B-6.3.4 Modeling of Soil Carbon Accumulation/Decomposition processes

Contact person Tomoyuki Hakamata
Global Agro-Environment Research Team
National Institute of Agro-Environmental Sciences (NIAES),
Ministry of Agriculture, Forestry and Fisheries
3-1-1 Kannondai, Tsukuba 305 Japan
Tel & Fax:81-298-38-8272
E-mail:tomo@niaes.affrc.go.jp

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Abstract Some kinds of problems which were pointed out on the international workshop for the project held in 1997 are resolving. All soil organic carbon (SOC) models with a similar formulation to RothC will have difficulty in simulating SOC dynamics in Japanese andisols without adjustment. For RothC, satisfactory simulations of SOC dynamics using realistic inputs requires the IOM pool to be set at a much higher level than that used for most other soil types. Some ways of revising carbon process on RothC model were investigated using some data sets on andisols from Japan. Throgh simulations using the Century model、 about 35 – 40% of SOC was decreased after clearing of forests on Andisols at Kanto district and at the same time was emitted into atmosphere. The decrease of SOC was stabilized and a new steady state was established under the modern cropping system. The new SOC level is 8,000 g C / m^2 (4.5%) and almost equal to the SOC level (4.3%) of the experimental field of NIAES.

Key Words Soil carbon, Soil organic matter, Andisols, Modeling

1. Introduction

It is well known that microorganism affects accumulating and decomposing process of soil organic carbon. The process, however, has been modeled for some years to simulate soil processes in the global carbon cycling related to global warming.

We have The Iwamoto-Miwa Model to predict carbon and nutrient cycling in a soil-plant system (Iwamoto & Miwa, 1985).

The Century Model (e.g., Parton et al., 1987) incorporates the concept of organic matter fractions with differing turnover times. A modeling simulation conducted by Cole and Keith Paustian predicted that the increasing trend of crop yields and adoption of no-till methods would render the Great Plains and the Corn Belt a significant sink for carbon from the atmosphere (http://www.nrel.colostate.edu/PROGRAMS/ageco.html).

The Rothamsted Carbon Model (RothC: Jenkinson & Rayner, 1977; Coleman & Jenkinson, 1996) has been widely used to simulate changes in soil organic carbon (SOC) content on a variety of soil types (Jenkinson et al., 1987) and for a variety of land-uses (Coleman el al., 1997) including arable, grassland and forestry. It has also been used at the regional scale (Parshotam et al., 1996) and at the global scale (Jenkinson et al., 1991; Post et al., 1982; Polglase & Wang, 1992) to estimate either net primary productivity or C02 fluxes. A recent comparison of nine leading SOC models showed RothC to be among the six with the best performance across a range of land-uses, soil-types and climatic regions (Smith et al., 1997). In this brief report, we describe attempts to simulate changes in SOC in Japanese Andisols, soils that are rich in allophanes, using RothC.

In this report, we will briefly introduce the results from some investigations including a workshop held at NIAES in 1997 for revising model parameters through modeling simulations by the RothC model. And a simulation by the Century Model is briefly described as well, due to lack of space.

2. Methods

(1) Parameterization of the soil carbon processes of Andisols using the RothC model

Some measured data on soil organic carbon (SOC) were provided. Mean meteorological files were provided, as were estimates of total annual C inputs to the soil under continuous wheat-soybean rotation (2.94 t C ha^{-1} y^{-1}). In this exercise, we have used RothC to examine the relationship between yearly C inputs and the initial Inert Organic Matter (IOM) pool of the RothC model (see Fig. 1).

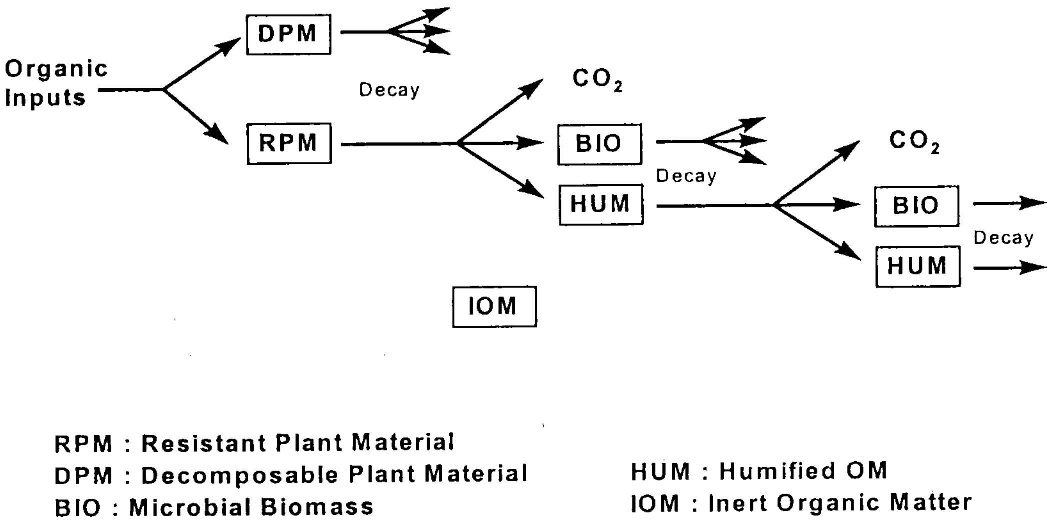

Fig. 1 Structure of the Rothamsted Carbon (RothC) model

(2) A simulation of a soil carbon history at Kanto district using the Century Model

Input data ware provides from reports on agricultural systems in some prefecture of this district. Soil carbon changes after 1800 according to the standard changes of cropping procedures on wheat soybean rotation on a forest-derived andisols were simulated.

3. Results & Discussion

(1) Parameterization of the soil carbon processes of Andisols using the RothC model

The size of the IOM pool of RothC is set using radiocarbon data where such data are available (Jenkinson et al., 1992; Coleman & Jenkinson, 1995). Using a regression of calculated IOM (from 26 sites at which radiocarbon values were available) against SOC content, a relationship is found suggesting that IOM can be approximated as 10% of total SOC across many land-uses (D.S. Jenkinson, pers. comm.). In the initial run, SOC was assumed to be approximately 5%. With a bulk-density of 0.8g cm^{-3} this gives a carbon content of 92 t ha^{-1} to 23cm depth. Using these figures, IOM was set to 9.2 t ha^{-1}. The model was run to equilibrium using these figures.

The single point at the left of Fig. 2 (Equ = TOMO) shows that using this IOM level and the C inputs provided, the estimated SOC content is too low (36.6 t ha^{-1} compared to 92 t h^{-1}). In order to achieve a correct equilibrium value for SOC using an IOM pool size of 9.2t ha^{-1}, C inputs would need to be increased by nearly 3 times (to 8.9 t ha^{-1} y^{-1}). The CENTURY group, performing the same exercise derive a C input value a little higher than that provided (3.5-4 t ha^{-1} y^{-1}: D. Ojima & K. Paustian, pers. comm.), but C inputs could not possibly be as high

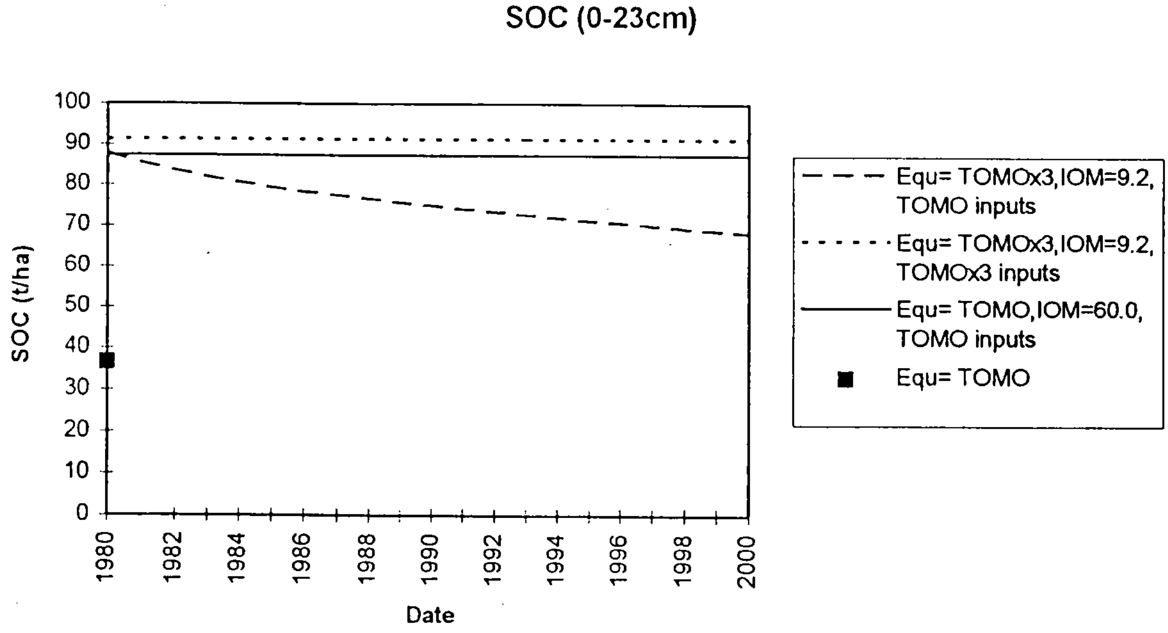

Fig. 2 Output of RothC under different assumptions of annual carbon input and IOM pool (see text in detail)

over the equilibration period. The high equilibrium C input is shown in figure 1 as "Equ = TOMOx3 IOM 9.2 TOMOx3 Inputs" assuming that inputs are 3 times greater than those given during equilibrium and 3 times greater over the past 20 years and as "Equ = TOMOx3, IOM=9.2. TOMO inputs" assuming equilibrium inputs to be 3 times those given but inputs of 2.94 t ha^{-1} (i.e. those given) over the past 20 years. If we assume that the C inputs are correct at least for the present, a marked decline in SOC would have been seen in the past 20 years which is clearly not the case.

If we assume that the annual C returns given at the Workshop are correct, the model assumption of 10% of SOC being IOM does not hold for this soil. If the IOM content is changed from 9.2 t ha^{-1} to 60 t ha^{-1} (i.e. 2/3 of SOC), a stable equilibrium SOC value of 92 t ha^{-1} can be achieved using the annual C inputs given. This is shown in Figure 1 as "Equ = TOMO. IOM=60, TOMO inputs". Such a high IOM level is consistent with the findings of the CENTURY group who needed a "passive pool" size of about 60%. SOC to achieve a stable equilibrium (D. Ojima & K. Paustian, pers. comm.).

All soil organic matter (SOM) models with a similar formulation to RothC will have difficulty in simulating SOC dynamics in Japanese andisols without adjustment. For RothC, satisfactory simulations of SOC dynamics using realistic inputs requires the IOM pool to be set at a much higher level than that used for most other soil types. This adjustment, however, inevitably leads to anomalously high estimates of radiocarbon age for the SOC in these relatively young volcanic soils. A similar situation has been found with CENTURY: Parfitt et al. (1997) found that the passive pool in CENTURY needed to be set to 75% of SOC when simulating allophane rich andisols from New Zealand and that even then, simulations were poor. The high cation exchange capacity and variable charge nature of the clays typical of andisols may also present problems to models that use the simple measure of clay content. Parfitt et al. (1997) found that even adjusting the clay content of New Zealand Andisols to above 90% failed to improve the performance of CENTURY. Most soil organic matter models available through the GCTE Soil Organic Matter Network (Smith et al., 1996 a and b) have a formulation similar to RothC and CENTURY and on the evidence of this exercise, any

SOM model would require some adjustment to successfully simulate SOC changes in Japanese andisols.

(2) A simulation of a soil carbon history at Kanto district using the Century Model

A steady state of soil carbon under a forest on Andisols at Kanto district was estimated at first, and then its change under development of four stages of cropping system was simulated. The result was shown in Fig. 3.

SOC of a plow layer (20 cm) was estimated to be 12,800 g C/m^2 (7.2%) at clearing forest possibly in 1800. It is comparable to the present SOC level at a natural forest in this district. SOC changes on an upland wheat-soybean rotation system on a forest derived Andisols were simulated. The cropping conditions were as follows:

(a) low yield variety - no nitrogen fertilizer - 1 t/ha of manure - removal of upper ground parts of crops (1800-1920),
(b) improved variety - 20 kg/ha of N fertilizer - 2 t/ha of manure - removal of upper ground parts (1920-1950),
(c) high yield variety – 50 kg/ha of N fertilizer – no manure – removal of upper ground parts (1950-1970), and
(d) High yield variety – 100 kg/ha of N fertilizer – no manure – removal of cereals (1970-1995).

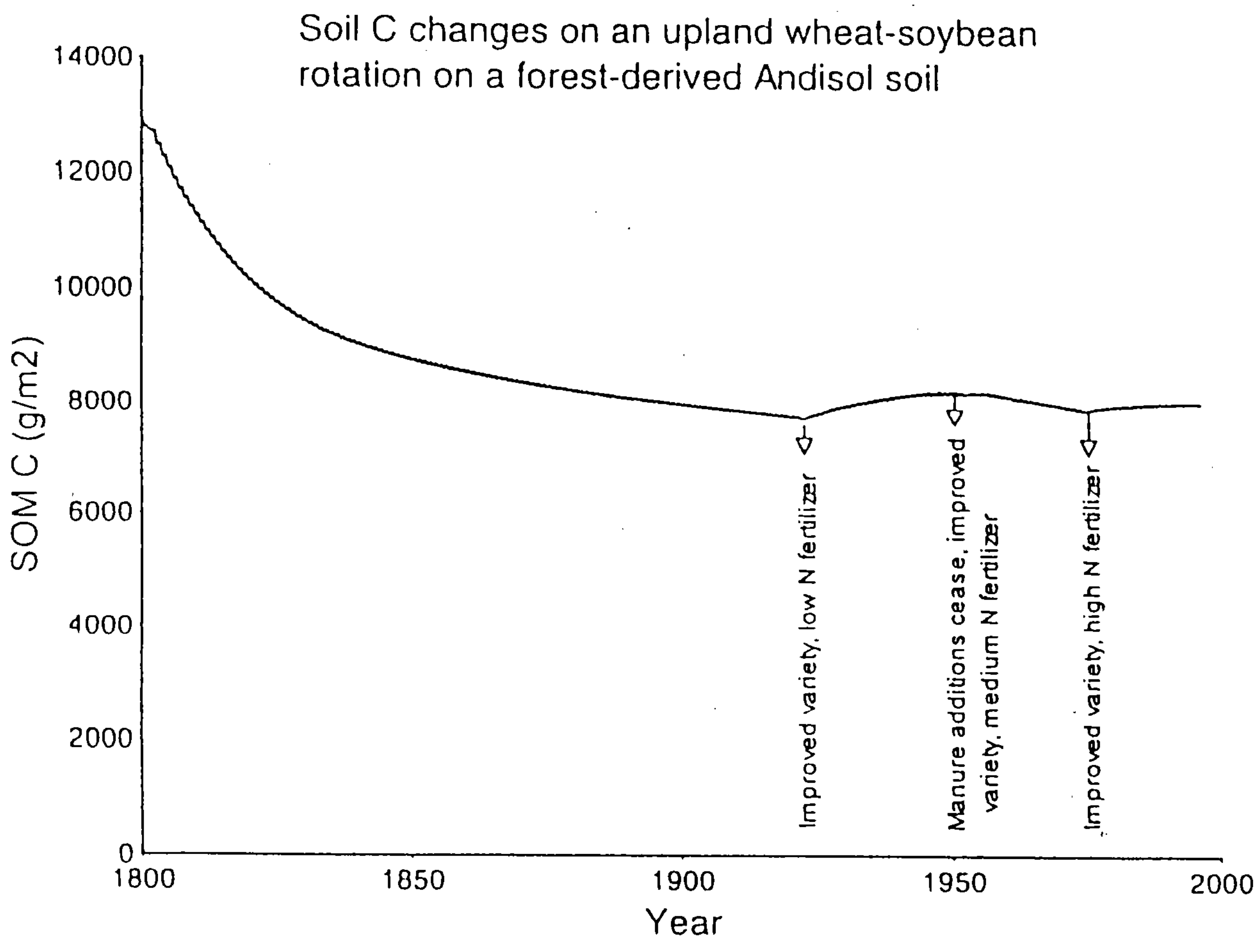

Fig. 3 Soil carbon changes on an upland wheat-soybean rotation on a forest-derived Andisols in Kanto district, Japan

After clearing of forests, about 35 – 40% of SOC was decreased and at the same time was emitted into atmosphere in this district. The decrease of SOC was stabilized and a new steady state was established under the modern cropping system. The new SOC level is 8,000 g C / m^2 (4.5%) and almost equal to the SOC level (4.3%) of the experimental field of NIAES.

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