Exogenous organic matter from agricultural and urban origins in temperate and tropical areas: usefulness of TAO to model the transformations in soil

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Abstract
This laboratory study aimed to test the model "Transformation of Added Organic material" (TAO) for its prediction capacities on Exogenous Organic Matter (EOM) from Madagascar and Reunion Island origins. The TAO model driven by biochemical data is particularly useful to predict complex EOM transformations in soil. The C mineralization of EOMs varied according to the nature of the material: (i) from 0.10 to 1.98 $gC.g^{-1}C_{added}$ for the raw materials, (ii) from 0.28 to 0.84 $gC.g^{-1}C_{added}$ for the composted materials, respectively. A "priming effect" was observed for few EOMs. For 83% of the studied EOM, the C mineralization was well predicted by the TAO model with the original parameters calibrated for temperate EOM. This study provides a validation/extrapolation of TAO from temperate and dry tropical EOM to those originating from humid tropical conditions. However, a readjustment of the TAO model seems to be necessary to consider the "priming effect" process.

Introduction

The recycling as soil amendment or fertilizer of the organic wastes (the so called Exogenous Organic Matters or EOM), originating from agricultural, agro-industrial and urban activities is one of the major solution commonly adopted for their reuse. Soil application of EOM could both contribute to environmental issue of improving C sinks to mitigate CO_2 emissions and to the restoration of soil properties related to soil organic matter content [1]. Tools for predicting the effect of EOM application on soil organic C would contribute to improvement of their management in cropping systems and to develop their use in agriculture [2]. When added to soil, the EOM transformations (e.g. C and N kinetics) differed according to their characteristics (C, N, fiber contents). Predictive models were needed to link EOM characteristics to EOM transformations in soil; TAO (Transformation of Added Organic materials) was proposed to predict the EOM transformations (C and N mineralization, N immobilization and re-mineralization of immobilized N) entirely driven by EOM biochemistry. The TAO-C structure was first selected and improved from eight published propositions [3]. It fractionates EOM into three compartments which decompose in parallel like input compartments of most of the more complex soil organic matter models [4] . It was simplified to use only two parameters which defined the very labile (P'_L) and stable (P_S) fraction of EOM, and had been linked to EOM biochemical properties [5].The TAO model driven by biochemical data is particularly useful to predict complex EOM transformations in soil. The objective of this study was to describe and model the transformations of selected materials from Reunion Island and Madagascar in respectively an Andosol and a Ferralsol .

Material and Methods

EOMs and their characterisation

The EOM used in this experiment included a range of fresh and transformed organic materials from agricultural, urban and agro-indrustrial waste applied in agriculture. The database included 16.6% of slurry, 27.8% of manure, 13.9% of composted animal dejection, 16.6% of agroindustrial waste, 16.6% of composted urban waste and 8.3% of potting soil.

Total C and total N were measured by dry combustion (Dumas method). Biochemical fractionations were determined according to the Van Soest method (AFNOR XPU 44-162) [6]. C and N mineralization were measured during a 180 days incubation of soil and EOM mixtures in controlled conditions (AFNOR XPU 44-163) [7].

Soils and incubation experiment

Our experiment was carried out with an andic cambisol soil and a ferrallitic soil respectively from Reunion and Madagascar Islands. The first soil was collected at Les Colimaçons in a medium elevation area on the western windward side of the Reunion Island. This loamy (38%) soil had a pH of 6.1, a total N content of 0.55%, and a C content of 2.7%.The second soil was a clayey soil, 31% of clay, ferralsol sampled at Lazaina located in the North East of Antananarivo, Madagascar. This soil had a pH of 5.5, a total N content of 0.14%, and a C content of 1.87%.
Incubation experiments used samples of 30 g air-dried soil and 0.5 g of EOM. A control sample of 30 g soil without EOM was also incubated. Three replicates were incubated in air-tight jars (1 L) during 182 days at 28 ± 1 °C in a dark room at 66% soil water-holding capacity (28 mL Milli-Q water for 100 g of the andic cambisol and 12 mL Milli-Q water for 100 g of the ferralsol).

TAO Model

TAO is a parallel three-compartment model using only two parameters to predict C mineralization [3]. The residual added organic carbon fraction (RAOCF) after C mineralization was given at a known time of incubation (t) from time of EOM application (t_0) by:

RAOCF = $P'_L e^{-0.4(t-t0)} + (1 - P'_L - P_s)e^{-0.012(t-t0)} + P_s$
where P'_L = proportion of Labile compartment and P_S= proportion of Stable compartment

Results

Measured C mineralization

Kinetics of C mineralization were different for each EOM. Most of EOM from animal origin were rapidly mineralized. For different slurries and droppings, 52% (FuF) and up to 100% (FiV and FiP) of EOM-C was respired. A “*priming effect*” which was defined as the increase in soil organic matter (SOM) decomposition rate after fresh organic matter input to soil was observed for FiV and FiP. *Priming effect* was often supposed to result from a global increase in microbial activity due to the higher availability of energy released from the decomposition of fresh organic matter [8]. For manures, measured mineralized C ranged between 22% and 69% according to their origin. For example, only 32% was mineralized during the 182 days for FuBb. This suggested that the complement was stabilized or was processed for stabilization. Mineralization of composted animal EOM varied with a range of mineralized C from 28 (CLPv) to 84% (Vgt). For CLPCo, 56% of C was mineralized, so it remained a little less than half C stabilized or being able to be stabilized in the soil. For the composted urban waste, the minimum and maximum mineralized C were respectively 30% (CDV LP) and 80 % (CoV). 50% of agro-industrial waste presented C mineralization up to 100% (SpA, SpH and SpP) i.e. a “priming effect” process occurred. For the other 50%, C mineralization ranged between 67% and 89%. The potting soil showed an important intra significant difference between TrA and TrI on one hand, and Trt on the other hand because mineralized C were 10%, 25% and 115% for TrA, TrI and TrT, respectively.

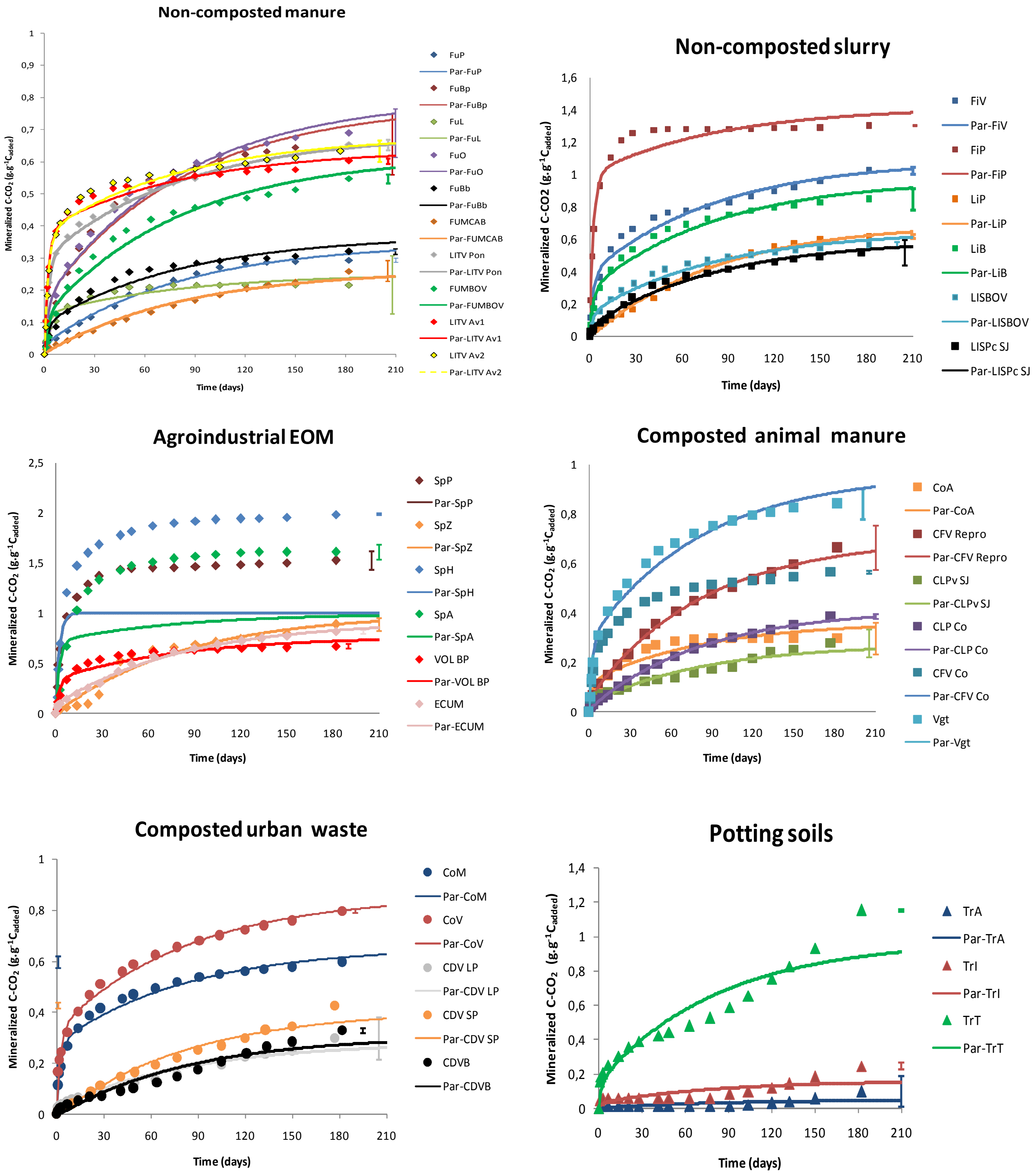

Figure 1. Measured and predicted C mineralization by using the TAO model

Predicted C mineralization with TAO

The TAO-parameters (TAO-Par) model is based on the optimized P'_L and P_S compartments. TAO-Par assessed accurately the C mineralization of EOM whose mineralization did not exceed 100%. The F-tests did not show any significant difference between the laboratory measurements and the predicted values for the 10 manures, 5 composted animal waste, 6 composted urban waste, 5 slurries, 3 agro-industrial wastes and 1 potting soil. For EOM presenting a priming effect, the TAO-Par for C reached a ceiling at 100 % (by construction). Not surprisingly, the differences were thus significant at a level of 10% for 1 potting soil and 3 agro-industrial waste; at a level of 5% for 1 slurry and 1 potting soil.

Conclusion and perspectives

The initial TAO model calibration was made using organic materials from temperate zone incubated in a Fluvisol. It was recently tested in an arid Ferric Lixisol from dry tropical climate (Burkina Faso). The present study on tropical waste incubated in two rainy tropical soils confirmed the validation/ extrapolation of TAO model. However, for the few EOM that cause a “priming effect”, the structure of TAO should be modified. This model can be a promising tool to predict the transformation in soil of the major EOM from Madagascar and Reunion Islands.

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