Nitrous oxide emissions from the semi-arid prairies: A first look

R.L. Lemke and B.G. McConkey
Agriculture & Agri-Food Canada, Semiarid Prairie Research Centre, Swift Current, SK, S9H 3X2

Introduction

We are concerned about nitrous oxide (N_2O) emissions from agroecosystems because N_2O is a powerful greenhouse gas, depletes stratospheric ozone, and represents the loss of a valuable crop nutrient. Canada, via the Kyoto Protocol, is committed to reducing greenhouse gas emissions to a level six percent lower than 1990 by the period 2008-2012. In order to meet this target, the federal government is currently developing a National Implementation Strategy (NIS), which will provide a basis for future policy development.

Agricultural activities contribute approximately 60% of all Canadian anthropogenic nitrous oxide (N_2O) emissions. Nearly 25% of this total is assigned to Saskatchewan agricultural activity (Janzen 1998). National and regional estimates are currently calculated using the Intergovernmental Panel on Climate Change (IPCC) methodology, which assumes that a constant fraction of the N in crop residues, fertilizer N, and manure is lost as N_2O. No accommodations are made for factors such as climatic, soil type, drainage, or landscape position, all of which are known to influence the magnitude of N_2O emission. The accuracy and appropriateness of this methodology has not been demonstrated, particularly for the semi-arid prairie region. Field data is urgently needed to validate or refute the emission factors applied to agricultural activities. Several field studies have been initiated at the Semiarid Prairie Agricultural Research Centre (SPARC) in Swift Current to quantify N_2O losses from representative cropping systems in the semiarid region. This paper presents some preliminary results of the first season of N_2O flux measurements, and discusses the implications of the findings in terms of current estimates of N_2O emissions from the semiarid prairie region.

Materials and Methods

This study was conducted on an existing long-term tillage experiment at SPARC. The tillage experiment was established in 1982 on a gently sloping loam textured soil. A detailed description of the site and tillage study can be found in Campbell et al. (1995). Measurements of N_2O fluxes were conducted on a subset of treatments during the growing season of 1999. Treatments selected were continuous wheat (W), wheat-fallow (W-F) and wheat-field pea (W-pea) in combination with two tillage levels. Tillage levels were No Till (NT) – plots which are direct seeded and weed control during the fallow year is accomplished with herbicides and, Conventional Till (CT) – plots receiving one pre-seeding tillage operation with weed control during the fallow year accomplished by mechanical means. Fertilizer was applied according to recommendations based on soil tests. The wheat phase of the W-pea and W-F rotations received 20 kg N ha^{-1}, while the CT-W received 50 kg N ha^{-1} and the NT-W received 57 kg N ha^{-1}, as side-banded urea. The pea phases also received 5 kg N ha^{-1} which accompanied the phosphorus source.

Gas samples were collected using vented soil chambers (Hutchinson and Mosier 1981). N_2O flux was estimated from the concentration change in the chamber headspace over a thirty minute collection period. Samples were drawn from the headspace using disposable 20 ml polypropylene syringes. The gas sample was then injected into pre-evacuated 13 ml exetainers for transport to the laboratory. The concentration of N_2O in the samples was determined using a gas chromatograph equipped with an electron capture detector. The field plots were sampled for N_2O emissions at least twice a week from the last week of April until mid-July when soil-water contents were high and the potential for N_2O loss was greatest. Sampling frequency was reduced to once a week or less during the latter part of the season when soil-water contents were low.

Temperatures during the May-July period were cooler than normal and much wetter, with cumulative precipitation being 43 % greater than the 114 year average (Table 1). Temperatures during the latter part of the season were much warmer and drier than normal with cumulative precipitation being only 55% of the 114 year average.

Table 1. Mean monthly air temperatures and precipitation measured at Swift Current during the 1999 field season and averaged over that past 114 years.

	Mean monthly air temperature		Mean monthly precipitation	
Month	1999	114 year average	1999	114 year average
	°C		mm	
May	9.9	10.9	93.9	43.9
June	14.1	15.4	86.2	72.7
July	16.4	18.6	60.3	51.7
August	18.9	17.6	16.8	43.0
September	11.1	11.8	3.0	31.0
October	6.2	5.6	16.2	18.8
November	2.6	-3.6	3.2	13.9
December	3.3	-9.6	15.5	15.5

Estimates of cumulative N_2O-N loss for the Swift Current site were calculated using the methodology proposed by the IPCC (OECD/IPCC, 1997). This methodology assumes that direct emissions from agricultural soils can be estimated by a simple linear extrapolation between nitrogen (N) inputs and N_2O emissions. Nitrogen inputs include commercial fertilizers, N from animal excreta applied as fertilizer, N from increased biological N-fixation, and N derived from enhanced organic matter mineralization resulting from agricultural activities. Nitrogen loss through volatilization processes is first removed from the total N value. The N inputs are summed, volatilization losses are subtracted, and the total N remaining is multiplied by an emission factor to estimate N_2O-N loss. We used the default values suggested by the IPCC for our calculations.

Results and Discussion

Despite the higher than normal rainfall received at Swift Current during the May-July period which should have favored N_2O emissions, particularly following fertilizer application, emissions were consistently low from this site. Seventy-five percent of the measurements had concentration changes under the headspace that were at or below our detection limits (Table 2). Emissions of N_2O above our detection limits were measured during May and the first week of June (figure 1). With one exception, no detectable fluxes were measured after June 9. This seasonal pattern is similar to other N_2O studies in western Canada (Corre et al. 1996; Lemke et al. 1998a), however, in this study the magnitude of the fluxes measured were generally lower, and the period during which detectable emissions were measured was considerably shorter. The range and frequency distribution of flux values was very similar for all treatments.

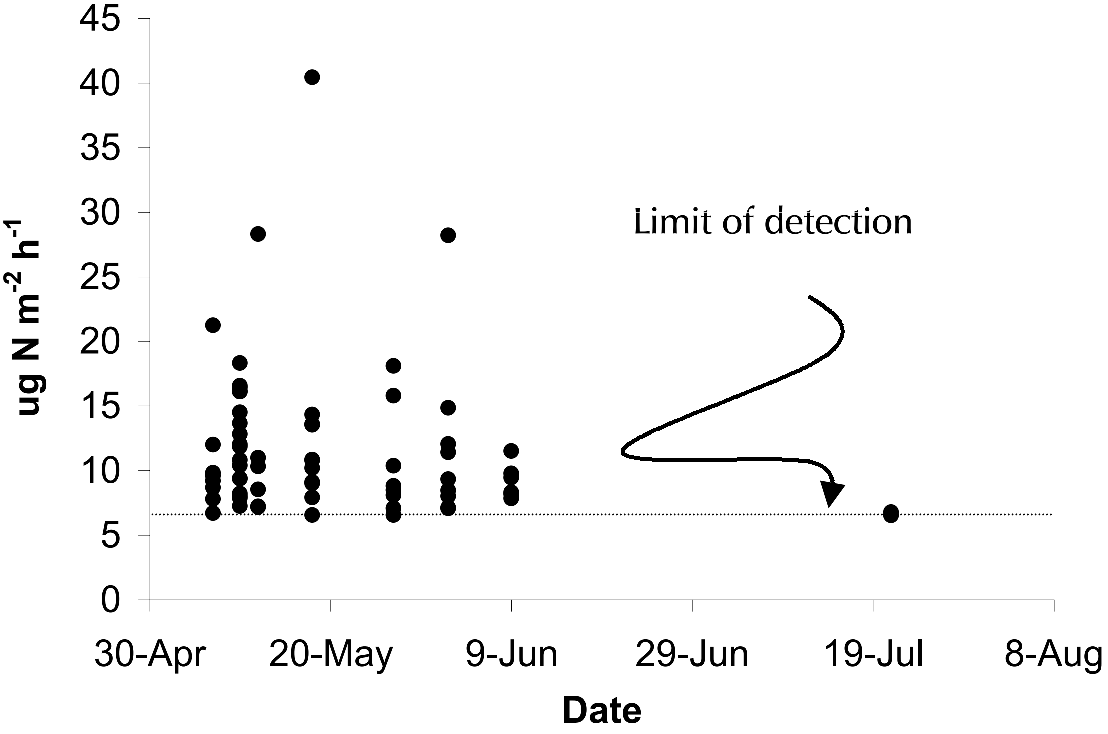

Figure 1. Seasonal distribution of N_2O emissions measured at Swift Current during 1999

More rigorous statistical treatment of the data is required before estimates of cumulative N_2O loss from this site can be developed with confidence. However, a first indication of the upper limit of the loss can be calculated from the range of fluxes observed. If we assume the maximum flux measured (40 μg N m^{-2} h^{-1}) was constant over the 35 day period when detectable fluxes were observed, then approximately 0.3 kg of N ha^{-1} would have been lost (Table 2). Similarly, if the constant flux had been 10 μg N m^{-2} h^{-1} (90 % of fluxes fell below this level) then 0.1 N ha^{-1} would have been lost. No detectable fluxes were measured at any other time of the season. However, since our limit of detection is about 6 μg N m^{-2} h^{-1}, it is possible that there were positive fluxes up to this level during other parts of the season. If we assume the highly unlikely scenario that there was a constant flux just at our detection limit throughout the season (330 days), in addition to a maximum flux during the 35 days of activity discussed previously, then the total possible cumulative emission would still only be 0.8 kg N_2O-N ha^{-1} (Table 3). This upper maximum is well below the 1.2 kg N_2O-N ha^{-1} which is the estimated loss calculated using the IPCC methodology. The low estimated losses from our site are consistent with losses estimated from a similar study being conducted at the Lethbridge Research Centre (B. Ellert, pers. comm.). The reader is cautioned that both the Swift Current and the Lethbridge study sites are relatively level, and have medium-textured, well-drained soils. Factors such as texture and topography have been shown to have a strong influence on N_2O emissions (Corre et al. 1996; Lemke et al. 1998b). Indeed, considerably higher losses of N_2O were measured from the lower slope positions during a concurrent study near Swift Current in 1999 (data not shown).

Table 2. Frequency distribution of N_2O fluxes measured on a tillage study at Swift Current in 1999, and estimated maximum potential cumulative loss of N_2O .

Quartile	Flux	Maximum Potential Loss^z
	μg N m^{-2} h^{-1}	kg N ha^{-1}
100	40	0.3
90	10	0.1
75	≤ 6	<< 0.1

^{z} assuming constant flux during the 35 day period when measurable fluxes were observed

Table 3. Maximum possible estimated N_2O loss based on emission patterns measured at Swift Current site in 1999.

Base^Z	Maximum^Y	Total	IPCC
kg N ha^{-1}			
0.5	0.3	0.8	1.2

^{Z} assuming a constant emission of 6 μg m^{-2} for 330 days
^{Y} assuming a constant emission of 40 μg m^{-2} for 35 days

Summary

The preliminary results from this study suggest that N_2O emissions from level, well-drained sites in the semi-arid prairie region are very low and may be considerably less than estimates based on IPCC methodology. The choice of No versus Conventional Till, fallow versus crop, or wheat versus field pea, had no apparent affect on the magnitude of N_2O emission. We remind the reader that conclusions drawn from a single seasons field data are tentative at best. This is especially true for N_2O emissions research, given the inherent spatial and temporal variability of N_2O flux measurements.

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