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Review

Greenhouse gas contributions of agricultural soils and potential mitigation practices in Eastern Canada

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Abstract

Agricultural soils can constitute either a net source or sink of the three principal greenhouse gases, carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4). We compiled the most up-to-date information available on the contribution of agricultural soils to atmospheric levels of these gases and evaluated the mitigation potential of various management practices in eastern Canada and northeastern USA. Conversion of native ecosystems to arable cropping resulted in a loss of ~22% of the original soil organic carbon (C)—a release of about 123 Tg C to the atmosphere; drainage and cultivation of organic soils resulted in an additional release of about 15 Tg C. Management practices that enhance C storage in soil include fertilization and legume- and forage-based rotations. Adopting no-till did not always increase soil C. This apparent absence of no-till effects on C storage was attributed to the type and depth of tillage, soil climatic conditions, the quantity and quality of residue C inputs, and soil fauna. Emission of N_2O from soil increased linearly with the amount of mineral nitrogen (N) fertilizer applied (0.0119 kg N_2O-N kg N^{-1}). Application of solid manure resulted in substantially lower N_2O emission (0.99 kg N_2O-N ha^{-1} $year^{-1}$) than application of liquid manure (2.83 kg N_2O-N ha^{-1} $year^{-1}$) or mineral fertilizer (2.82 kg N_2O-N ha^{-1} $year^{-1}$). Systems containing legumes produced lower annual N_2O emission than fertilized annual crops, suggesting that alfalfa (*Medicago sativa* L.) and other legume forage crops be considered different from other crops when deriving national inventories of greenhouse gases from agricultural systems. Plowing manure or crop stubble into the soil in the autumn led to higher levels of N_2O production (2.41 kg N_2O-N ha^{-1} $year^{-1}$) than if residues were left on the soil surface (1.19 kg N_2O-N ha^{-1} $year^{-1}$). Elevated N_2O emission during freeze/thaw periods in winter and spring, suggests that annual N_2O emission based only on growing-season measurements would be underestimated. Although measurements of CH_4 fluxes are scant, it appears that agricultural soils in eastern Canada are a weak sink of CH_4, and that this sink may be diminished through manuring. Although the influence of agricultural management on soil C storage and emission of greenhouse gases is significant, management practices often appear to involve offsets or tradeoffs, e.g., a particular practice may increase soil C storage but also increase emission of N_2O. In addition, because of high variability, adequate spatial and temporal sampling are needed for

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accurate estimates of greenhouse gas flux and soil C stock. Therefore a full accounting of greenhouse gas contributions of agricultural soils is imperative for determining the true mitigation potential of management practices.

Keywords: Greenhouse gases; Soil carbon; Nitrous oxide; Carbon dioxide; Methane; Agricultural management practices; Mitigation

Contents

1. Introduction

Rising atmospheric levels of the greenhouse gases carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4) have caused an increase in radiative forcing of the earth's atmosphere. Agriculture plays an important role in the global flux of these gases. In Canada, agriculture accounts for about 8% of total greenhouse gas emission from all sectors (Environment Canada, 2002). Since agroecosystems are usually intensively managed, agricultural practices may offer a way to curb agricultural emission, in turn partially mitigating the enhanced greenhouse effect.

Agricultural soils can constitute either a net source or sink of greenhouse gases. The ways that these soils are managed can influence the flux of greenhouse gases by changing one or more of the following: the soil climate (i.e., temperature and water content), the physical/chemical environment of the soil, and the amount and chemical composition of organic residues applied to soil. Changes in these variables control the rate and extent of microbial processes, which in turn control the stabilization of C in soil and affect the production of greenhouse gases. These gases can play different roles in the metabolism of micro-organisms, serving as metabolic and stoichiometric products or as growth substrates (Conrad, 1996). Changes in the soil physical environment affect the aeration and diffusion of these gases.

Net CO_2 emission from Canadian agricultural soils are currently considered small (Environment Canada, 2002). However, the potential exists to increase soil C by increasing organic matter content (Janzen et al., 1998; VandenBygaart et al., 2004), thereby converting these soils to a net CO_2 sink. Management practices