Soil Biology & Biochemistry xxx (2015) 1–16

Contents lists available at ScienceDirect

Soil Biology & Biochemistry

journal homepage: www.elsevier.com/locate/soilbio

Modelling the long-term effect of urban waste compost applications on carbon and nitrogen dynamics in temperate cropland

P.E. Noirot-Cosson, E. Vaudour, J.M. Gilliot, B. Gabrielle, S. Houot*

UMR ECOSYS, AgroParisTech, INRA, Université Paris-Saclay, 78850 Thiverval-Grignon, France

ARTICLE INFO

Article history:
Received 24 July 2015
Received in revised form
18 November 2015
Accepted 22 November 2015
Available online xxx

Keywords:
Compost
NCSOIL
CERES-EGC
C and N dynamics
Long-term experiment
Parameterisation

ABSTRACT

The recycling in agriculture of Exogenous Organic Matter (EOM) issued from organic waste treatment is a promising way to restore soil organic matter (SOM) content in intensively managed soils. EOM applications to crop fields may also be used as substitute to synthetic fertilisers. The CERES-EGC mechanistic model was used to simulate the effects of repeated applications of urban waste composts and manure over 13 years on both soil carbon (C) and nitrogen (N) dynamics in the soil–crop–water–air system of the long-term field experiment QualiAgro. Several EOMs were considered: a farmyard manure, FYM; a municipal solid waste compost, MSW; a bio-waste compost, BIO; a co-compost of green waste and sewage sludge, GWS. Each EOM application brought the equivalent of 220–400 kg N ha^{-1}. The sub-model NCSOIL was parameterised from C and N mineralisation kinetics of EOMs measured during incubations of soil–EOM mixtures in controlled conditions. The simulation correctly reproduced the experimental kinetics. When transposing these parameters into the CERES-EGC model, C storage at the field scale was well simulated, together with crop N uptake and yields, as well as soil mineral N contents despite a slight overestimation. The GWS compost generated the highest C storage over the 13 y-period and MSW the lowest with 65% and 36% of the Exogenous Organic Carbon (EOC) applied incorporated into the soil organic C, respectively. The GWS and MSW had the highest potential of N loss because of high mineral N content and a high potential of N mineralisation, respectively in contrast to FYM and BIO. MSW had also the highest apparent N use efficiency (48.8%) thanks to a high potential of mineralisation (76.3% of organic N applied). The achieved CERES-EGC parameterisation offers promising prospects for predicting the effects of a larger panel of EOMs, and for further using this soil–plant–water–atmosphere model to manage EOM application practices at the regional scale in compliance with crop production and environmental aims.

© 2015 Elsevier Ltd. All rights reserved.

1. Introduction

Low level of soil organic matter (SOM) in cropped soils has become a worldwide threat for soil sustainability, notably in Europe (Ciais et al., 2010). Increasing soil organic carbon (SOC) content may contribute to the carbon (C) storage into soils and the mitigation of climate change (Lal et al., 2004b) while improving soil chemical, physical and biological properties (Kundu et al., 2007), including increased nutrient availability and soil water retention, reduced risk of crust formation and soil erosion, therefore enhanced crop productivity (Lal et al., 2004a). One strategy to increase SOC is amending soils with exogenous organic matter (EOM) defined as organic residues issued from agriculture (manures, litters, slurries), from urban activities (sewage sludge, biowaste composts, green waste composts), or from industries (Marmo et al., 2004). These EOM have variable efficiencies at increasing SOC and enhancing N availability, depending on their biochemical characteristics and C and N contents (Peltre et al., 2012) and on the pedo-climatic context of their application. Potential trade-off may also take place through mineral N leaching, NH_3 volatilisation or greenhouse gas emission (Parnaudeau et al., 2009). EOM applications may also lead to soil, water, atmosphere or plant pollutions with various xenobiotic compounds (Houot et al., 2014).

Mechanistic models make possible to simultaneously simulate all C and N fluxes in a soil–plant–water–air system after repeated EOM applications while considering a wide range of soils and EOM types (Smith et al., 1997; Gabrielle et al., 2004). Process-based models were parameterised for the purpose of simulating SOC stocks after EOM application: Roth-C (Guo et al., 2007; Peltre et al., 2012), Century (Falloon et al., 2002), DAISY (Bruun et al., 2003). Modelling was also used to simulate the N behaviour after applications of EOM (Chalhoub et al., 2013). The effects of EOM

* Corresponding author.
E-mail address: sabine.houot@grignon.inra.fr (S. Houot).

http://dx.doi.org/10.1016/j.soilbio.2015.11.014
0038-0717/© 2015 Elsevier Ltd. All rights reserved.

Please cite this article in press as: Noirot-Cosson, P.E., et al., Modelling the long-term effect of urban waste compost applications on carbon and nitrogen dynamics in temperate cropland, Soil Biology & Biochemistry (2015), http://dx.doi.org/10.1016/j.soilbio.2015.11.014

application on N dynamics were often studied and simulated on a short term basis to determine potential N availability for crops. In case of repeated applications, simulation models make possible to distinguish the increase in mineral N availability related to the last application from the enhanced N availability due to mineralisation of the accumulated OM in soils (Chalhoub et al., 2013). The QualiAgro long term experiment was set up in 1998 in Ile de France to study the effects of repeated EOM amendments in a cropped soil on SOM stocks, nutrients availability for crops and potential accumulation of contaminants in soil. Gabrielle et al. (2004, 2005) used CERES-EGC, a modified version of the crop model CERES (Jones et al., 1986) in which the soil C–N module was substituted with the NCSOIL model (Molina et al., 1983) to simulate the first years of the experiment (4 years).

In most models, OM is split into several compartments or "pools" characterised with different parameters. The parameterisation of EOM C and N behaviour is quite challenging as they may be composed of a broad variety of biodegradable materials, and calibration may highly vary among EOM with different constituents (Gabrielle et al., 2004). Recently, Lashermes et al. (2009) elaborated the indicator of residual organic carbon in soil (I_{ROC} indicator) aiming to predict exogenous organic carbon (EOC) potential contribution to soil organic C and an I_{ROC} database including many EOM categories was constructed. Peltre et al. (2012) used the I_{ROC} indicator to parameterise the partition of EOM organic C into the entry pools of Roth-C thus making possible to predict SOC stocks evolution based on scenarios of EOM applications. The N availability from EOM is conditioned by its content in mineral N, its mineralisation rate related with the biochemical composition and C/N ratio of the EOM (Janssen, 1996). Additionally, mineral N availability is also increased in amended soils because of the increased SOM stocks after repeated EOM applications. Many authors have used optimisation procedure to determine EOM unknown parameters in the NCSOIL model such as the C/N ratio for the different EOM pools (Beraud et al., 2005; Burger and Venterea, 2008; Antil et al., 2011). However, optimisation procedures may not be generic as they rely on specific datasets and often require time-consuming experimental data such as kinetics of C and N mineralisation in soil. Under given climatic conditions, the rates of decomposition of organic materials in soil primarily depend on their composition, and are not clearly dependent of the soil type (Hadas and Portnoy, 1994), or vary inconsistently with soil properties (Smith et al., 2007).

Using the CERES-EGC model, and revisiting the parameterisation of the OM sub-model NCSOIL, the effect of 13 years of different EOM applications on C and N dynamics was studied in the QualiAgro experiment, in order to predict the C storage, the increase in N availability for crops and plant response and finally the N leaching risk. The objectives of this paper were: (i) to evaluate a generic parameterisation method to be able to simulate the C and N behaviours of EOM pools based on both I_{ROC} indicator and kinetics of C and N mineralisation during laboratory incubations in soil, (ii) to evaluate the capacity of NCSOIL-parameterisation based on laboratory data to be transposed into the CERES-EGC model accounting for long-term plant response to N mineralisation, C storage and nitrate leaching in field condition, (iii) to compare the EOMs through their effects on C and N dynamics in cropped soil.

2. Materials and methods

2.1. The QualiAgro long-term experiment

The QualiAgro experiment (INRA-Veolia collaboration), located at Feucherolles 50 km west of Paris, France (48°53′ N, 1°58′ E) was set up in 1998 on a hortic glossic Luvisol (IUSS Working Group WRB, 2014) with a silt-loam texture (15.0% clay, 78.3% silt) and a pH of 6.9 in the surface horizon (0–30 cm). The crop rotation was maize (*Zea mays* L.) – wheat (*Triticum aestivum* L.) but barley was cropped in 2006–2007 due to prognosis of regional attack of *Diabrotica virgifera* to maize that year. Sowings occurred early May for maize, early November for wheat and mid-October for barley. Mineral fertiliser applications occurred once a year for maize (early May) and barley (early March), twice for wheat (early March, early April). Crop yields and biomass of residues at harvest time were determined by sampling 8 surfaces of 1 m^2 for maize and 0.5 m^2 for wheat and barley in each plot. Dry matter and N content (elemental analysis) were analysed in grains and aerial crop residues.

The 6-ha experiment followed a split-plot design comprising 40 plots: 4 replication blocks for each treatment including (i) 4 EOM applications and a control treatment without EOM application, crossed with (ii) 2 mineral N treatments corresponding to either "optimal" (N_{opt}) or "minimal" (N_{min}) dose of a N solution (50% urea–50% ammo-nitrate). N_{opt} fertilisation corresponded to applications of 140 (±37) kg N ha^{-1} for wheat depending on the year, 82 (±34) kg N ha^{-1} for maize and 82 kg N ha^{-1} for barley, whereas for N_{min} it was 61 (±31) kg N ha^{-1} for wheat, 0 (±0) kg N ha^{-1} for maize and 31 kg N ha^{-1} for barley. The EOM applications started in September 1998 and occurred every 2 years in September on wheat stubble at a rate of 4 Mg C ha^{-1}. An additional EOM spreading occurred in 2007 after barley harvest. The four block-lines were separated by a 25 m wide buffer strip and within each block, plots (10 × 45 m each) were 6 m apart from each other. The 4 EOMs described in Annabi et al. (2007) included a dairy farmyard manure (FYM), a municipal solid waste compost (MSW) issued of the composting of mechanically separated organic fractions from residual waste after selective collection of dry and clean packaging, a bio-waste compost (BIO) obtained by composting green wastes and a source-separated organic fraction of municipal solid waste, and a co-compost of green waste (70%) and sewage sludge (30%) (GWS), the green wastes being collected from private and public gardens.

Mineral N content in the soil was determined in each plot at 3 depths (0–30, 30–60 and 60–90 cm) for 3 soil cores, each pooled from 3 separate samplings with an automatic auger. Mineral N was then extracted with KCl (1 mol L^{-1}) and analysed on a continuous flow analyser (Skalar, the Netherlands) using the Berthelot method for N–NH_4 and the Griess method for N–NO_3. The sampling occurred 3 times a year: at the end of the drainage period early February, after harvest in August and at the beginning of the drainage period in November for the wheat years; early February, before sowing in April and after harvest in November for the maize years. To quantify water and N leaching, glass fibre wick and stainless steel plate lysimeters were installed at 45 cm in 2004 in one plot of each treatment receiving optimum mineral N. Waters were collected up to 8 times between December and June, depending on the year rainfall frequency and intensity.

The soils were sampled in the ploughed layer (0–30 cm) in each plot (10 pooled samples) before each EOM application (1998–2000–2002–2004–2006–2007–2009–2011) at the end of August for analysis of total organic carbon (TOC) and total nitrogen contents by elemental analysis of air-dried 200-μm ground samples (AFNOR, 1995 for C and AFNOR, 1998 for N). For TOC analysis, carbonates were removed with hydrochloric acid treatment (Bisutti et al., 2004).

Before starting the field experiment, the potential mineralisation of total soil organic C and N was assessed during 91-day incubations under controlled conditions (temperature of 28 °C and gravimetric water content 23%) following a standard method (AFNOR, 2009b). Fresh 4 mm-sieved soil samples (equivalent to 25 g of dry soil) representative of the initial conditions, were incubated in air-tight 500 mL jars, with four replicates, for either

Please cite this article in press as: Noirot-Cosson, P.E., et al., Modelling the long-term effect of urban waste compost applications on carbon and nitrogen dynamics in temperate cropland, Soil Biology & Biochemistry (2015), http://dx.doi.org/10.1016/j.soilbio.2015.11.014

Download English Version:

https://daneshyari.com/en/article/8363614

Download Persian Version:

https://daneshyari.com/article/8363614

Daneshyari.com