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Potential GHG mitigation and carbon sequestration from European cropland by modelling crop residues management

Carozzi M.^{1,*}, Haas E.², Scheer C.², Butterbach-Bahl K.², Recous S.³, Loubet B.¹, Massad R.S.¹

¹ INRA, EcoSys, Grignon, France, marco.carozzi@inra.fr;

² IMK-IFU, Karlsruhe Institute of Technology, Garmisch-Partenkirchen, Germany

³ INRA, Reims, France

Abstract

Crop residue management are a key lever to increase soil carbon (SOC) stock but can promote nitrous oxide (N₂O) emissions, modifying the greenhouse (GHG) footprint of the agroecosystems. This work aims to estimate SOC balance and N₂O emissions from different crop residue managements in the European cropping systems over climate change scenarios. Two ecosystem models (Landscape-DNDC and CERES-EGC) were used to simulate four residues managements: exported, buried into the soil, left on surface, exported or recycled in function of the crop specie. Results highlights that both models shown similar and representative trends of crop production, SOC and N₂O emissions. Climate change scenarios have an overall effect to increase N₂O emissions and reduce SOC storage toward 2100 in all the residue management scenarios with the worst effects with the fully exported one. The benefits in terms of GHG balance of the complete buried residues is limited to 2-4 decades from nowadays, since the elevated N₂O emissions will offset the carbon sequestration benefits.

Introduction

Effective agronomic practices are needed to achieve long-term climate objectives. Crop residue management represent a key lever to counteract the net greenhouse gas (GHG) balance in the soil, improve soil organic carbon (SOC) and fertility. Quality and composition of crop residues, management in the field and pedoclimatic conditions are able to increase or decrease nitrous oxide (N₂O) emissions or SOC, modifying the GHG footprint of the agroecosystems. Process based models represent a suitable tool for extrapolating from current knowledge in both time and space, facilitating the analysis of management scenarios and decision making.

The aim of this work is to simulate SOC balance and N₂O emissions from different scenarios of residue management in the European cropping systems and over climate change. This work was carried out in the framework of the project ResidueGAS (FACCE ERA-GAS) with the specific objective to improve the estimation and mitigation of N₂O emissions and SOC storage from crop residues.

Materials and Methods

Two ecosystem models, Landscape-DNDC (Haas et al., 2012) and CERES-EGC (Gabrielle et al., 1995), were applied to evaluate the effects of crop residue management scenarios in the EU-27. Three residue managements were evaluated: i) completely exported, ii) recycled into the soil, iii) exported or recycled in function of the crop species.

Models were first assessed to reproduce specific field scale experiment in different European locations. They were later applied to a spatialized dataset (0.25° × 0.25° latitude-longitude grid) composed by climate, soil and crop data. An historical weather dataset (1951-2004) with two IPCC's climate change projections to 2100 were assessed: a "mild" scenario with robust actions to control GHG emissions,

RCP4.5, and a “strong” scenario with no actions to counteract GHG, RCP8.5. Soil representative characteristics were extracted from the European Soil Database, whereas crop specie and management data were obtained from the CAPRI model (Britz and Witzke, 2008) and Eurostat statistics. The first 30 years of the climatic data were used to spin-up the models and initialise soil C and N pools. N fertilisation was applied to 91% of the cropping systems with a yearly average spanning from a few dozen to 370 kg N ha⁻¹ y⁻¹ (mean of 97 kg N ha⁻¹ y⁻¹). Crop were irrigated according to their needs.

Results and Discussion

Data are reported for one ecosystem model exploring two climatic scenarios and one crop residue management in function of the crop type (iii). This is assumed as the most reasonable scenario for crop management to assess the most realistic long-term trend of N₂O and SOC.

During the historical period considered (1978-2004) N₂O emissions remain stable to 3.1 kg N-N₂O ha⁻¹ y⁻¹ to gradually increase to 3.5 kg N-N₂O ha⁻¹ y⁻¹ towards 2100 in the RCP4.5 scenario. In the RCP8.5 scenario, characterised by a constant increase in air temperatures, N₂O emissions increases on average up to 4.3 kg N-N₂O ha⁻¹ y⁻¹.

The net ecosystem exchange (NEE) shows a general net C uptake by the European cropping system. During the historical and over the RCP4.5 climate scenario was observed a slight and constant decline of the ability to stock C by the system, reducing by 9% (from -347 to -316 kg CO₂ ha⁻¹ y⁻¹ from 2005 to 2100). In the other projection scenario assessed, RCP8.5, the NEE shows an inversion in the trend, with an increase of the uptake capacity of the same magnitude, 9%, from 2005 to 2100.

Given that the net primary production (NPP) is almost equal in the two climate scenarios, it can be concluded that a decline in heterotrophic respiratory activity occurred, which is directly related to low decomposition of crop residues by soil biota. This inversion is also supported by a reduction of about 20% of the crop yields in the RCP8.5 scenario compared to the RCP4.5 scenario, passing from 4.9 to 3.9 Mg ha⁻¹ y⁻¹, respectively.

Conclusions

The use of ecosystem models allowed observing long-term N₂O emission and SOC stock in European cropping systems. Climate change scenarios highlighted a potential reduction in soil C storage associated with a substantial increase in N₂O emissions.

Keywords

Crop residue management, greenhouse gas emission, soil carbon stock, cropping systems, ecosystem modelling

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