Long-term evolution of organic matter in Sudano-Sahelian conditions (Burkina Faso) under different agricultural practices and its modelling.

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Abstract
The unique long-term experiment of Saria offers the possibility to analyze soil carbon dynamics over more than 40 years under different agricultural practices in the Sudano-Sahelian region. Complete historical datasets offer the possibility to test carbon models. Maintaining a high carbon level here appeared more difficult than predicted by current carbon models. This finding suggests additional processes to be included in carbon models.

Introduction

Under Sudano-Sahelian pedoclimatic conditions, the level of soil organic carbon (SOC) is a critical if not vital component of fertility. Due to the low nutrient status and the drought constraint to the vegetation, accumulation of soil organic matter is a key factor that contributes to the improvement of productivity in a positive feedback loop. The key functions of soil organic matter are here the retention of bases, the storage of available P and N, the significant contribution to water retention and to the physical environment of seedbed and roots (Balaya et al. 2002 Bationo1 and Buerkert, 2004, Mondo et al. 2005). Data on long term fate of SOC, in such regions are scarce and current SOC models haven't been tested here. The objective of our research was to evaluate the stocks of C in the soil and show the mechanisms concerned, under the action of farming practices.

Materials and methods

This study is based on the long-term experiment of Saria (Burkina Faso) initiated in 1960 (Sedogo, 1993). Studied treatments varied the rates of mineral fertilization and of animal straw, compost, or manure application as well as the tillage practices (scraping and ploughing) under a continuous sorghum crop. Soil is a ferric acrisol, MAT was 28.0°C and precipitation 800 mm a^{-1} over the experiment period. The duration of soil moisture deficit is 8 to 9 months. Measurements concerned: (1) in the field the soil morphological characterization, bulk density and crops outputs, (2) in the laboratory the organic matter input (biochemical composition) and soil C, N, and particle-size fractionation. The model RothC 26.3 (Coleman and Jenkinson, 1999) was run to simulate several of the of plots using the default dataset of parameters.

Results and discussion

The C stock on this type of soil measured on the non-deteriorated herbaceous fallow is 20.6 Mg ha^{-1} in the 0-20 cm horizon. The current practice with ploughing and low organic input caused a decrease of the C stocks by 42, 44 and 68% of the initial herbaceous fallow, after 10, 20, and 40 years of continuous farming, respectively. The most efficient practices tested with high organic input made it possible to maintain 45 to 90% of the fallow stock, according to the duration of the experimentation. Coarse size fraction of organic matter exhibited the highest time variations. When there is a manure input together with nitrogen fertilizer, this situation is favourable for preferential storage of C in the fine fractions, thus showing the advantage of this practice in the stabilization of the SOM.

The definition of a critical value of C in the soil, between 6 and 7 mg C g^{-1} is confirmed by the convergent results of two approaches: the analysis of sorghum outputs with the “envelope curve” method and the definition of a C sill value for the sustainability of the system (Feller 1995) which show 6 and 6.8 respectively. The outputs decrease below 6 mg C g^{-1} and stabilize above this value.

The modelization of C stock with the RothC model (0-20 cm horizon) simulated with success the plots with the highest C decrease and the lowest C content. On the contrary, it overestimated C stock in manured plots and therefore the potential to maintain high C levels. Besides hypotheses concerning the model hypotheses themselves (e.g. climatic decomposition modifiers and nonlinearity), this brought us more to admit the existence of an unsuspected loss of manure-derived matter (evaluated to 67% of it) from the topsoil. We attributed the latter to the activity of the soil macrofauna, incorporating carbon to deeper horizons and

diluting accordingly topsoil with deeper soil material and possibly to soluble C movement. Such a negative effect of soil engineers activity on the carbon level in surface horizons had been poorly addressed up to now.

Conclusions

Increasing the storage of C in the soil is possible with the current farming practices but their optimisation has to be achieved. This study opens onto possible actions and concludes on the necessity to take into account the macrofaunic and microbial activities in interaction with the organic matter for a better control of the organic flows.

Keywords: RothC, Saria, carbon stock, ferric Acrisol, Burkina, farming practices, organic matter, manure, compost, particle-size fractionation.

References

Bayala, J., Teklehaimanot, Z., Ouedraogo, S.J. 2002. Agroforestry Systems 54, 203-214.
Bationo A., Buerkert. A. 2004. Nutrient Cycling in Agroecosystems 61, 131-142.
Coleman K & DS Jenkinson DS. 1999. ROTHC-26.3. November 1999 issue. IACR - Rothamsted Harpenden Herts. ISBN 0 9514456 8 5
Mando, M. Bonzi, M.C.S. Wopereis, F. Lompo, L. Stroosnijder. 2005. Soil Use and Management 21, 396–401
Sedogo p.m., 1993 Thèse de Doctorat es-Sciences – Mention Sciences naturelles. Université d'Abidjan (C.I.) Février 1993 - 330 pages.

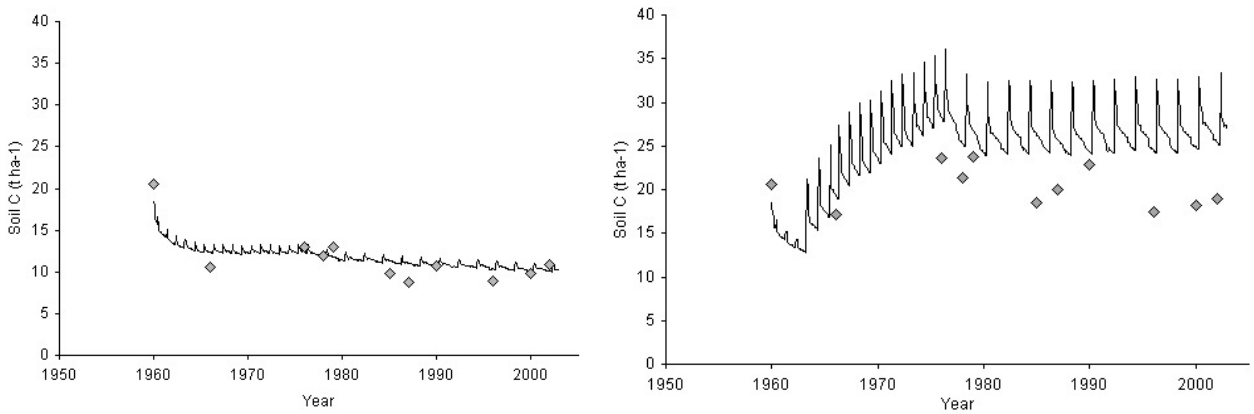

Figure : Adequation and inadequation of the RothC Model (lines) to simulate the observed C content (points) in the 0-20 cm topsoil of the long-term experiment in Saria (Burkina-Faso). Unmanured (left) and manured plot (right).