# Soil Nitrous Oxide Emissions from a Continuous Wheat Cropping System in Montana

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## Introduction

Nitrous oxide ($N_2O$) is a trace gas in the atmosphere that has come under increasing scrutiny because it contributes to global warming and destruction of the stratospheric ozone layer. Human alterations of the global N cycle, including the use of N fertilizer, are known to promote the release of $N_2O$ from soils into the atmosphere. Nitrous oxide production in soils occurs as a result of two microbial processes: 1) nitrification of ammonium and ammonium-producing fertilizers (e.g. urea) under aerobic conditions and 2) denitrification of nitrate under anaerobic conditions (Fig.1). During the past 250 years there has been a 17% increase in the atmospheric $N_2O$ concentration to its present level of 316 parts per billion. Agriculture is reported to account for 65-70% of global anthropogenic emissions, and fertilizer N use (commercial and manure) is considered the primary contributor by the International Panel on Climate Change (IPCC, 2001). Regional and global estimates of $N_2O$ production from agriculture have frequently been adopted using IPCC methodology. Beginning in 1997, IPCC methodology assumed as a default that 1.25% of all N inputs, including fertilizer N, are lost directly as $N_2O$. This default value was developed from databases currently available at the time, most of which came from regions that were considerably more humid than Montana. Given that soil $N_2O$ emissions are known to be affected by differences in cropping systems and climate, there is uncertainty as to the accuracy of the 1.25% default value to Montana agriculture. This study was undertaken to describe seasonal patterns of $N_2O$ release from a continuous wheat cropping system and provide an estimate of the effect of N fertilization on $N_2O$ emission losses.

### Methods

Nitrous oxide gas samples were collected over two years (Apr. 14, 2004 to Apr. 15, 2006) at the Montana State University – Arthur Post Farm in Bozeman. The soil at the site is classified as an Amsterdam silt loam (fine-silty, mixed, superactive, frigid Typic Haplustolls) with pH 7.2, and organic matter content of 1.5% in the surface 8 in. The field study was part of a larger cropping system study, but only the results from the no-till winter wheat – spring wheat rotation are presented here. The wheat-wheat system was divided into subplots representing three target levels of available N, including a low-unfertilized regime, a moderate available N regime (90 lb N/ac), and a high available N regime (180 lb N/ac). The treatments were replicated four times. Available N pool was estimated from the sum of soil $NO_3$-N (0–24 in.) plus fertilizer N applied, with the fertilizer N application rates in the moderate and high regimes calculated by the difference between soil $NO_3$-N tests and the target N level. Fertilizer N applications (as urea) were equivalent to 156 and 218 lb N/ac over two years for the moderate and high N regimes, respectively. Gas sampling was conducted using static chamber techniques. Gas samples were collected from the headspace during the early to mid-afternoon (1 – 3 p.m.). The concentration of $N_2O$ in the container was determined using a gas chromatograph.

### Results

Nitrous oxide flux vs. time profiles (Fig. 2) from the continuous wheat rotation revealed that emissions were episodic and responsive to periods of high soil water-filled pore space and availability of N substrate (soil or fertilizer). Examination of the curves reveals that N fertilization was perhaps the single most important event that stimulated an increase in $N_2O$ emissions. The elevation in emissions occurred within a week following fertilization, and peaked after approximately 2-4 weeks. The duration of elevated flux above background (>2.0 µg $N_2O$-N $m^2$/h) for spring applications in 2004 and 2005 was approximately 10 weeks, but extended somewhat longer for the fall application in 2005 (Sept. 30). The majority of $N_2O$ losses during the 10-wk period following fertilization were probably a result of nitrification, except in the fall 2005, when denitrification may have been important as soil water contents were high and frequently exceeded >70% water-filled pore space. In addition to N fertilization, freeze-thaw cycles in the winter or early spring were also important in stimulating significant $N_2O$ emission activity.

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Emissions during these periods were likely a result of denitrification, as rises in air temperature triggered snowmelt and resulted in saturated conditions near the soil surface. Together, the 10 week post-N application and freeze-thaw cycle periods account for 84% of $N_2O$ emissions over a two year period. When $N_2O$ emissions were summed, the results showed that only modest levels of $N_2O$ losses were observed (Table 1). Fertilizer induced emissions were equivalent to 0.43% of the applied N (mean of moderate and high). This is considerably below the IPCC 1.25% default value, and suggests emission of $N_2O$ in semi-arid regions are more modest than suggested by IPCC default methodology.

**Fertilizer Fact:**
Nitrogen fertilization results in an elevation in $N_2O$ emissions from a Montana soil, but the losses (0.43% of applied N) are considerably lower than the IPCC mean default value of 1.25%.

**Reference**:

Intergovernmental Panel on Climate Change. 2001. Climate change 2001: Synthesis report. Summary for Policy makers. IPCC Plenary XVII. Wembley, UK., Sept. 24–29.

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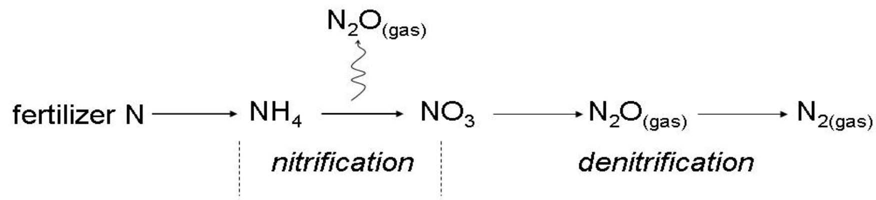


Figure 1. Nitrous oxide production from soils occurs during both nitrification and denitrification.

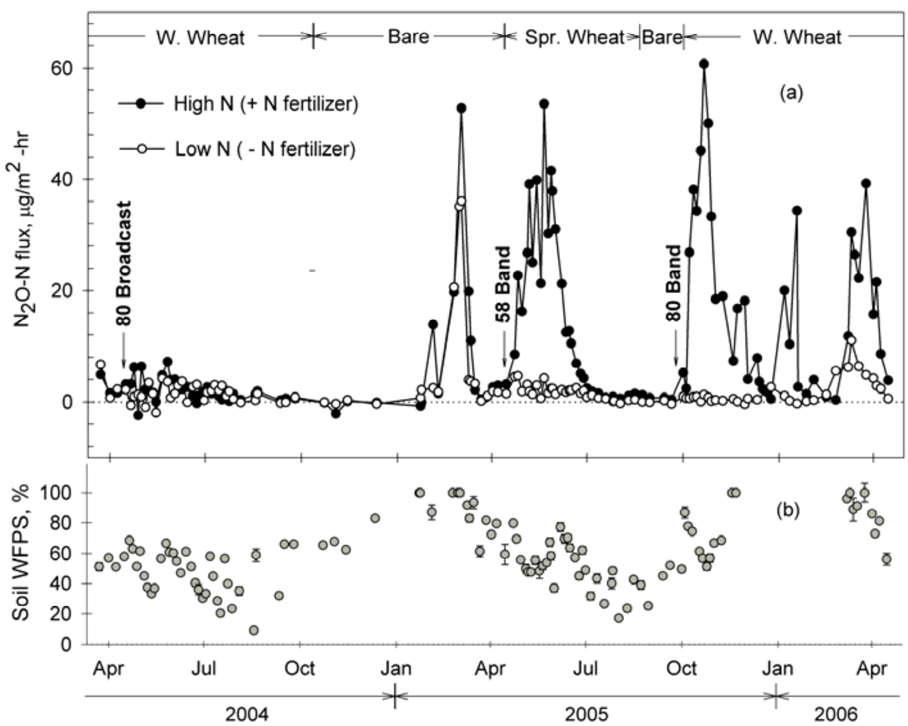


Figure 2. **a)** Nitrous oxide emissions over time for a continuous wheat system at two N management levels (moderate regime not shown for clarity). Arrows indicate date, amount of applied N (lb N/ac), and method of N placement. **b)** Percent of soil water-filled pore space (Soil WFPS) over time (mean of two N levels).

Table 1. Estimated cumulative emissions of $N_2O$, fertilizer induced emissions (FIE) and fraction of applied N fertilizer lost as $N_2O$ over two years for a winter wheat – spring cropping system at 3 available N management regimes.

| Available N regime | Total N applied over 2 years | Cumulative $N_2O$-N losses over 2 years | FIE* of $N_2O$-N over 2 years | Fraction of applied N loss as $N_2O$ |
|---|---|---|---|---|
| | (lb N/ac) | (lb N/ac) | (lb N/ac) | (%) |
| Low | 0 | 0.26 | - | - |
| Moderate | 156 | 0.96 | 0.70 | 0.45 |
| High | 218 | 1.17 | 0.91 | 0.42 |

* FIE = Fertilizer Induced Emission: Cumulative $N_2O$-N losses from fertilizer applications (moderate or high).