Field measurements of agricultural emissions

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Summary

Nitrous oxide plays an important role for the balance of greenhouse gases (GHG) on agricultural soils, followed by carbon dioxide and methane. The methods that are used to calculate the GHG balance include theoretical estimations based on data taken from literature, and the application of different models by using default emissions factors values or local data. It is recommended that local data are used because they improve the model results and lead to better estimations of the nitrous oxide emissions. In Argentina several groups of INTA have begun to carry out field measurements to obtain carbon dioxide, nitrous oxide and methane emissions by using the static chamber methodology. On one site, we are measuring with the eddy covariance methodology, that allows us to obtain continuous data on a large study area, which typically comprises hundreds of m^2. On the contrary, emissions measured with static chambers refer to areas of less than a square meter and a high variability has been found at different sites. N_2O emission rates depend on soil type, soil management, moisture in the soil and soil temperature. The variability of these parameters leads to variable emissions. The implementation of micrometeorological techniques with sensors which measure the N_2O net exchange at the scale of an entire field is thus necessary to reduce uncertainty.

1. INTRODUCTION

There is a growing interest in investigations of the changes of atmospheric concentrations of carbon dioxide (CO_2) and their potential impacts on global climate change. The increasingly frequent extreme events that are registered worldwide and the change of precipitation patterns and mean temperatures have begun to cause concerns in the international community. In this context, several trace gases such as nitrous oxide and methane are receiving attention because of their effects on the radiation balance in the atmosphere. Although the industrial activities have a high responsibility for the increase of the CO_2 atmospheric concentration, land use and land use change also have a great impact on the atmosphere composition. The main greenhouse gases are carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4). Agriculture soils are the main source of CO_2 and N_2O. Livestock and paddy soils are the main source of CH_4. To quantify the so-called carbon footprint of a product or process, it is necessary to take into account all GHG emissions in the course of the production process.

Cultivated areas occupy about 40% of the terrestrial surface (FAO, 2003) and this proportion is increasing (Green et al. 2005; Betts and Falloon 2007), with the consequence that agricultural ecosystems play a major role in the GHG balance (Salinger, 2007). In countries like Argentina, where agriculture is one of the main commercial activities, data from GHG emissions from agricultural soils have a high impact on national inventories of GHG emissions. These inventories are elaborated with models of different complexity and are based on different assumptions and emission factors measured on the field.

Worldwide great efforts are undertaken to describe the carbon fluxes in different ecosystems. A measurement network called FLUXNET was created, consisting of flux towers which use the eddy covariance method to estimate the balance of carbon and water. This methodology allows for a continuous quantification of the CO_2 sequestration and respiration on large areas and does not interfere with the behaviour of the ecosystem. The participants of the network share information and many works have been carried out to obtain a synthesis of the data (Canadell et al. 2000, Baldocchi et al. 2001, Tupek et al. 2010). The data from this network have let to an improvement of the knowledge about the impact of seasonal variability, inter-annual variability, the management of agricultural and other areas, as well as on gains and/or loss of carbon and water in different ecosystems.

Agricultural soils are a major source of nitrous oxide emissions. Nitrous oxide has a 298 times higher warming potential than CO_2. It is emitted naturally from microbial processes of nitrification and denitrification in the soil (Davidson 1991, Conrad 1996). The use of nitrogen fertilizer and the return of animal dung and urine in agricultural activities increase the content in mineral soil nitrogen. In turn, this increases the rate at which bacteria release N_2O. It is also known that emission rates are highly variable, depending on soil type, type of management and environmental variables such as humidity in air, soil temperature, water content in the soil and soil porosity are important. Based on the results of some studies, several models have been developed to simulate the behaviour of nitrogen in ecosystems, especially in agriculture. Most of these models have a strong theoretical component and are supported by some empirical data (Li et al. 1992, Parton et al. 1998). Some papers have compared model results with values obtained from field measurements. These studies have shown that in some cases the model estimations are acceptable but in some situations the models overestimate or underestimate the measured values (Abdalla et al. 2010, Frolkin et al. 1998, Li et al. 2000). So, it is necessary to enlarge the database of nitrous oxide emissions measured in the field in order to check the model results.

Non steady-state chambers are widely used for measuring soil to atmosphere fluxes of N_2O. Chamber measurements provide many of the data used in “bottom-up” assessments of regional and global N_2O emissions and are used to calibrate emission models (Del Grosso et al. 2005). There is some diversity in the characteristics of chamber measurements, e.g. there are vented or non-vented chambers (with or without air flow), as described in Livingston & Hutchinson (1995) (Fig. 1). Chambers have two parts: the anchor which is buried in the ground a few days before the measurement and a cup that confines a portion of soil. Different research groups have agreed a common methodology to make their measurements comparable.

2. OBJECTIVE & METHODOLOGY

A large group of scientists from Europe developed a common protocol called GRACEnet (Parking and Venterea 2010). This protocol sets certain methodological bases concerning the relation between the surface and the height of the chambers, the type of container for the air samples, the adjustment type to be done with the data to calculate the emission rate, the time period in which the measurement is carried out, and the hours in the course of the day which are most convenient for the sampling. In Argentina, the National Institute of Agricultural Technology (INTA) has several sites where regular measurements have been made, adopting the GRACEnet protocol with some local modifications. There are six working groups that perform measurements in six different agricultural areas, from north (Tucuman province) to the pampas region (Buenos Aires province). In each region, two main crops were chosen for the measurements and the original vegetation was also measured for comparison purposes. The crops were soybean, maize, sugarcane and rice, depending on the region. In all cases, data are taken with vented static chambers. The emission rate is calculated based on the change in the concentration of nitrous oxide in the air inside the chamber and the elapsed time (30 or 45 minutes) (Fig. 2). The gas samples are analysed in an electron capture GC (Gas Chromatography).

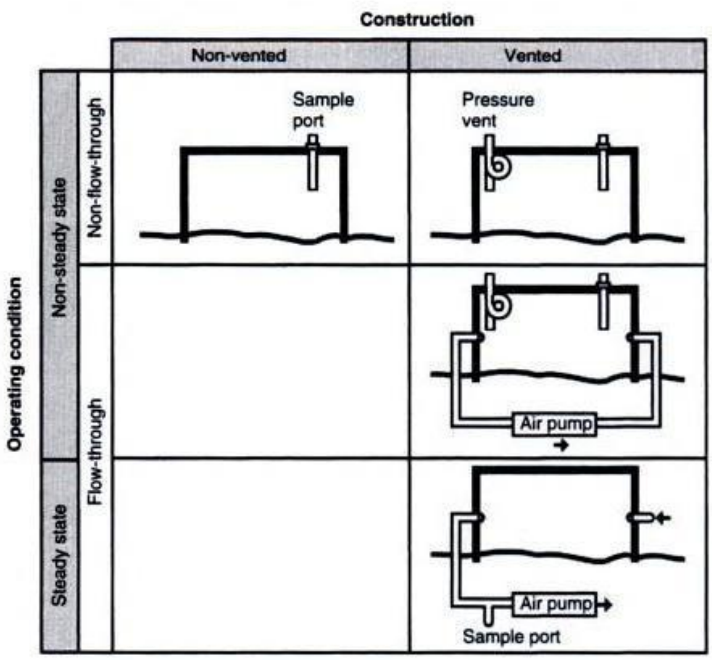

Figure 1: Chamber types reviewed by Livingston and Hutchinson (1995)

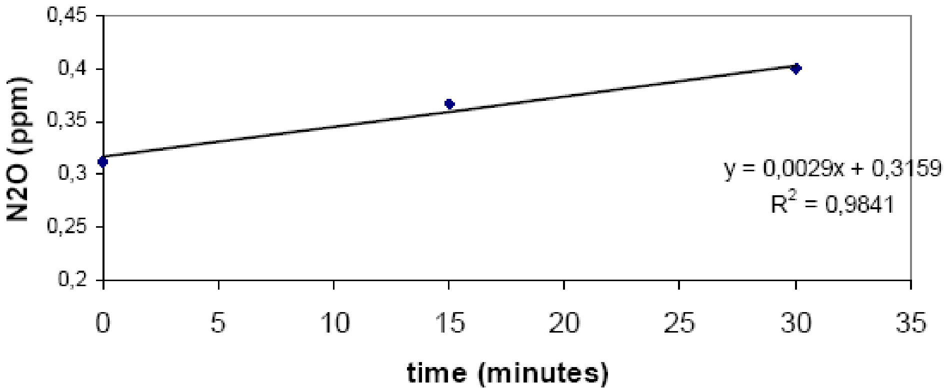

Figure 2: Change of N_2O concentration inside the chamber space over time. The slope of the regression represents the emission rate.

3. RESULTS & DISCUSSION

At the Institute of Climate and Water (INTA-ICyA), we began to make field measurements with static chambers in 2009. After some proof comparison of results between different chamber size and forms, we decided to use a rectangular chamber with a 37 × 25.5 cm base area (943.5 cm^2) and a height of 14 cm (Fig. 3).

Figure 3: Non steady-state chambers used by the Institute of Climate and Water (INTA Argentina) on a soybean field.

The cup of the chamber had a sampling port with a key for closing and opening the port. Air samples were taken from the chamber headspace at intervals of 0, 15 and 30 minutes after closing the chambers. Air samples, from which the concentration of nitrous oxide was determined, were sampled in glass vials of 10 cc (which were evacuated before taking the sample with a manual vacuum pump). Based on the increase of the concentration in the measurement period, we calculated the emission rate per unit area. Each measurement included collection of data on air temperature and soil. A soil sample was taken in each chamber site at the end of the measurements, in order to analyse water filled pore space and nitrate and ammonium content. Presently, we are carrying out measurements at two sites. Both sites are in Buenos Aires province, but they have different soil structures. Field site 1, situated in the north-east of the province, is an area of clay soils with high water retention. There, we took measurements during two soybean growing seasons and maize growing seasons. Measurements after harvest were also carried out. The nitrous oxide emissions were in average 83 microgram N-N_2O m^{-2} h^{-1}. Only on one date, we could record an emission peak, with more than 300 microgram N-N_2O m^{-2} h^{-1}. In the second field site, we began to take measurements in November 2012. There, we use to measure N2O fluxes non steady state chambers and eddy covariance methodology. This site is located in the west of the province of Buenos Aires where the texture is coarser than at site 1. We followed the more typical rotations made in this region: soybean I - wheat - soybean II rotation. So far, the average values were 12 microgram N-N_2O m^{-2} h^{-1} during the soybean I and II campaign and 10 microgram N-N_2O m^{-2} h^{-1} in a wheat field (Fig. 5).

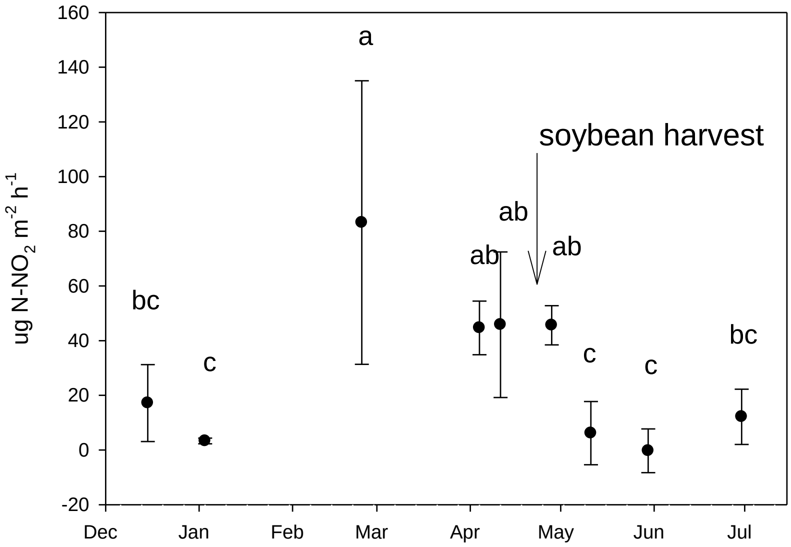

Figure 4: Average N_2O emissions obtained with static chambers over a complete soybean growing season, from sowing to post harvest on a fallow field at field site 1. The bars are standard deviations.

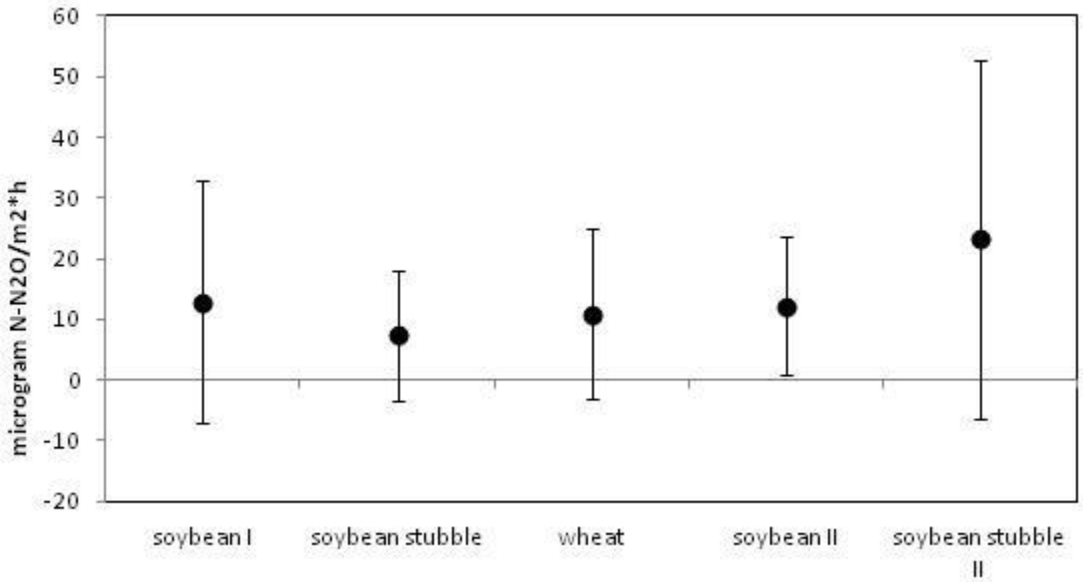

Figure 5: Average N_2O emissions in soybean I, stubble soybean, soybean II and wheat obtained with static chambers at field site 2. The bars are standard deviations.

The high variability found in the emissions rates could not be attributed exclusively to differences in soil humidity and/or nitrates. It is possible that other variables were influenced by this variability. In order to quantify the balance of the entire growing season or annual balance it is necessary to estimate emissions between measurement dates. To improve these estimations, different models can be applied. Another option is to measure data continuously, for example with the eddy covariance method. As discussed above, this method is approved and widely used in regional estimates of CO_2 and H_2O fluxes. It is also feasible to use this method to estimate nitrous oxide emissions. In this case, it would be necessary to add to the traditional towers (which measure CO_2 and H_2O fluxes) a specific sensor which measures the concentration of N_2O in the air. In an effort to improve estimates of nitrous oxide emissions, such a tower was installed at site 2. This tower has been recording the emissions of CO_2, N_2O and water vapor continuously since December 2012 (Fig. 6 and 7). With these measurements we expect to obtain reliable data from different growing seasons and crops and to enhance the carbon footprint calculation. We plan to use these local data to adjust different models. With these adjustments, we could make estimations for different scenarios of climate change or management practices. The data and information compiled from each study site in our country will be useful to improve our knowledge about the GHG balance in Argentina and propose management adaptations to diminish GHG emissions.

Figure 6: Field site 2, where eddy covariance (CO_2, N_2O and water vapour) and non steady-state chamber (N_2O) measurements are carried out.

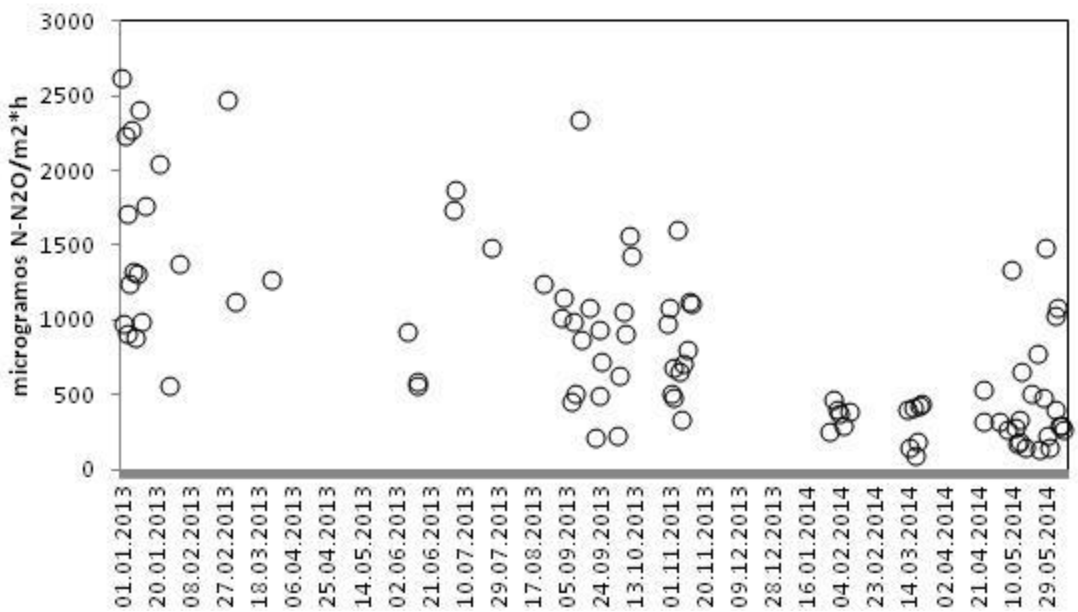

Figure 7: N-N_2O emissions average in soybean I/soybean II/wheat rotation, with Eddy Covariance tower at field site 2.

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