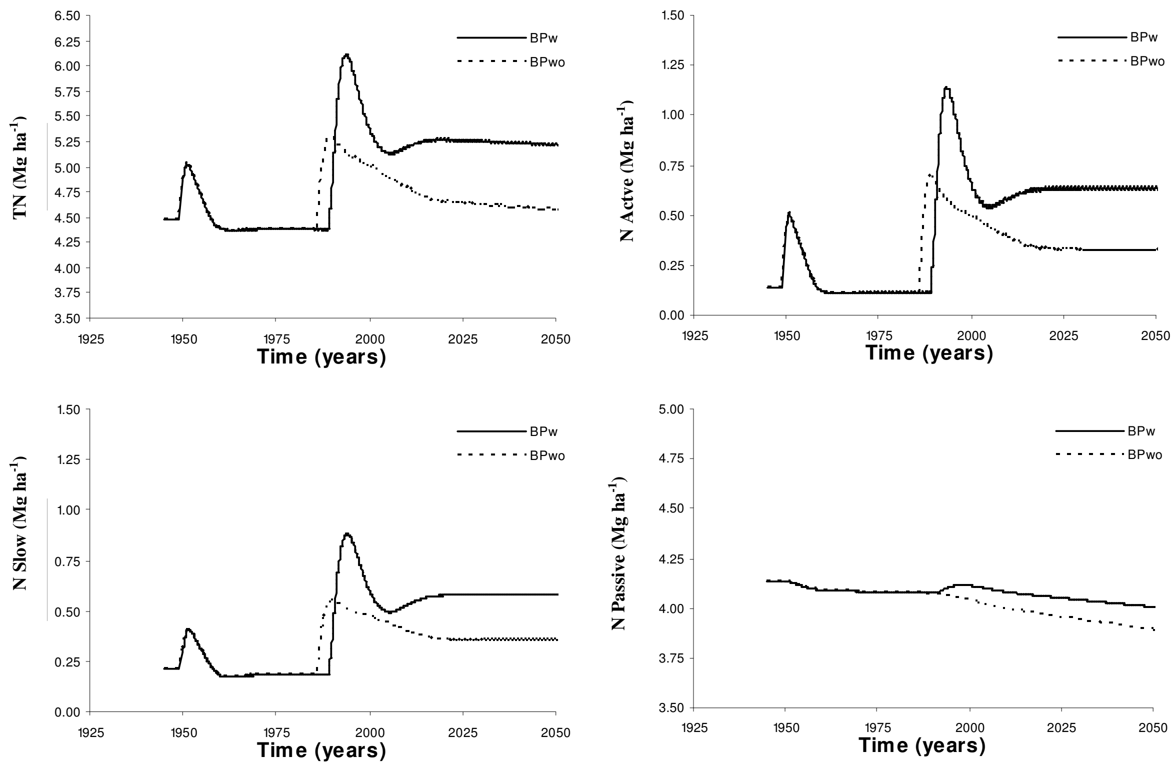

Figure 2. Total Nitrogen Stocks, active (N active), slow (N slow) and passive pools (N passive) in the Oxisol area for brachiaria pasture with fertilizer (BPw) and without fertilizer (BPwo), estimated by the Century model, in Coronel Pacheco/MG. (Data from source vary monthly).

The substitution of the secondary forest by pastures did not cause decrease in soil C and N stocks (Figure 1 and 2). The perennial pasture exempt soil tillage operations, keeping though, the C and N content in more physical and colloidal protected pools from microbial attack (STEVENSON, 1994; SÁ et al., 2002).

Field Scenario simulation in the Inceptisol area

Figures 3 and 4 show the simulated TOC and TN stock dynamics and their respective pools for the Inceptisol areas (alluvial soil). Because it is an alluvial soil, where the water retention is higher, the place was favorable for a higher initial TOC and TN stock than the Oxisol area.

In the simulations done by the Century model, the treatment with coast cross (CC) and sugar cane (SC) resulted no big changes on their TOC and TN stocks, as well as the passive compartment. After the felling of the secondary forest, the management in these areas was rather less impressive, almost without soil tillage, with an exception of CC, where oat and corn was sown for a few years (from 1980 to 1991). This period with an annual crop caused a small decrease in soil TOC and TN stocks, but with the coast cross introduction, the stocks recovered and remained stable until 2050.

The sugar cane introduction (SC) in 1980 resulted in a small decrease in the stocks simulated by the Century. In these simulations in the state of São Paulo, growing sugar cane caused a 28% reduction of TOC stocks int the first 12 years after establishment and 42 % after the 50-year simulation (SILVEIRA et al., 2000). In this project, the reduction was lower, however, it would certainly be higher if the Century model, in its plant yield sub model, considered a lower yield over the years. This yield loss was noticed in the field, and caused by the lack of nutrient replacement and by the vigor loss, since it is not replanted as per recommendation (once every five years on average). One strategy to avoid losses and still improve the C and N stocks in sugar cane areas would be to reduce and eliminate the burning and use N fertilization, as seen with simulations done in Australia (VALLIS et al., 1996). With the use of fire, both, C and N are lost to the atmosphere. The N fertilization increases the quantity and quality of the plant material that becomes part of the system, thus, increasing this element stock.

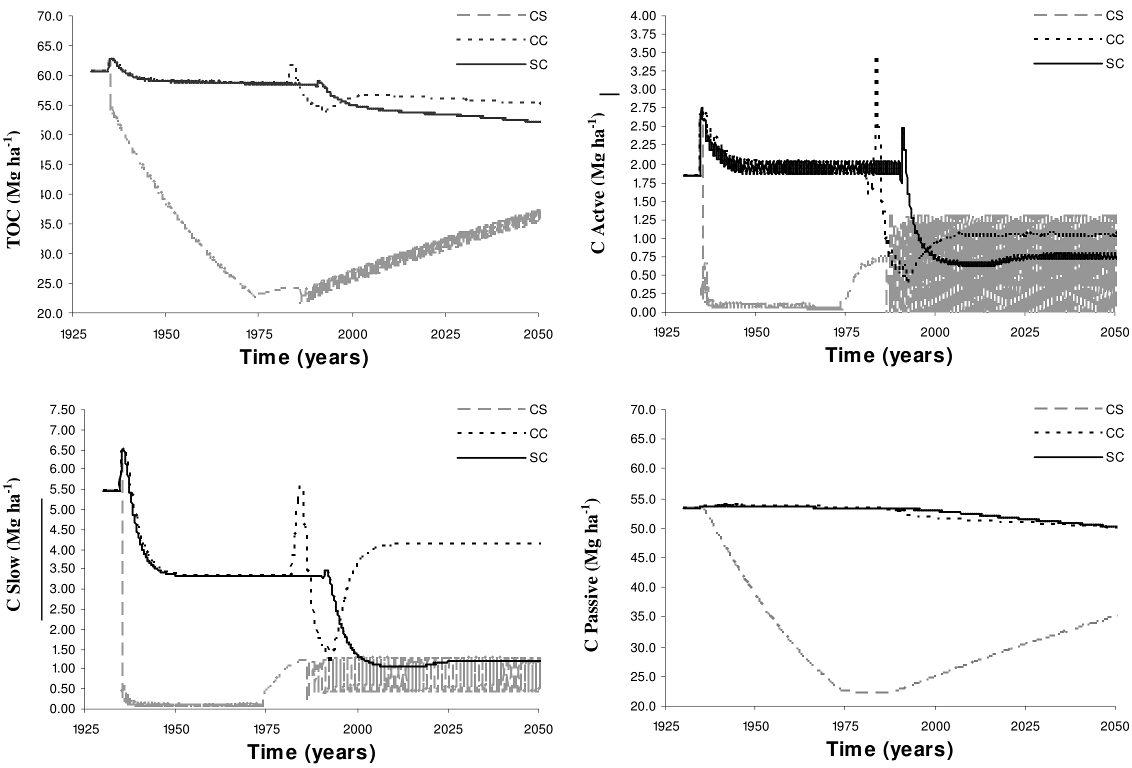

Figure 3. Total organic carbon (TOC) stocks, active (N active), slow (N slow) and passive pools (N passive) in a Inceptisol area for corn silage (CS), Coast Cross (CC) and sugar cane (SC), estimated by the Century model, in Coronel Pacheco/MG. (Data source varies monthly).

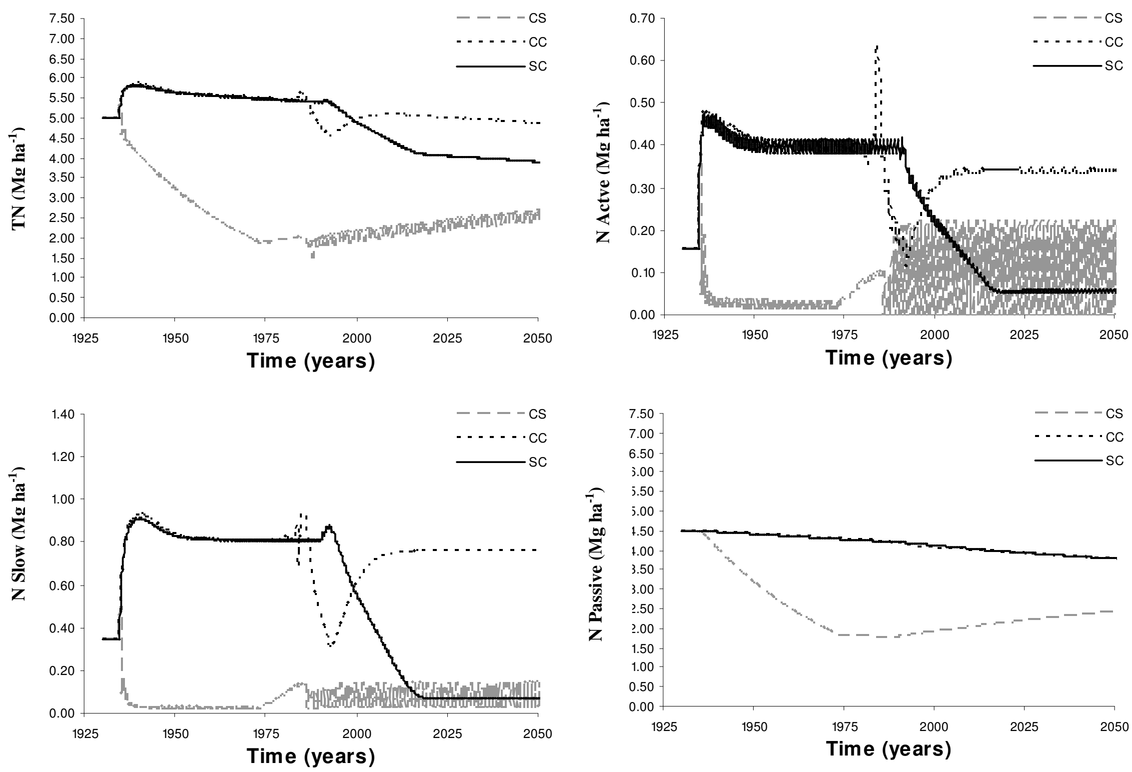

Figure 4. Total nitrogen (TN) stocks, active (N active), slow (N slow) and passive pools (N passive) in a Inceptisol area for corn silage (CS), Coast Cross (CC) and sugar cane (SC), estimated by the Century model, in Coronel Pacheco/MG. (Data source varies monthly).

The actual area used for corn silage (CS) was that that had the highest reduction in TOC and TN stocks (and respective pools) simulated by the Century model. According to the model, it is not the growing corn silage that was the responsible for these stock losses, but the cultivation of vegetable crops on this area until 1973. Growing vegetable crops requires intense soil tillage, keeping it uncovered for long periods, and almost all production is exported from the area. These facts justify the total stock losses and losses in the C and N pools. Intense soil tilling accelerates the plant material oxidation (STEVENSON, 1994) and leaves the higher recalcitrant or intra-aggregate C and N compounds more exposed to microbial activity (SIX et al., 2002). Along with the problem caused by the oxidation of most of the compounds present in the soil, the quantity added is minimum. With the minimum input there is not a maintenance or elevation of these C and N stocks, which are directly dependent on the material input in the system (AMADO et al., 2001; DEBARBA, 2002).

The active and slow pools were the most affected by the crop change (Figures 3 and 4). For CC and SC the simulated stock increased in the first years, remaining stabilized until the crop change intervention, oat and corn to CC and SC. After these interventions, the active and slow C and N stock decreased in CC, but with the introduction of the CC the stocks presented a slight recovery, because of the biomass production increase.

When considering the C and N stocks in the passive compartment, in CC and SC the simulated values had a slight decrease when compared to the initial ones, showing that this compartment is less affected by the use and management (STEVENSON, 1994; LEITE et al., 2004a; LEITE et al., 2004b) mainly when they are less impressive and produce high amount of biomass. The same may not be observed for CS, where the management was very impressive because of the many years of vegetable crop cultivation, having a reduction of simulated stocks of passive C and N higher than 50%. These stocks presented recovery by the time corn silage was implemented in 1986. The cultivation of corn silage is very impressive, because the total plant shoot is removed from the area, but in this study, the C and N stocks were recovered, maybe by the fact that at the beginning of the project the soil C and N stocks were much lower than the balance limit, allowing recovery. The corn also is a crop that produces high amount of root biomass, which contributes to this improvement.

Comparison of simulated and measured stocks

The simulated TOC stocks were very close to the measured (Table 4). The treatments BPw, BPwo, MS and CC had very small differences, less than 3 % and within the limit that the average standard error allows. For SC, the model underestimated the simulated stocks by about 13% in comparison with the measured, even though it is not a large difference, since the soil TOC variability is very high. These results strengthen belief in the capacity of Century model to properly simulate the TOC stocks in tropical soils, corroborating with the results of other projects also done in the tropical region (LIANG et al., 1996; LEITE et al., 2004a; LEITE et al., 2004b).

In the active pool (Table 4), the simulated stocks were also very close to the observed, with an exception for SC, where they were a little lower. For these pools, which vary constantly in the soil because of humidity, temperature and crop development stage changes (SILVA; MENDONÇA, 2007) it may be aware when comparing simulated and measured stocks. In Figures 1 and 3 we may see this variation between certain time periods. The differences between the measured and simulated values were very similar to those found in other research (MOTAVALLI et al., 1994; LEITE et al., 2004a; LEITE et al., 2004b), however, in the present work the estimated values were underestimated by the Century model.

In the Oxisol area, for the treatments BPw and BPwo, the stocks simulated by the model for the slow pool (Table 4) were higher by more than 100 % when compared to the measured. This great difference is explained by the very long recycle time considered by the Century model for this pool (20 to 50 years), which, for tropical conditions may not be the reality (WENDLING et al., 2008). However, the PFLF used in this project, does not include materials smaller than 0.25 mm or other compounds, which may be part of this pool (MOTAVALLI et al., 1994). In CS, where there was an intense soil disturbance and in SC, where fire was used, the simulated stocks for slow C were lower than the those measured. This shows the sensitivity of the model to those managements since those are practices that provide conditions for fresh material decomposition, mainly fire, where the plant material is transformed into CO_2. The passive pool (Table 4), presented the highest stocks, always participating with more than 86 % of the TOC. In temperate climate soils, the scenario is different. There most of the time these pools represent from 30 to 50 % of the TOC (PARTON et al., 1987). This large C proportion in the passive pool is related to the accelerated microbial decomposition of the materials in the active and slow pool, because of the high humidity and temperatures (STEVENSON, 1994), as well as the clayey conditions presents in the soil, where kaolinite and iron oxide types predominate, which make decomposition difficult (STEVENSON, 1994; SIX et al., 2002), keeping this pools stock on high levels.

Table 4. Comparison between stocks of total organic carbon (TOC) and active (C active), slow (C slow) and passive pools (C passive) simulated by the Century model and those obtained in the field by laboratorial methods in Coronel Pacheco/MG

Soil/treat[/1]	Pool (Mg ha^{-1})	Simulated	Observed
	Oxisol		
BPw	TOC	54.03	55.50 (3.51)[/2]
	C Active	1.89	1.21 (0.14)
	C Slow	5.52	1.83 (0.12)
	C Passive	46.62	52.47 (3.29)
BPwo	TOC	51.94	51.20 (0.45)
	C Active	1.77	1.10 (0.04)
	C Slow	4.81	2.11 (0.26)
	C Passive	45.36	47.99 (0.30)
	Inceptisol		
CS	TOC	27.39	27.46 (1.04)
	C Active	0.35	0.32 (0.02)
	C Slow	1.11	1.43 (0.08)
	C Passive	25.93	25.71 (0.98)
CC	TOC	56.48	56.57 (4.79)
	C Active	1.00	0.99 (0.13)
	C Slow	4.00	2.44 (0.14)
	C Passive	51.48	53.15 (4.91)
SC	TOC	54.56	45.66 (0.90)
	C Active	0.64	0.78 (0.06)
	C Slow	1.13	1.51 (0.20)
	C Passive	52.78	43.36 (1.06)

[/1] BPw – braquiaria pasture with fertilizer, BPwo –braquiaria pasture without fertilization, CS – silage corn, CC –coast cross pasture, SC– sugar cane crop. [/2] values in parenthesis refer to average standard error

Regarding the TN and passive N, the stock simulated by the Century model were similar to those measured (Table 5), with differences smaller than 20%. Although for the active and slow pool, the differences between the simulated and the measured values were higher than 50 %.

These results indicate that the model has the potential to simulate the TN stocks and the passive N pool, exactly where the stocks are higher, and where the stocks are smaller (active and slow N). Adjustments in the model must be made in order to obtain better results. Most of the works using the Century model provide results about the C and a few refer to the N dynamics in the soil. However, the good results for TN, was noticed in a work also done in state of Minas Gerais, Brazil, under a similar climatic conditions (LEITE et al., 2004a; LEITE et al. 2004b).

Table 5. Comparison between stocks simulated by the Century model and those obtained in the field by laboratorial methods for total nitrogen (TN) and active pool (C active), slow (C slow) and passive (C passive) in Coronel Pacheco/MG

Soil/treat[/1]	**Pool (Mg ha^{-1})**	**Simulated**	**Observed**
	Oxisol		
BPw	TN	5.13	5.19 (0.24)[/2]
	N Active	0.54	0.12 (0.01)
	N Slow	0.50	0.18 (0.02)
	N Passive	4.10	4.89 (0.22)
BPwo	TN	4.90	4.20 (0.11)
	N Active (t/ha)	0.44	0.12 (0.01)
	N Slow (t/ha)	0.44	0.14 (0.04)
	N Passive (t/ha)	4.02	3.94 (0.08)
	Inceptisol		
CS	TN	2.14	2.86 (0.08)
	N Active	0.08	0.05 (0.01)
	N Slow	0.10	0.62 (0.01)
	N Passive	1.96	2.74 (0.07)
CC	TN	5.06	5.30 (0.31)
	N Active	0.32	0.11 (0.01)
	N Slow	0.71	0.22 (0.04)
	N Passive		
		4.03	4.97 (0.29)
SC	TN	4.67	3.90 (0.08)
	N Active	0.17	0.12 (0.01)
	N Slow	0.41	0.11 (0.02)
	N Passive	4.09	3.68 (0.11)

[/1] BPw – braquiaria pasture with fertilizer, BPwo –braquiaria pasture without fertilization, CS – silage corn, CC –coast cross pasture, e SC – sugar cane crop. [/2] values between parentheses refer to average standard error

CONCLUSIONS

The simulated C and N stocks, as well as their pools were sensitive to the soil management changes.

The slow and active pools respond more immediately to these changes, making early indicator of soil quality possible to.

For the year 2050 the Oxisol area, the stocks simulated by the Century model showed the importance of fertilization on the improvement of the total stocks and C and N pools.

In the Inceptisol area, the model showed to be sensitive to intensive soil tillage, showing the negative impact of this practice on the simulated total stocks and on the C and N pools.

The Century model presented high potential to simulate the total C and N stock dynamics for tropical soils, proven by the similarity between the simulated values and those measured in the field.

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RESUMO: Simulação da matéria orgânica no solo em longo prazo é uma ferramenta importante para testar cenários futuros, permitindo a adoção de uma gestão menos impactante ao meio ambiente. Os objetivos do presente estudo foram: (a) simular o modelo do CENTURY, com os impactos sobre a matéria orgânica do solo em função do manejo diferente em culturas com fins de forragem em dois solos diferentes e, (b) comparar o estoque simulado com os reais de matéria orgânica, medidos no campo. Foram avaliados os seguintes tratamentos: na área de Latossolo Vermelho em uso de pastagem com fertilizantes (BPW) e sem fertilizante (BPwo), no Cambissolo - testou os usos com milho para silagem (CS), e pastagem com coast cross (CC) e um plantio de cana-de-açúcar (SC). A biomassa microbiana ativa representa compartimento de carbono e do nitrogênio, a fração leve livre de partículas representada o compartimento lento do carbono e de nitrogênio e os compartimentos passivos foram determinadas pela diferença do total menos o ativo e os compartimentos lentos (Passivo Total = - Ativo + Lento). O modelo Century demonstrou grande potencial para simular a dinâmica do C total e estoques de N para solos tropicais, o que foi comprovado por semelhança entre os valores simulados e medidos no campo.

PALAVRAS-CHAVE: Modelo de Century. Carbono. Nitrogênio. Solos tropicais.

REFERENCES

AMADO, T. J. C., BAYER, C., ELTZ, F. L. F.; BRUM, A. C. R. Potencial de culturas de cobertura em acumular carbono e nitrogênio no solo no plantio direto e a melhoria da qualidade ambiental. **Revista Brasileira de Ciência do Solo**, Viçosa, v. 25, n. 1, p. 189-197, 2001.

BROOKES, P. C., LANDMAN, A., PRUDEN, G.; JENKINSON, D. S. Chloroform fumigation and the release of soil nitrogen: a rapid direct extraction method to measure soil microbial biomass nitrogen in soil. **Soil Biology Biochemistry,** Queensland, v. 17, n. 1, p. 837-842, 1985.

CAMBARDELLA, C. A.; ELLIOTT, E. T. Carbon and nitrogen dinamics of soil organic matter fractions from cultivated grassland soil. S**oil Science Society America Journal**, Madison, v. 1, n. 58, p. 123-130, 1994.

CERRI, C. E. P., COLEMAN, K., JENKINSON, D. S., BERNOUX, M., VICTORIA, R.; CERRI, C. C. Modeling soil carbon from forest and pasture ecosystems of Amazon, Brazil. **Soil Science Society of America**, Madison, v. 67, n. 1, p. 1879-1887, 2003.

DEBARBA, L., **Simulação pelo modelo century do impacto da agricultura sobre o estoque de Carbono orgânico em solos do Planalto Riograndense**. 2002. 172 f. Tese (Doutorado em Ciência do solo) - Programa de Pós-Graduação em Ciência do Solo, Universidade Federal do Rio Grande do Sul, Porto Alegre, 2002.

FERREIRA, A. S., CAMARGO, F. A. O.; VIDOR, C. Utilização de microondas na avaliação da biomassa microbiana do solo. **Revista Brasileira de Ciência do Solo**, Viçosa, v. 23, n. 1, p. 991-996, 1999.

FRANZLUEBBERS, A. J., HONS, F. M.; ZUBERER, D. A. Long-term changes en soil carbon and nitrogen pools in wheat management systems. **Soil Science Society of America**, Madison, v. 1, n. 1, p. 1639-1645, 1994.

ISLAM, K. R.; WEIL, R. R. Microwave irradiation of soil for routine measurement of microbial biomass carbon. **Biology and Fertility Soils**, Berlin, n. 27, n. 4, p. 408-416, 1998.

LEITE, L. F. C., MENDONÇA, E. D. S., MACHADO, P. L. O. D. A., FILHO, E. I. F.; NEVES, J. C. L. Simulating trends in soil organic carbon of an Acrisol under no-tillage and disc-plow systems using the Century model. **Geoderma**, Michigan, v. 1, n. 120, p. 283-295, 2004a.

LEITE, L. F. C., MENDONÇA, E. M., MACHADO, P. L. O. D. A., NEVES, J. C. L.; FERNANDES FILHO, E. I. Simulação pelo modelo Century da dinâmica da matéria orgânica de um Argissolo sob adubação mineral e orgânica. **Revista Brasileira de Ciência do Solo**, Viçosa, v. 28, n. 2, p. 347-358, 2004b.

LEITE, L. F. C.; MENDONÇA, E. S. Modelo century de dinâmica da matéria orgânica do solo: Equações e pressupostos. **Ciência Rural**, Santa Maria, v. 1, n. 33, p. 679-686, 2003.

LIANG, B. C., GREGORICH, E. G.; MACKENZIE, A. F. Modeling of organic and inorganic amendments on organic matter in Quebec soil. **Soil Science**, Baltimore, v. 161, n. 1, p. 109-114, 1996.

MIKHAILOVA, E. A., BRYANT, R. B., DEGLORIA, S. D., POST, C. J.; VASSENEV, I. I. Modeling soil organic matter dynamics after conversion of native grassland to long-term continuous fallow using the CENTURY model. **Ecological Modelling,** Amsterdam, v. 132, n. 1, p. 247-257, 2000.

MOLINA, J. A. E.; SMITH, P. Modeling carbon and nitrogen processes in soil. **Advances in Agronomy**, San Diego, v. 62, n. 1, p. 253-298, 1998.

MOTAVALLI, P. P., PALM, P. C. A., PARTON, W. J., ELLIOT, E. T.; FREYS, S. D. Comparasion of laboratory and modeling simulations methods for estimating soil carbon pools in tropical forest soils**. Soil Biology & Biochemistry**, Queensland, v. 1, n. 26, p. 935-944, 1994.

PARTON, W. J., SCHIMEL, D. S., COLE, C. V.; OJIMA, D. S. Analisys of factors controlling soil organic matter levels in great plais grasslands. **Soil Science Society of America**, Madison, v. 51, n. 1, p. 1173-1179, 1987.

PARTON, W. J., STEWART, J. W. B.; COLE, C. V. Dinamics of C, N, P and S in grasslland soils: a model. **Biogeochemistery,** Dordrecht, v. 1, n. 5, p. 109-131, 1988.

REEVES, D. W. The role of soil organic matter in maintaining soil quality in continuous cropping systems. **Soil & Tillage Research**, Amsterdam, v. 1, n. 43, p. 131-167, 1997.

SÁ, J. C. M., CERRI, C. C., DICK, W. A., LAL, R., VENZKE FILHO, S. P., PICCOLO, M. C.; FEIGL, B. E. Soil microbial biomass and organic components affected by no-tillage chronosequence in a Brazilian Oxisol. **Soil Biology and Biochemistry**, Queensland, v. 1, n. 1. 2002.

SHAFFER, M. J.; HANSEN, S. Introduction to simulation of carbon and nitrogen dynamics in soils. In: SHAAFFE, M. J.; HANSEN, S. (Editors), **Modeling carbon and nitrogen dynamics for soil management**. Lewis Publishers, Boca Raton, 2001. p. 11-26.

SILVA, I.; MENDONCA, E. S. Matéria Orgânica do Solo. In NOVAIS, R. F. et al., **Fertilidade do Solo.** Sociedade Brasileira de Ciência do Solo. Viçosa, 2007, p.1017.

SILVEIRA, A. M., VICTORIA, R. L., BALLESTER, M. V., CAMARGO, P. B., MARTINELLI, L. A.; PICCOLO, M. D. C. Simulação dos efeitos das mudanças do uso da terra na dinâmica de carbono no solo na bacia do rio Piracicaba. **Pesquisa agropecuária brasileira**, Brasilia, v. 1, n. 35, p. 389-399, 2000.

SIX, J., CONANT, R. T., PAUL, E. A.; PAUSTIAN, K. Stabilization mechanisms of soil organic matter: Implications for C-saturation of soils. **Plant and Soil**, Pretoria, v. 241, n. 1, p. 155-176, 2002.

SMITH, P., SMITH, J. U., POWLSON, D. S., MCGILL, W. B., ARAH, J. R. M., CHERTOV, O. G., COLEMAN, K., FRANKO, U., FROLKING, S., JENKINSON, D. S., JENSEN, L. S., KELLY, R. H., KLEIN-GUNNEWIEK, H., KOMAROV, A. S., LI, C., MOLINA, J. A. E., MUELLER, T., PARTON, W. J., THORNLEY, J. H. M.; WHITMORE, A. P. A comparison of the performance of nine soil organic matter models using datasets from seven long-term experiments. **Geoderma**, Michigan, v. 1, n. 81, p. 153-225, 1997.

SOIL SURVEY STAFF. **Keys to Soil Taxonomy**, 11th Ed. Washingthon, D.C, USDA-Natural Resources Conservation Service, 2010

SPARLING, G. P.; WEST, A. W. A direct extration method to estimate soil microbial C: Calibration in situ using microbial and ^{14}C labelled cells. **Soil Biology & Biochemistry**, Queensland, v. 20, n. 3, p. 337-343, 1988.

STEVENSON, F. J., **Humus chemistry: genesis, composition, reactions**. 2ª Ed., Canadá, 1994. 496p.

TEDESCO, M. J., BOHNEM, H., GIANELLO, C., BISSANI, C. A.; VOLKWEISS, S. J., **Análise de solo, plantas, e outros materiais**. Universidade Federal do Rio Grande do Sul, Porto Alegre, 1995. 174p.

VALLIS, I., PARTON, W. J., KEATING, B. A.; WOOD, A. W. Simulation of the effects of trash and N fertilizer management on soil organic matter levels and yields of sugarcane. **Soil & Tillage Research**, Amsterdam, v. 38, n. 1, p. 115-132, 1996.

WATSON, R. T., NOBLE, I. R., BOLIN, B., RAVINDRANATH, N. H., VERARDO, D. J.; DOKKEN, D. J. **Land use, land use change and forestry: a special report of the IPCC**. Cambridge. Universy Press, Cambridge, 2000. 377p.

WENDLING, B., JUCKSCH, I., MENDONÇA, E. S., NEVES, J. C. L., SILVA, I. R.; COSTA, L. M. Organic-Matter Lability and Carbon-Management Indexes in Agrosylvopasture System on Brazilian Savannah. **Communication in Soil Science Plant Analisys**, New York, v. 39, n. 1, p. 1750-1772, 2008

YEOMANS, J. C.; BREMNER, L. M. A rapid and precise method for routine determination of organic carbon in soil. **Communication in Soil Science Plant Analisys**, New York, v. 19, n. 13, p. 1467-1476, 1988.