MEASUREMENTS AND VERIFICATION OF GHG EMISSIONS FROM AGROECOSYSTEMS

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ABSTRACT

An estimate of the main sources of methane and nitrous oxide from agroecosystems in Canada will be presented. Two of the most up-to-date micrometeorological techniques available for obtaining reliable measurements of GHG emissions will be described. For point sources, a mass balance approach, using open path lasers, was recently used to quantify methane emissions. A recovery of about 97% was obtained using this technique. For diffuse sources, such as nitrous oxide emissions from agricultural farmlands, observations using aircraft-based fluxes will be examined. It will be shown how such flux measurements can provide valuable information for verifying regional estimates of nitrous oxide emissions during episodes when nitrous oxide emissions are relatively large.

INTRODUCTION

Agriculture is responsible for about 10% of Canada's greenhouse gas emissions (Desjardins and Riznek, 2000). If the CO_2 emitted during fertilizer and machinery manufacturing and the CO_2 produced by burning fossil fuels on farms is included, agriculture accounts for about 13% of the anthropogenic emissions in Canada. This extra 3%, which is usually attributed to the manufacturing and transportation sectors, will not be discussed here.

Agriculture, being one of the most managed ecosystems, lends itself well to possible reduction of GHG emissions. However, we need to improve GHG emission estimates before making recommendations on how to reduce emissions. Current estimates of GHG emissions are still highly uncertain. In this paper we present an estimate of the GHG emissions from agroecosystems in Canada for the last five census year and briefly describe two measuring techniques being used to improve and verify GHG emission estimates.

GHG EMISSIONS FROM AGROECOSYSTEMS IN CANADA

The GHG emissions from agroecosystems in Canada are given in Table 1 for the last five census years. The CO_2 emissions, which are from agricultural soils, have been estimated using the Century model (Smith et al., 2000). The absolute value of these emissions is rather difficult to estimate accurately. It is, however, easier to estimate the change in CO_2 emissions, due to changes in management practices. These changes are reasonably well documented since 1981. The decrease in CO_2 emissions from 1981 to 2001 is due to an increase soil C sequestration associated with the adoption of soil conservation practices such as reduced tillage, reduced summer-fallowing, etc. (Desjardins et al., 2001b).

Table 1: GHG emissions (Tg of CO_2 equivalent) from agroecosystems in Canada for the last five census years. The CO_2 equivalent values are based on a 100-year time horizon and the global warming potential values reported by IPCC (2001).

	1981	**1986**	**1991**	**1996**	**2001**
CO_2	8	7	5	2	0
CH_4	24	22	22	25	26
N_2O	25	24	25	30	31
Total	**58**	**53**	**52**	**57**	**57**

For estimates of N_2O and CH_4 emissions, we mainly follow the methodology recommended by the International Panel for Climate Change (IPCC) incorporating Canadian data wherever possible. N_2O emissions come from three primary sources: direct emissions from cropping systems; direct emissions from animal producing systems; and indirect emissions from agricultural systems. Desjardins et al., (2001a) recently estimated regional and national estimates of the N_2O emissions from agroecosystems in Canada, for 1996, using the IPCC methodology adjusted for conditions in Canada (IPCC, 1996). The adjustments were the following: 1) the estimated proportion of applied N leached annually was reduced to 15% from the original 30%. 2) N_2O emissions during N fixation were assumed to be negligible except for pulse crops. 3) N_2O emissions that had been considered a function of N fertilizer type were now assumed to be independent of the form of fertilizer applied. By selecting emissions coefficients that are considered to be more representative of conditions in Canada, N_2O emission estimates for 1996 are 30 Tg CO_2 equivalent compared to the previous estimate of 37 Tg CO_2 equivalent.

Methane emissions from animals in Canada are calculated using the livestock inventory data from Statistics Canada. The emission rates for various livestock are based on IPCC default values. We will soon, however, be in a position to use emission factors more representative of conditions in Canada, thanks to an intensive measuring program employing a wide range of micrometeorological techniques.

Figure 1 shows the spatial and temporal scales of several of the micrometeorological techniques that are now being used to measure N_2O and CH_4 emissions from agroecosystems. The spatial measurements range from cm^2 to m^2 using chambers and from 10 km^2 to 1000 km^2 using aircraft-based flux measurements. The temporal scale ranges from minutes to days.

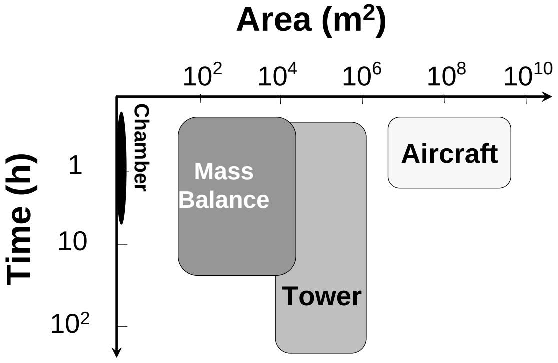

Fig. 1: Time and space scales covered by some of the micrometeorological techniques being used to measure CH_4 and N_2O fluxes.

FLUX MEASUREMENTS OF CH_4 AND N_2O

Two of these techniques will be examined more closely in this paper: (1) the mass balance technique, which can be used to quantify CH_4 emissions from point sources, and (2) the aircraft-based technique, which can be used to verify N_2O emissions at a regional scale.

The mass balance technique relies on the wind speed and CH_4 concentration profiles upwind and downwind of a point source to quantify CH_4 emissions. This technique is applicable to a large number of on-farm sources, including emissions from animals, manure piles and lagoons, Several research groups have reported CH_4 emissions with this technique (Denmead et al., 1998; Harper et al., 1999). The advent of open-path laser-based gas analyzers (Boreal Laser MC GasFinder) that can measure average concentrations of CH_4 over long path lengths (< 300 m) make it possible to simplify this technique. Instead of drawing air into closed-path gas analyzers, open-path laser-based gas analyzers can measure instantaneous concentrations over long path lengths. It is then possible to simplify the method so that concentration measurements need only be made in one plane upwind and one parallel plane downwind of the CH_4 source. In conjunction with sonic anemometers that can measure the instantaneous wind velocity, the method can be simplified to

$$F = X\int_0^Z \overline{U_{n,z}\left(C_{CH_4,d,z} - C_{CH_4,u,z}\right)}dz$$

provided that the downwind measuring path is sufficiently long to encompass the entire width of the diffusing plume and that $U_{n,z}$ is uniform across the path. F is the magnitude of the source. The overbar denotes the time means. X is the length of the laser path. $U_{n,z}$ is the wind speed normal to the boundaries at the measurement height z, and the subscripts d and u denote downwind and upwind of the methane source.

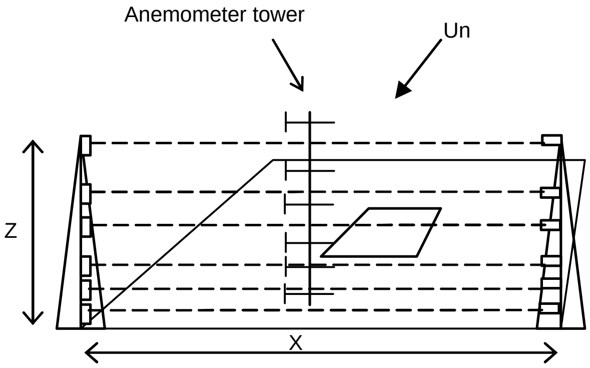

Fig. 2: The simplified system used to measure CH_4 fluxes. The laser paths between the two towers are indicated by the dashed lines. Wind speed and direction were measured at corresponding heights on the anemometer tower using 2-D sonic anemometers. The release grid is indicated in the centre of the rectangular test area.

This technique was recently tested by determining the recovery of CH_4 released at a known rate upwind. A sketch of the experimental setup is shown in Figure 2. The laser path length was set at 50 m. CH_4 concentrations were measured at 6 heights between 0.4 to 6 m. Wind speed and direction were measured with sonic anemometers (Vaisala WAS 425 ultra sonic wind sensors) mounted on a third tower located 3 m upwind of the mid-point of the laser path. The heights of these sensors corresponded to the laser heights. Releases of CH_4 were made from a grid, approximately 3m x 3m made from 17.5 mm ID PVC tubing with 16 0.8 mm ID holes drilled at approximately 1m intervals. Methane was fed to the grid from a cylinder of 99% purity through a Thermo Systems Inc. mass flow meter. An MKS mass flow controller was used to control the mass flow rate at 79 mg CH_4 s^{-1}. The grid was positioned near the mid-point of the laser path line with its center at about 12 m upwind of the laser line.

Figure 3 shows the ensemble mean CH_4 flux profile for the three releases. It also shows the standard errors of the flux estimates for six levels. A mean recovery of better than 97% was obtained. Such excellent result will however be more difficult to obtain near building and when the emissions originate from a larger surface.

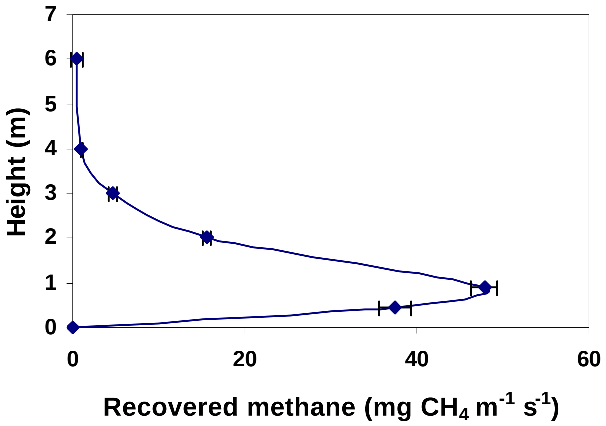

Fig. 3: Measured flux of CH_4 and standard errors as a function of height based on three releases of 79 mg CH_4 s^{-1}.

Most of the techniques identified in Figure 1 are better suited for measuring the fluxes from diffuse sources. Micrometeorological flux measurements using towers offer the best approach to obtaining quasi-continuous measurements of such sources. Deployment of such systems is limited and only a few systems have been used to measure N_2O emissions (Maggiotto and Wagner-Riddle, 2001; Grant and Pattey, 2003). Measurements of N_2O emissions at an even wider scale are needed to ensure that all sources are accounted for. At a regional scale (>10 km^2) aircraft platforms have proven highly successful in measuring turbulent trace gas fluxes using the eddy covariance technique (Desjardins et al., 2000).

For N_2O and CH_4 there are no fast response sensors that can presently be mounted on an aircraft to use the eddy covariance system. The relax eddy accumulation technique (Businger and Oncley, 1990; MacPherson and Desjardins, 1991) allows the measurements of scalar fluxes based on the same fundamental principles as eddy covariance, but without the need for fast response analysis. It involves the partitioning of the sampled gas into two reservoirs, based on whether the real-time wind measuring system senses ascending or descending air. The vertical flux estimate $\overline{W'C'}$, for a trace gas is a function of the standard deviation of the vertical velocity, s_w, the difference of the mean concentration in the two reservoirs, $(\overline{C_u} - \overline{C_d})$, and an empirical coefficient A (MacPherson and Desjardins, 1991).

$$\overline{W'C'} = A s_w(\overline{C_u} - \overline{C_d})$$

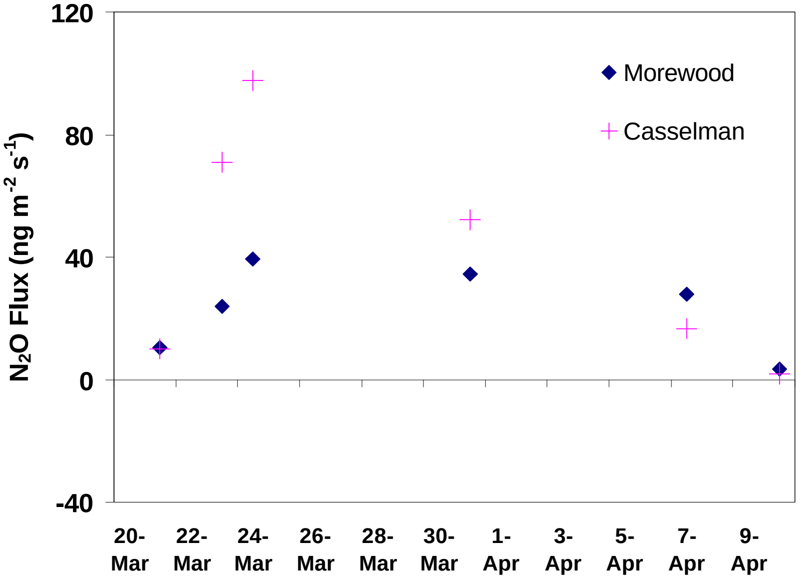

Fig. 4: N_2O fluxes measured by the Twin Otter aircraft along two 10 km transects over agricultural fields near Ottawa, Canada, during the spring of 2000.

This technique, which has already been successfully applied to the flux measurements of agrochemicals (Zhu et al., 1998) and volatile organic compounds (Zhu et al., 1999), can now be used to measure N_2O fluxes. An example of such flux measurements along two transects is given in Figure 4 for the spring of 2000 during the snowmelt period. This period is quite significant in temperate regions as up to 50% of the annual emissions have been reported to occur (Maggiotto and Wagner-Riddle, 2001). Each data point represents the flux based on four runs at about 30 m above the ground. Each run consists of two passes over transects 10 km long. The area sampled during each pass is about 100 km^2 based on flux footprint estimates. The detection level of this technique is a function of the resolution of the tunable diode laser used to analyze the air samples associated with updrafts and downdrafts. In several tests it was demonstrated that a resolution of 10 ppt was possible more than 90% of the time for N_2O. This means that under light wind conditions, with a s_w of 0.3 m s^{-1} for the vertical wind, a resolution of about ± 3 ng N_2O $m^{-2}s^{-1}$ is possible. This value is substantially smaller than the N_2O fluxes reported in Fig 4. A mean flux of about 23 ng N_2O $m^{-2}s^{-1}$ was observed along the Morewood transect and about 42 ng

N_2O $m^{-2}s^{-1}$ along the Casselman transect which is located about 15 km west of the Morewood transect. The differences in N_2O emissions between the two transects are most likely due to different management practices and environmental conditions.

SUMMARY

This paper presents the magnitude of greenhouse gas emissions from agroecosystems in Canada for the last five census years. It shows that most of the GHG emissions are either in the form of N_2O or CH_4 and that these emissions are increasing. Methane emissions, which are primarily from point sources, can accurately be measured using the mass balance technique. Measurements of N_2O emissions using aircraft-based technology are presented as useful information for verifying regional estimates of N_2O emissions.

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