Control of Greenhouse Gas Emissions from California Vineyards by Soil Carbon and Water and its Policy Implications

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Summary

The increase in atmospheric concentrations of the greenhouse gases (GHG) are leading to changes in global climates. Such climatic alterations could seriously impact upon the agricultural practices of California and even diminish yields and production of California’s specialty crops including the wine industry. The project has started to address and concentrate on the issues of uncertainty in the emissions of GHGs seasonally and annually from vineyards, and will continue to characterize spatial and temporal variation of CO2, N2O and CH4 fluxes within the soil zone where nitrogen fertilizers and water are applied. In 2006 we started collecting samples of soil gas to monitor the GHGs of N2O and CH4 in order to have a full accounting of the primary agriculture generated GHGs. We have identified the increase of N2O emissions after precipitation events at both sites, where the oak grassland produced the greatest emissions seasonally compared to the vineyard. We have also obtained preliminary data, which suggests that N2O fluxes are influenced by the quantity and application of nitrogen (N) fertilizers.

Objectives

The initial identification of two suitable sampling sites with different land management practices was successful. The implementation of a rigorous trace gas sampling regime and collar location and positioning also was successful during the first year of the project. The compilation of a large data set was essential to begin the process of creating an annual budget for trace GHG emissions within both systems and has proved to provide useful information in temporal patterns of N2O fluxes. Future research in this area will result in not only a continued analysis of the seasonal flux of N2O, but also focus on emissions of CH4 and CO2.

Keywords: Soil-plant water and carbon relationships, greenhouse gas, denitrification, CO2, N2O, CH4 emissions.

Approach and Procedures

To measure soil CO2 efflux in situ, we use a non-dispersive infrared gas analyzer (model LI-6400/6400-09, LICOR, Lincoln NE). Permanent 10.16 cm diameter PVC collars were inserted two cm into soil one month prior to the first measurement. All vegetation within the collars is removed. Vineyard soil collars were placed within the vine rows and between and underneath the oak canopies. All efflux measurements are corrected for

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vapor pressure, soil temperature, and chamber temperature. Percent gravimetric soil moisture content at 0-20 cm is determined following each efflux measurement and deep (1 m) soil cores will be taken to determine bulk densities and particle size analyses. The soil respiration measurements are made between approximately 11 a.m. and 3 p.m. and every two to three weeks. To measure \( \text{N}_2\text{O} \) and \( \text{CH}_4 \), permanent 20.32 cm diameter PVC collars are inserted two cm into soil. Sealed soil covers modified from Hutchinson and Mosier are then fitted over the collars (Hutchinson and Mosier 1981). Two 20 ml vials of gas are removed from the chamber at \( T=0 \), \( T=1 \) hour and \( T=2 \) hours. \( \text{N}_2\text{O} \) is analyzed on a gas chromatograph (GC) with Poropak Q Column (1.8 m, 80/100, 90ºC) and a \( ^{63}\text{Ni} \) electron capture detector. \( \text{CH}_4 \) will be analyzed on the GC with Poropak Q Column and a flame ionization detector (300ºC).

Figure 1: Shown in a.) is the vineyard site with the vineyard, fallow, and riparian areas delineated; b.) The oak grassland site with the uphill, stream conflux, grass valley, and under tree canopy areas delineated; c.) is the Oakville vineyard showing the wetting areas after drip irrigation.

Site descriptions

Our vineyard site is located in the Carneros region of Napa County. The vineyard is planted on a hill with a slope of approximately 18%. The vines are planted running parallel to the slope of the hill. Three pairs of collars are placed in the vineyard at the top of the hill, middle of the hill and the bottom of the hill. There is also a pair of collars inserted into a riparian zone at the very base of the slope. Lastly, there are two collars located on top and on the bottom of a fallow field just to the south of the vineyard (fig. 1a).

Our grassland site is a cattle grazed mixed oak grassland located approximately 4.7 km away from the vineyard site on similar soil types. Four collars installed in a flat grass valley are paired with collars placed under an adjacent tree canopy. There are also two collars placed in a flood plane at the conflux of two seasonal streams. Thirdly, there are three collars installed up a hill with comparable slope to our vineyard sites (fig. 1b).

For our fertilization experiment, we installed collars directly under the emitters in a drip-irrigated vineyard in Oakville, CA (fig. 1c). Our team then applied potassium nitrate
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fertilizer directly on the soil in the amounts of 0, 5, and 40 lbs of N/acre. The fertilizer was then drip irrigated in using seven gallons of water applied over seven hours. Temporally intensive gas samples were taken from the static soil chambers immediately before and immediately after application of fertilizer.

mean N₂O flux from both sites

![Mean N₂O Flux from Both Sites](image)

**Figure 2:** The mean N₂O emissions in ng N/m²h from both the vineyard and the oak grassland sites.

**Results**

**N₂O annual budgets**

Since the initiation of the trace gas sampling, considerable time was spent determining the study sites from which to sample and installing the PVC collars at various locations for each of the two sampling sites (fig. 1). The data presented within this report focuses mainly upon N₂O gas flux measurements as we are currently in the process of purchasing a new gas chromatograph to measure CH₄, therefore, samples collected during the 2006 sampling campaign are currently being stored awaiting analysis. The CO₂ data also obtained within the 2006 sampling period is also currently in the process of being analyzed.

The preliminary results for N₂O gas flux measurements obtained during the sampling period, February 2006 to July 2006, at the vineyard and the natural oak grassland sites shown in figure 2. The results shown are a mean of a total of 10 and 12 flux measurements for the vineyard and oak site respectively. The average N₂O flux over the sampling period was 1665.4 ng N / m² h⁻¹ with a range of -13.5 to 5150.4 ng N / m² h⁻¹ for the vineyard and 6950.5 ng N / m² h⁻¹ with a range of -848.0 to 22077.6 ng N / m² h⁻¹ for the natural oak grassland. A marked difference was observed between sampling sites, where higher N₂O fluxes were observed for the oak site compared to the vineyard site (fig. 2). The basic pattern of N₂O emissions was similar between each site, fluxes for both sites observed temporal effects with differences in flux occurring over the duration of
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Greatest flux increases were observed where N₂O production occurred after precipitation events in the spring (April-May). Consumption of N₂O occurred in the drier summer season (June-July) and provided a negative flux. Previous research observed similar seasonal variations in a variety of soil types for N₂O emissions (Ishizuka, Tsuruta et al. 2002). The observed differences may be due to a number of reasons, such as land use management, soil and vegetation type and irrigation application between the oak and vineyard site.

![Graphs showing N₂O emissions and precipitation](image)

**Figure 3:** The N₂O emissions in ng N/m²h and precipitation in inches from the four areas of the oak grassland site.

Figures 3 and 4 show the individual collar fluxes at each of the two sites, oak grassland and vineyard. These figures also include total daily precipitation throughout the
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sampling period. At the oak grassland (fig. 3) mean emissions ranged from 96.5 6 ng N / m² h⁻¹ to 23038 6 ng N / m² h⁻¹, where the lowest emissions were observed from the collars located within the open grass and the highest emissions were taken from under the oak tree canopy. N₂O emission concentrations for each of the collar locations varied with time and a general trend of increased gas flux was observed after any period of precipitation in the spring. Negative fluxes indicate the consumption of N₂O in the soils and occurred at each collar location in the dry season, highest consumption rates occurred at the stream conflux where concentrations decreased continuously throughout the sampling period.

![Graphs showing nitrogen dioxide emissions and precipitation](image)

**Figure 4.** The N₂O emissions in ng N/m²h and precipitation in inches from the three areas of the vineyard site.

Emissions of N₂O also decreased with time within the vineyard (fig. 4), where mean emissions for each collar location ranged from 141.8 ng N /m² h⁻¹ to 8731.8 ng N /m² h⁻¹. The lowest fluxes evolved at the top of the fallow field, where highest emissions were observed at the bottom of the fallow field in the vineyard. Following a similar precipitation trend to the oak site, an increase in N₂O emissions was observed after
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precipitation events and then decreased into the drier season. However, an increase in flux was observed in the July 2006 sampling, within the vineyard rows pertaining to irrigation practices.

**Fertilization experiment**

Results for the fertilization experiment looking into the effects of N fertilizer application quantities upon N$_2$O gas flux from soils in a vineyard are presented in figure 5. Initial N$_2$O flux concentrations ranged from -98.8 ng N / m$^2$ h$^{-1}$ to 96.4 ng N / m$^2$ h$^{-1}$ before the application of N fertilizer to the collars. Preceding the application of the N fertilizer emission of N$_2$O increased compared to background initial concentrations after 24 hours after treatment. Flux rates after application were 543.8 ng N / m$^2$ h$^{-1}$ for the no N treatments and 863.9 ng N / m$^2$ h$^{-1}$ and 1470.1 ng N / m$^2$ h$^{-1}$ for the 5 lbs of N/acre and 40 lbs of N/acre treatments respectively. The increased N$_2$O emissions observed from the no treatment collar were due to the administration of water onto this collar plot, and are consistent with the increase in seasonal emissions observed for the oak and vineyard sites after precipitation events. Highest flux rates were observed within the collar which had 40 lbs of N/acre applied to it. Increases in N$_2$O flux have been observed previously, especially where increases peak up to the first 2 days after application (Velthof, Oenema et al. 1996). This is due to the fact that within most agricultural soils N$_2$O is formed biogenically due to an increase in mineralized N, which in turn increases nitrification and denitrification rates (Mosier, Kroeze et al. 1998). Therefore the addition of N fertilizers will directly enhance the formation of N$_2$O.

![Figure 5](image)

**Figure 5.** The N$_2$O emissions in ng N/m$^2$h before and after fertilization and irrigation in a vineyard site in Oakville, CA.
Discussion

Global warming and climate change could seriously impact upon the natural resources, environment and agricultural economy of the state of California. The mounting concern regarding increases in greenhouse gases (GHGs) with the potential to modify regional climate patterns has prompted California to reduce its GHG emissions, which has resulted in the passing of the California Global Warming Solutions Act 2006. In conjunction with this and the Kearney Mission, this project has started to develop a field measurement procedure to determine GHG emissions from a variety of sites with varying land use management practices. The results from the fertilization study and future work in this area will enable the evaluation of alternative mitigation strategies to be investigated in which to reduce GHG emissions. These results indicate that there is scope for reducing N\textsubscript{2}O emissions from agricultural practices, such as the wine industry, by choosing nitrogen fertilization quantity and application procedures. Thus, avoiding excess N treatments may also minimize N\textsubscript{2}O emissions from intensely managed vineyards. In turn, the results from continued research in this project will develop useful information for the sustainability of such ecosystems.

References


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