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Validation of the CENTURY model to simulate the dynamics of soil organic matter under different production systems in the Cerrado region - Brazil.

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Introduction

The soil organic matter (SOM) represents a susceptible attribute to the effect of soil degradation and it is also an effective indicator to evaluate the effectiveness of conservation practices on the soil quality recovery and maintenance. Its management represents one of the basic foundation to be pursued in sustainable production systems. To understand its dynamics, and to simulate it with reasonable accuracy from models previously validated may allow planning of SOM management strategies in order to maximize its beneficial effects on the system. The improvement of existing mathematical models and their calibration for the specific conditions of crop-livestock integration systems in the tropics and subtropics can enable simulations of the potential for carbon sequestration in these systems. Such information is strategic for Brazil, in the face of the leadership position it has taken the reduction of greenhouse gases emissions negotiations.

The CENTURY model, described by Parton *et al.* (1987), was initially developed to simulate the carbon and nutrient dynamics in ecosystems of native grasslands of the United States of America (USA). It has been widely used in various other natural and cultivated ecosystems, including tropical regions. The relative ease of the treatments of biogeochemical processes and the good relationship found between measured and simulated values (r^2 above 0.75, according Parton *et al*., 1994) have been consolidating the model as an important tool to study the MOS dynamics for several situations of soils use and management (Leite; Mendonça, 2003).

The aim of this study was to parameterize and validate the CENTURY model to simulate the soil carbon stocks under different production systems in the Cerrado region, using data from a long-term experiment at Embrapa Agropecuária Oeste, Dourados / MS .

Materials and methods

It was used data from a long-term experiment conducted at Embrapa Agropecuária Oeste (Dourados / MS). Secondary data were compiled from reports of the research project "Mathematical modeling and simulation of the dynamics of soil organic matter in tillage system "(EMBRAPA, 2007).

The experiment was established in 1995 in an area under Oxisol very clayey, with 90, 170 and 740 g kg-1 sand, silt and clay, respectively. Originally the area was deforested in 1975 and cultivated with soybeans- wheat rotation. The soil management systems that constitute the experiment are: Natural vegetation – Cerrado (VN) and systems composed of tropical perennial pastures - braquiaria (PP), annual crops under conventional tillage - soybeans-wheat rotation (CT) and no-tillage systems - oilseed adish/corn/oat/soybeans/wheat/soybeans (PD), and pasture rotation with annual crops - soja/aveia/braquiaria (ILP).

The soil samples were taken after maturation of summer crops in April 2005. The samples were dried at 60^{o}C to constant weight. Total soil organic carbon (C) was determined using an Elemental Analyzer (LECO-CR412) in laboratory of Embrapa Pantanal (Corumbá-MS). The 0-20 cm layer C stocks was calculate after the value correction for all areas to a same soil mass basis, considering as reference the soil density of native area as suggested by Sisti *et al.* (2004).

To simulate the historical usage of the area it was eployed the 4.0 version of the Century model, available at URL http://www.nrel.colostate.edu/projects/century. Statistical analysis of the model simulation results of was made using the approach proposed by Smith *et al*. (1996, 1997).

Results and discussion

In the native area (VN), the value of 0-20 cm layer C stocks was 72.0 Mg ha^{-1}. After deforestation and agricultural use (1975-1995), this value decreased to 39.8 Mg ha^{-1}. After the experiment implementation and conduction (1995-2005) the stocks of soil C have changed, increasing in the tropical perennial pastures systems (PP) - 47.5 Mg ha^{-1}, no-tillage systems (PD) - 43 , 5 Mg ha^{-1}, and pasture rotation with annual crops (ILP) - 45.2 Mg ha^{-1}.
Before the start of the experiment, the simulation of deforestation and early use of the experimental area in the period 1975-1995 the total C stocks simulated by CENTURY were reduced from 68 Mg ha^{-1} under native vegetation to 42. 9 Mg ha^{-1} after 20 years of conventional tillage with wheat-soybean succession. This represents a reduction of 37% of the initial stock, or a loss rate of 1.26 Mg C ha yr^{-1} (Figure 1). After the start of the experiment, the area of conventional tillage continued to lose C, but at a slower rate than observed in the previous 20 years. This may be related to a better system management, involving more appropriate fertilization and practices. The adoption of no-tillage (NT) induced a positive response in the simulations, increasing the levels of C with time. The trends of increasing system C stocks due to the adoption of PD are consistent with the observed data, indicating that this would be a real trend (Figure 1). The largest increase in total C stocks were observed for systems involving the presence of forage - pastures permanent (PP) and integrated crop-livestock system (ILP). At the Table 1 can be observed that the total C stocks simulated by CENTURY and measured in the experiment for the different production systems. All simulated values were lower than the measured values, except for the simulation of the initial value of the experimental area in 1995. The differences ranged between 2.67 and 11.11%. Statistical analysis comparing the simulated and measured data of total C, as suggested by Smith et al. (1996.1997), showed that the model was able to accurately simulate the experiment, showing a high correlation between the simulated and measured values (R2 = 0.96), a good match between measured and simulated values (RMSE = 6.92%), and a low relative error (E = 6.41).

Conclusions

The Century model showed good adaptability to the studied systems (Oxisol under different tillage systems). For the Cerrado region, under the conditions studied, the systems of perennial pastures and crop-livestock integration are those with the greatest potential for restoration and maintenance of soil carbon stocks.

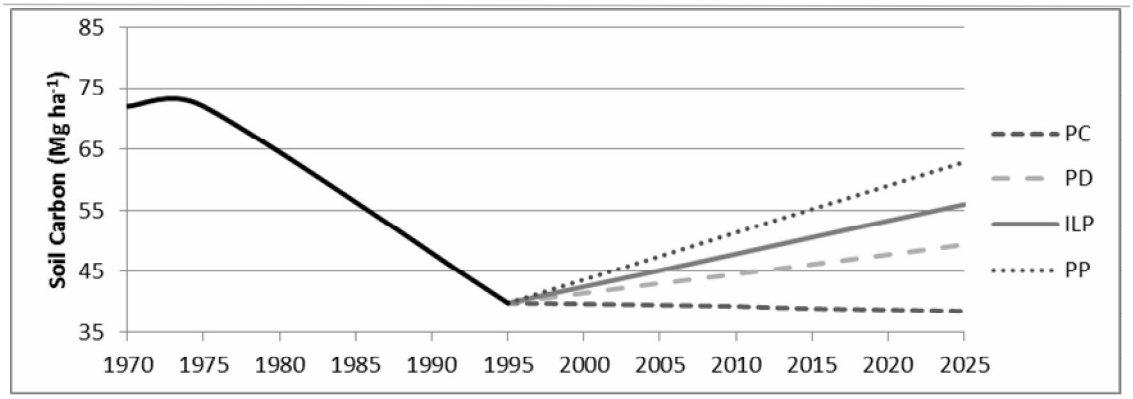

Figure 1. Total Soil Carbon simulated for the long-term experiment at Embrapa Agropecuária Oeste, Dourados-MS, Systems: tropical perennial pastures - braquiaria (PP), annual crops under conventional tillage - soybeans-wheat rotation (CT) and no-tillage systems - oilseed radish/corn/oat/soybeans/wheat/soybeans (PD), and pasture rotation with annual crops - soja/aveia/braquiaria (ILP)

Table 1. Soil organic carbon stocks simulated by the CENTURY model and observed for the long-term experiment at Embrapa Agropecuária Oeste, Dourados-MS. (2005 sampling)

Area	C-mes**	C-mod	Difference
		$Mg.ha^{-1}$	
Base*	39,80	42,90	7,23
PC	39,44	38,42	-2,67
PD	43,05	38,74	-11,11
ILP	45,17	40,75	-10,86
PP	47,50	45,07	-5,37
VN	72,00	68,33	-5,37

*Base –experimental initial stocks (1995); Natural vegetation – Cerrado (VN), tropical perennial pastures - braquiaria (PP), annual crops under conventional tillage - soybeans- wheat rotation (CT), no-tillage system - oilseed radish/corn/oat/soybeans/wheat/soybeans (PD), and pasture rotation with annual crops - soja/aveia/braquiaria (ILP). ** C-mes – carbon stocks measured; C-mod – carbon stocks simulated

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