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TREATMENT AND USE OF ORGANIC RESIDUES IN AGRICULTURE: CHALLENGES AND OPPORTUNITIES TOWARDS SUSTAINABLE MANAGEMENT

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DEVELOPMENT OF A STRUCTURED SET OF TOOLS FOR EVALUATION AND MANAGEMENT OF AGRICULTURAL RECYCLING OF ORGANIC RESIDUES AT LOCAL SCALE

De Junet A.¹, Cambier P.¹, Peltre C.¹, Houot S.¹, Michaud A.¹, Parnaudeau V.², Cazevielle P.³, Doelsch E.³, Farinet J.L.³, Saint-Macary H.³, Nazaret S.⁴, N'Dour Y.⁵, Masse D.⁶, Rafolisy T.⁷

¹UMR INRA-AgroParisTech "Environnement et Grandes Cultures", 78850,

Thiverval-Grignon, France, pcambier@grignon.inra.fr

²UMR INRA-AgroCampusOuest SAS, Rennes, France

³Unité CIRAD "Risque environnemental lié au recyclage", Montpellier, France

⁴UMR "Ecologie Microbienne", Lyon, France

⁵Institut Sénégalais de Recherches Agricoles, Dakar, Sénégal

⁶UMR IRD "Eco & Sols", IRD, Dakar, Sénégal

⁷Laboratoire des Radioisotopes, Université d'Antananarivo, Madagascar

1 INTRODUCTION

The development of integrated methods for optimising the recycling of organic residues at local scales and in contrasted peri-urban contexts of Northern and Southern countries is the general purpose of an international programme supported by the French National Research Agency (ANR). This ISARD programme involves 12 teams of different research organisms and universities with a multidisciplinary approach, and focuses on 4 areas in France ("Plaine de Versailles", 40 km from Paris, and La Réunion, Indian Ocean), in Madagascar, and in Senegal. We present here the methodology and preliminary results to build up a structured set of tools to characterize the feedstock of organic residues and potential receiving crop-soil systems. They should serve for evaluating different practical scenarios of transformation and agricultural recycling of organic residues at the chosen scale. Positive and negative impacts related to organic residue recycling in agriculture are concerned, with focuses on soil organic matter, soil physicochemical properties, major plant nutrients, trace elements and human pathogens.

2 GENERAL APPROACH, MATERIALS AND METHODS

2.1 Elaboration of an extensive list of preparation and analytical methods for soils, organic residues and plants

First, following our experiences in sampling and analysing soils, organic residues and plants, a list of characteristic variables had to be completed, including qualitative and quantitative variables, like description of a cultivated soil or total N content of compost. Preparation and analytical methods related to these variables had to be compared between participants' laboratories and with ISO or national standard methods.

Referring again to the experience of involved laboratories and to updated literature, a few usual methods had to be improved or replaced by alternative ones, equally relevant and more efficient with respect to the aims of the programme ISARD. These methods should be tested upon selected samples of different types, the definition of such types and the choice of reference materials being another task of the programme, and the results compared with those obtained with standard methods. As examples, the following techniques are presented:

- measurements of CO₂ emitted during mineralization kinetic studies of organic amendments using the OxiTop® system (WTW, Weilheim, Germany),
- NIR spectroscopy for the determination of organic residues properties.

2.2 Selection of models and other predicting tools

Any law or model, mechanistic or empirical, leading to characterise or predict the effect of organic residue application on cultivated soils, had to be considered and brought together with the characterisation methods, in order to build up a consistent and useable set of tools for the management of these organic residues and the assessment of these practices. We present here the preliminary steps for selecting models predicting the fate of C and N in soil and in the plant-soil-exogenous organic matter (EOM) systems. These models should present some adequacy between

the needed input values and the information available on at least several systems of the 4 regional contexts of the programme. First, compartment models describing C and N fluxes in soil receiving EOM were considered to improve our understanding and prediction of C and N mineralisation. In a further step, soil-plant models will be also considered to assess environmental risks such as nitrate leaching. The simulations will use data sets issued from a long-term field experiment and then from a current survey of arable fields of the “Plaine de Versailles”.

3 RESULTS AND DISCUSSION

3.1 List of characterisation tools

About 40 determinations applicable to organic residues, soils and cultivated plants have been listed and methods were selected for each one. Table 1 summarises the list applicable to organic residues. Each method or technique is well managed by one or more participants of ISARD. All of them are considered useful but obviously are not applied systematically.

TABLE 1 List of analytical tools for characterising organic residues

Designation (principle)	ISO or other reference*
Preparation for physicochemical analyses	ISO 11464
Dry matter (weight loss at 105°C)	ISO 11465
Mineral N (KCl extraction and NO ₃ NH ₄ analyses)	ISO 14256-2
OM content estimation (weight loss at ≤550°C)	NF EN 13039
Total organic C (total C corrected for carbonate)	ISO 10694, ISO 14235
Total carbonate (volume of out gassed CO ₂)	ISO 10693
Total N (“Kjeldhal” or C-N analyser)	ISO 11261 and NF EN 13654-1
Total element analyses (after strong acid or alkaline attack)	ISO 11466, ISO 14869-1, ISO 14869-2
Available P ₂ O ₅ (moderate alkaline extraction)	ISO 11263
Available or exchangeable trace elements (extracted by EDTA or CaCl ₂)	ISO 31120, ISO 10390
Total or extractible polyphenol	Cirad, Montpellier
pH (in standard aqueous suspension)	ISO 10390
Electric conductivity (of standard water extract)	NF EN 13038
Near IR, Mid-IR and visible spectrometric characterisation	
Van Soest fractionation (biochemical extractions)	XP U 44-162
C & N mineralization potential (controlled incubation and measuring emitted CO ₂ and/or extractable mineral N)	ISO 14238, XPU 44-163
Microbial biomass (CHCl ₃ fumigation and measuring soluble C or amine N)	ISO 14240-2
Chemical demand of oxygen	ISO 15705 NF T 90-101
Presence or quantification of pathogens	X33-017, X33-018, ISO 9308-3 and 7899-1

(*) all “NF” or “X” standard methods are described in AFNOR (1999)

3.2 Optimisation or replacement of some methods

Two examples are presented: i) the determination of potential mineralization of organic C of an organic residue, ii) the use of NIR spectroscopy to predict organic residue characteristics.

Use of OxiTop®, a device for monitoring CO₂ during incubation of organic matter

The usual technique for measuring C mineralization potential of EOM consists in analyzing C-CO₂ trapped in NaOH solution during standardized incubations. This procedure is tedious and most often only three repetitions are conducted despite the dispersion of data. In this study, we applied this technique to 7 day incubations, with the NaOH solution changed and analyzed after 1, 3 and 7 days. The “Oxitop” technique enabled a continuous follow-up of C mineralization by measuring a difference of pressure related to CO₂ emission and trapping in NaOH. We compared the routine and the “Oxitop” techniques on the C mineralization of EOM in a Luvisol. We also compared the difference of pressure observed when Oxitop jars are opened after 1, 3 and 7 days or closed during the 7 days.

C-CO₂ values obtained with the Oxitop are reproductive and similar to the standard values for each date measured (Figure 1). We observed a close relation between the curves obtained with the Oxitop jars opened and closed, except for a translation originated during the two first hours of incubations. This gap should be mainly due to

the difference of T°C between the laboratory and the incubation room. Thus the Oxitop technique appeared quite promising for following C mineralization, enabling more replicates and avoiding flask opening and CO₂ analyses.

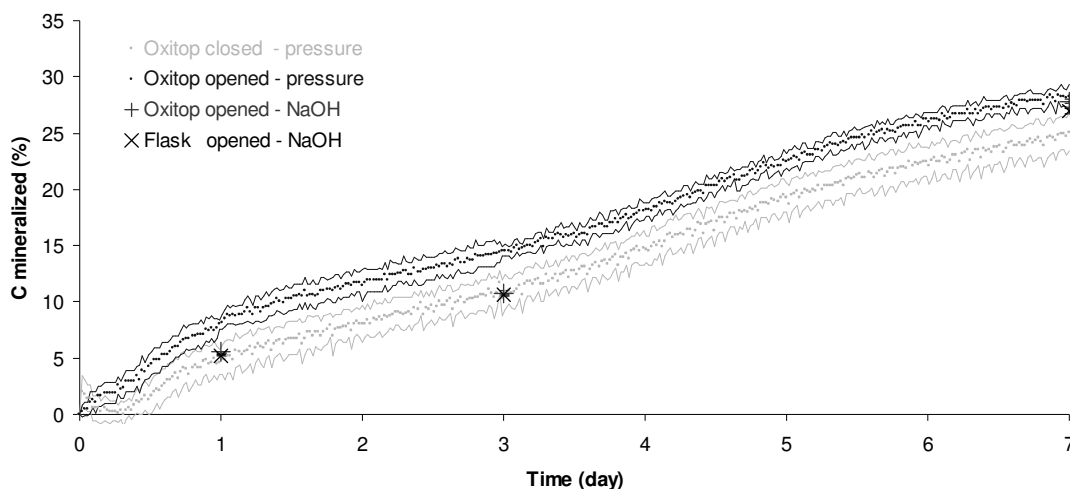


FIGURE 1 EOM C mineralization (% total organic C) calculated from NaOH trap analyses in the standard (flask) method and Oxitop jars opened after 1, 3 and 7 days, and from difference of pressure measurements with Oxitop opened after 1, 3 and 7 days or closed during 7 days.

Now we are going to pay attention to the beginning of the incubations and to pursue with different types of soil and EOM in order to know if this technique is suitable for all kinds of substrates.

NIR spectroscopy to determine exogenous organic matter properties

NIR spectroscopy (NIRS) is an emerging tool, relatively fast, cheap, and non destructive, which can complete or replace classical methods for laboratory characterizations of EOMs (Thuriès et al., 2005; Galvez-Sola et al., 2010). The potential of NIR spectroscopy to determine the indicator of potential residual organic C in soil (I_{ROC} , Lashermes et al., 2009) has been assed using an heterogeneous set of 300 EOMs gathering fresh and transformed organic residues (Peltre et al., 2009). The I_{ROC} corresponds to the proportion of EOM remaining in soil over the long term after application; it is calculated from the proportion of C mineralized after 3 days of incubation and from biochemical fractionation results (Van Soest method). The I_{ROC} could be predicted from NIR spectra with a fairly good accuracy with $R^2 = 0.86$ in cross-validation and $R^2 = 0.83$ on an independent validation sample-set and with coefficients of variation < 10% between measured and predicted values (Figure 2).

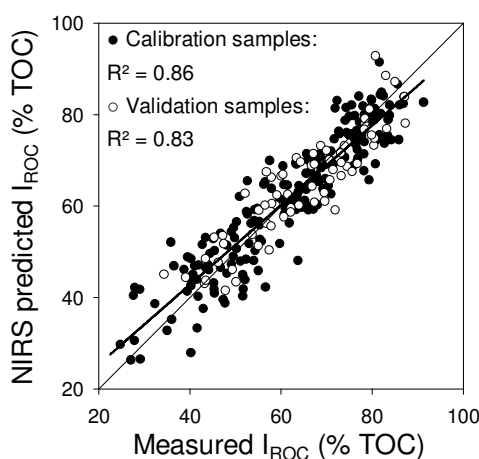


FIGURE 2 Relationship between values of the indicator of residual organic C in soil (I_{ROC} expressed as % of EOM total organic C) calculated from laboratory characterisations and predicted from NIR spectra. Calibration set during cross-validation (black circles, continuous regression lines) and predictions on the independent validation set (white circles, dashed regression lines)

3.3 Example of predictive tools: simulation model of C and N in the soil-plant-water system

Model of C and N dynamics in soils receiving organic matter amendments

In a first step, models such as Cantis (Garnier et al., 2001; Parnaudeau, 2005), and TAO (Thuriès et al., 2002) were selected, in order to simulate organic residue mineralisation in soil under laboratory conditions. Their parameterisation was based on the EOM biochemical fractionation and incubation results. In the second modelling step, the soil-plant-atmosphere model STICS (Brisson et al., 2002) will be adapted to simulate N fluxes resulting from the EOM land spreading in the different scenarios selected in the ISARD programme.

The model will be first tested on an experimental field, devoted to measure the long-term agronomic and environmental effects of recycling urban waste composts in arable crop systems, and where all needed variables are followed. Then to fulfil the objectives of the programme, a survey of arable fields in the “Plaine de Versailles”, including major types of soils and different management practices, is currently collecting quantitative information upon soil organic C, total and mineral N, texture and other major soil properties. Simultaneously, information on use of organic amendments is looked for and all available organic residues are sampled and characterized. Together with agricultural statistics, these data should be sufficient to take up the challenge of estimating the effects of different scenarios of recycling organic matter resources in local cropping systems upon their C and N compartments.

4 CONCLUSIONS

The examples chosen of characterisation methods and predicting tools concerned at first the organic residues and the fate of C and N. They illustrate promising steps toward the assessment of different scenarios of recycling organic residues in agriculture at a pertinent scale. Comparable efforts are conducted on cultivated soils and crops, and the fate of other elements or substances like trace metals and pathogens is also approached. The last challenge of the ISARD programme will be to integrate all addressed predictions or assessments of the effects of recycling organic residues in crop systems of small peri-urban regions.

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